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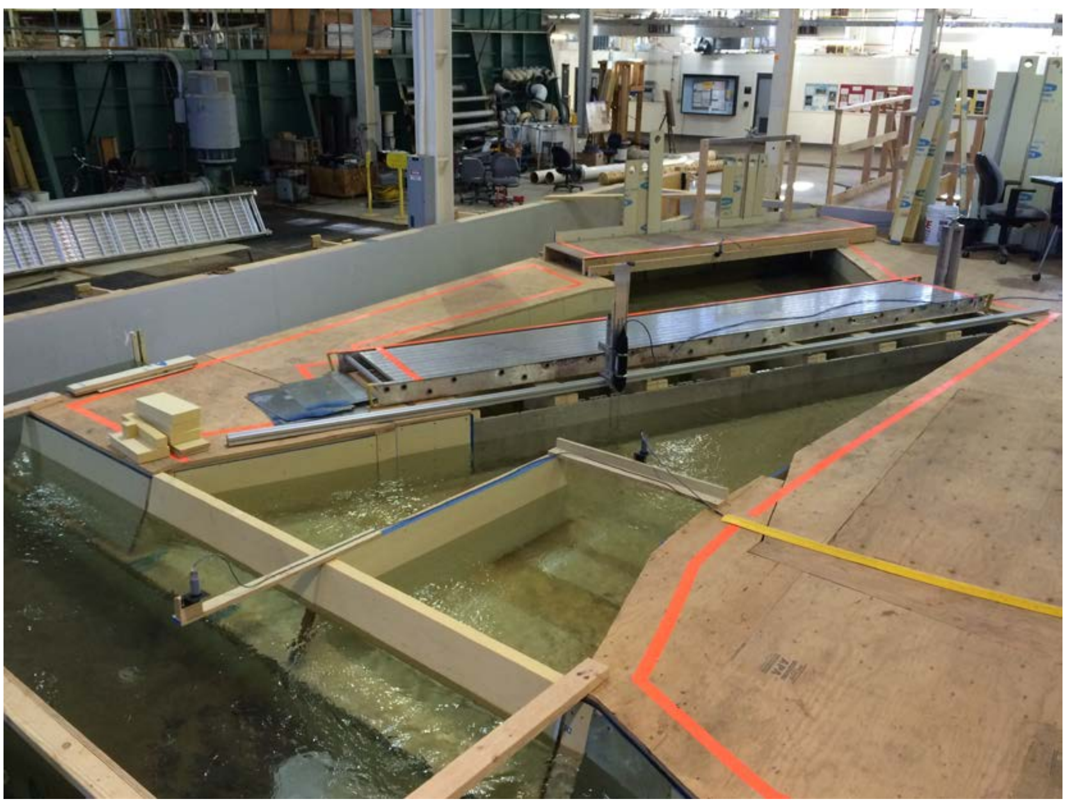
Hydraulic Laboratory Report HL-2015-05

Hydraulic Model Study of Roza Dam Flat Plate Fish Screens



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Hydraulic Model Study of Roza Dam Flat Plate Fish Screens

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Bureau of Reclamation
Technical Service Center
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The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

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.

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CONTENTS

EXECUTIVE SUMMARY 1

INTRODUCTION 2

MODEL OBJECTIVES 3

MODEL DESCRIPTION 4
Model Scale 4
Model Features 4
Instrumentation 9

MODEL TEST PLAN 11

RESULTS 12
7-Screen Bay Configuration 12
    No River Velocity 12
    River Velocity 2 ft/s 15
5-Screen Bay Configuration 18
    No River Velocity 18
    River Velocity 1.8 ft/s 18

CONCLUSIONS 20

REFERENCES 21

APPENDIX – SCREEN PERCENT OPEN AREA TESTS 22

FIGURES

Figure 1 - Roza Dam Arial photograph with labels identifying important features. 2

Figure 2. Google Earth™ image showing the extents of the physical model in the 7-screen bay and 5-screen bay configuration. 5

Figure 3. Physical model plan view and description for the 7-screen bay configuration. The 5-screen bay does not include screens 6 and 7, but all other features remained the same. 6

Figure 4. Overview of physical model in 7-screen bay configuration showing major model features. 6

Figure 5. Overview of physical model in 5-screen bay configuration showing major model features. 7

Figure 6. View of downstream side of the fish screen including flow baffles, curved piers, and isolation plates. 8

Figure 7. Reservoir velocity sweeping past the front of the trashrack was generated using a removable velocity wall. 8

Figure 8. Location of the reservoir bypass channel bulkhead. When the velocity wall was removed and the bulkhead was installed, no reservoir velocity swept past the front of the trashrack. 9

Figure 9. Ultrasonic water level sensor. 10

Figure 10. V-notch weir to measure fish bypass flow. 10

Figure 11. Nortek Vectrino+ 3D velocimeter mounted in the model at 0.75 depth. 11

Figure 12. Approach and sweeping velocities along 7-screen bay with no reservoir velocity. Flow is from left to right. Piers are curved. Baffles are all 100% open. Head loss across the screen is 0.06 ft. Average approach velocity is 0.41 ft/s. Data were collected at 0.5 depth. 13

Figure 13. Approach and sweeping velocities along 7-screen bay with no reservoir velocity. Flow is from left to right. Piers are curved. Baffles are 33-100% open. Head loss across the screen is 0.10 ft. Average approach velocity is 0.40 ft/s. Data were collected at 0.25, 0.5, 0.75, and 0.9 depth. 14

Figure 14. Approach and sweeping velocities along 7-screen bay with no reservoir velocity. Flow is from left to right. Piers are vertical. Baffles are 33-100% open. Head loss across the screen is 0.11 ft. Average approach velocity is 0.40 ft/s. Data were collected at 0.25, 0.5, and 0.75 depth. 15

Figure 15. Approach and sweeping velocities along 7-screen bay with reservoir velocity of 2 ft/s. Flow is from left to right. Piers are curved. Baffles are all 100% open. Head loss across the screen is N/A. Average approach velocity is 0.38 ft/s. Data were collected at 0.5 depth. 16

Figure 16. Approach and sweeping velocities along 7-screen bay with reservoir velocity of 2 ft/s. Flow is from left to right. Piers are curved. Baffles are 33-100% open. Head loss across the screen is 0.06 ft. Average approach velocity is 0.38 ft/s. Data were collected at 0.25, 0.5, and 0.75 depth. 16

Figure 17. Approach and sweeping velocities along 7-screen bay with reservoir velocity of 2 ft/s. Flow is from left to right. Piers are vertical. Baffles are 33-100% open. Head loss is 0.09 ft. Average approach velocity is 0.39 ft/s. Data were collected at 0.5 depth. 17

Figure 18. Eddying downstream of the center pier under the trashrack deck.................. 17

Figure 19. Approach and sweeping velocities along 5-screen bay with no reservoir velocity. Flow is from left to right. Piers are curved. Baffles are all 100% open. Head loss across the screen is 0.06 ft. Average approach velocity is 0.42 ft/s. Data were collected at 0.5 depth.. 18

Figure 20. Approach and sweeping velocities along 5-screen bay with reservoir velocity of 1.8 ft/s. Flow is from left to right. Piers are curved. Baffles are all 100% open. Head loss across the screen is 0.09 ft. Average approach velocity is 0.41 ft/s. Data were collected at 0.5 depth.. 19

Figure 21. Approach and sweeping velocities along 5-screen bay with reservoir velocity of 1.8 ft/s. Flow is from left to right. Piers are curved. Baffles are 33-100% open. Head loss across the screen is 0.10 ft. Average approach velocity is 0.40 ft/s. Data were collected at 0.5 depth.. 19

Executive Summary

A 1:8-scale physical hydraulic model of Roza Fish Screening Facility was constructed at Reclamation's Hydraulics Laboratory in Denver, Colorado to examine the proposed replacement of the existing drum screens with flat plate fish screens. The model study examined performance of the flat plate screens in a 7-screen bay and a 5-screen bay configuration with no river velocity and with a river velocity of 2 ft/s sweeping past the front of the trashrack.

The objectives of the model study were to demonstrate acceptable hydraulic performance along the fish screen with approach velocities perpendicular to the screen face of less than or equal to 0.4 ft/s (NMFS, 2011), evaluate baffling techniques and/or other structures or modifications needed to achieve screen criteria, and evaluate the screening bay for eddies, recirculation zones, and stagnant zones where fish might hold.

Baffling was needed in the 7-screen bay configuration (screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open) to improve approach velocity distributions along the screen face. The proposed baffle location of 4 ft behind the screen face provided sufficient flow control at the screen face. Baffles did not need to be moved forward to a more typical position of 1 ft behind the screen face. Baffling was not needed in the 5-screen bays. To save construction costs, baffles could be omitted from the 4 bays that contain only 5 screens. However, these bays should be designed to accept baffles after construction if they are needed due to operational changes or other factors.

There are a few locations on the fish screen face where approach velocities were slightly above screen criteria (0.4 ft/s) and velocity uniformity requirements were not met (within 110% of criteria). For all conditions tested, approach velocities at the most downstream screen (near the fish bypass) exceeded criteria due to the restriction in flow width between the far wall and the screen. Baffling was not effective at reducing approach velocities in this area. With the existing curved piers, results show that there was no significant vertical variation in screen velocities. Therefore, curved piers did not need to be retrofitted with vertical piers. No significant eddying, recirculation, or stagnant zones were observed in the model.

Recommendations from this model study apply to screens with an open area of 40% or less. Model results show that screen open area should be 40% or less in the prototype to prevent localized lower velocities from occurring at screen locations in front of the piers. Screens with larger open areas showed lateral skewness of approach velocity distributions across each screen panel that exceeded screening criteria.

Introduction

Roza Diversion Dam is part of the Roza Division of the Bureau of Reclamation's (Reclamation) Yakima Project. Constructed in 1939, the dam is located 10 miles north of the city of Yakima, Washington on the Yakima River at river mile 127.9. The diversion dam is a 486-ft-long, 67-ft-high concrete weir, movable crest structure. Up to 2,200 ft^3/s of water is diverted from the Yakima River into the Roza Canal to provide irrigation water to approximately 72,500 acres of land north of the Yakima River.

In 2010, Reclamation modified the 110-ft-long west roller gate to provide a downstream surface passage route over the gate for juvenile salmon and steelhead on their downstream migration to the Pacific Ocean. Before reaching the west roller gate, juveniles may be attracted to the headworks area leading into the Roza Canal. Roza Fish Screening Facility protects fish from being entrained in the canal. The headworks consist of a concrete structure in the right abutment with a trashrack at the inlet to protect a series of fish screens from debris. The screening facility consists of 27 rotating drum screens (17.5 ft diameter, 12 ft width) in 5 bays with 7 screens in the upstream bay and 5 screens in each of the remaining bays. Each bay contains an intermediate fish bypass. An adjustable weir gate in each bypass controls flow through the fish bypass system. The intermediate bypasses converge into a separation chamber where excess water is recovered through four vertical traveling screens. The terminal fish bypass returns fish to the Yakima River at an outfall downstream of Roza Dam. Figure 1 provides an overview of the major features at the Roza facility.

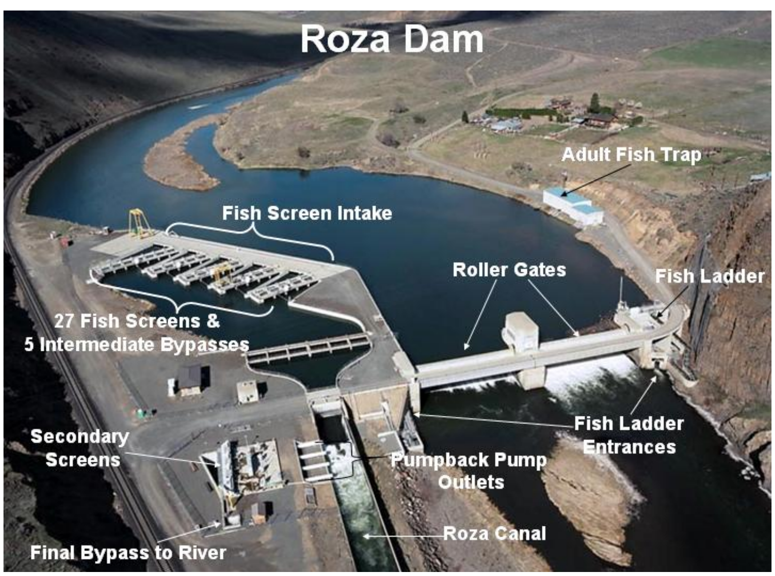

Figure 1 - Roza Dam aerial photograph with labels identifying important features.

The problems and needs of the existing fish screen facility include (Reclamation, 2013):

- Existing screens do not meet current National Marine Fisheries Service (NMFS) criteria for the effective downstream passage of juvenile anadromous fish due to approach velocities and mesh opening size.

- Onsite observations have verified that post-emergent salmonids can be impinged on the drum screen fabric and transported over the screens into the Roza Canal.

- The existing drum screens are reaching their service life and removal, transport, major overall, and reinstallation is expected to be very expensive.

- Current operations and maintenance is very costly to keep all 27 drum screens operating per design requirements.

In May 2013, Reclamation examined alternatives to modify the Roza screening facility to meet current NMFS design guidelines (NMFS, 2011). The study recommended retrofitting the existing drum screens with flat plate fish screens in order to meet criteria, provide for more efficient operation, and reduce maintenance costs. The proposed design included new structural steel work, flat plate fish screens, automated screen cleaners, and an automated air burst system. To control flow through each screen bay, isolation plates would be added between individual screen bays at the existing piers. Flow control baffles would be added behind each screen between the existing piers. With a total surface area of 5,085 ft^2, design approach velocities would be 0.433 ft/s at maximum canal flow rate of 2,200 ft^3/s and 0.393 ft/s at the 5% exceedence flow of 2,000 ft^3/s (based on 25 year mean daily flow, Reclamation, 2013).

Model Objectives

A physical hydraulic model was constructed at Reclamation's Hydraulics Laboratory in Denver, Colorado to examine the proposed Roza flat plate fish screens. The physical model included one bay of the fish screen, a portion of the screen forebay, and a portion of the area downstream from the screen.

The model study focused on the following objectives:

1.) Achieve acceptable velocity distributions along the fish screen, with approach velocities perpendicular to the screen face of less than or equal to 0.4 ft/s (NMFS, 2011).
2.) Evaluate baffling techniques and/or other structures or modifications needed to achieve acceptable velocity distributions.
3.) Evaluate the screening bay for eddies or recirculation zones where fish could hold.

Model Description

Model Scale

Similitude between the model and the prototype is achieved when the ratios of the major forces controlling the physical processes are equal in the model and prototype. Since gravitational and inertial forces typically dominate open channel flow, Froude-scale similitude was used to establish a kinematic relationship between the model and the prototype. The Froude number is defined as

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

where v = velocity, g = gravitational acceleration, and d = flow depth. When Froude-scale similitude is used for a 1:8 scale, the following relationships exist between the model and prototype where the r subscript refers to the ratio of model to prototype:

Length ratio: $L_r = 1:8$

Pressure ratio: $P_r = 1:8$

Velocity ratio: $V_r = L_r^{1/2} = (8)^{1/2} = 1:2.83$

Time ratio: $T_r = L_r^{1/2} = (8)^{1/2} = 1:2.83$

Discharge ratio: $Q_r = L_r^{5/2} = (8)^{5/2} = 1:181.02$

Model Features

The physical model was constructed to evaluate performance of a 7-screen and a 5-screen bay. The 7-screen bay configuration was constructed and evaluated first, and was later modified to the 5-screen bay configuration. Figure 2 shows an overlay of each model configuration on a Google Earth™ image of the facility. Each model configuration consisted of a single fish screen bay with a portion of the river, trashrack overhang and center pier, fish screen, flow baffles, isolation plates, fish bypass, and a portion of the area downstream from the screen (Figure 3 through Figure 5).

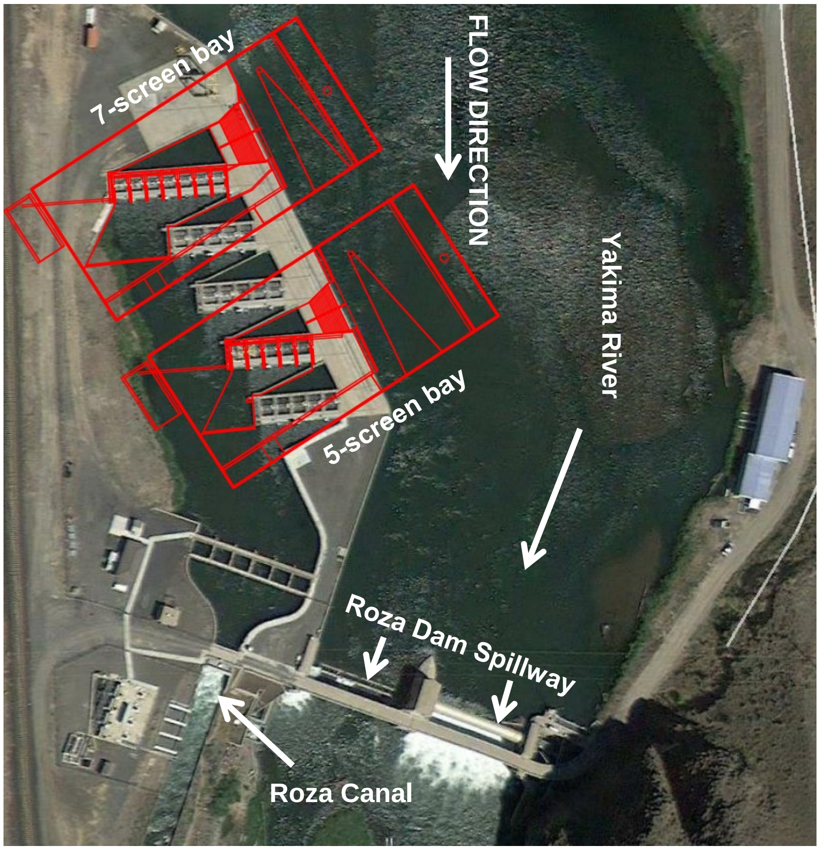

Figure 2. Google Earth™ image showing the extents of the physical model in the 7-screen bay and 5-screen bay configurations.

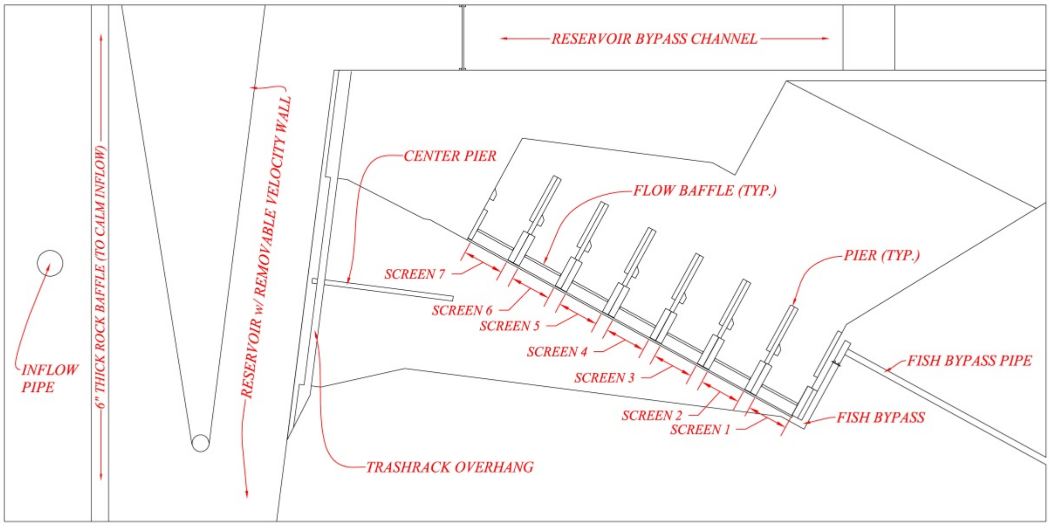

Figure 3. Physical model plan view and description for the 7-screen bay configuration. The 5-screen bay does not include screens 6 and 7, but all other features remained the same.

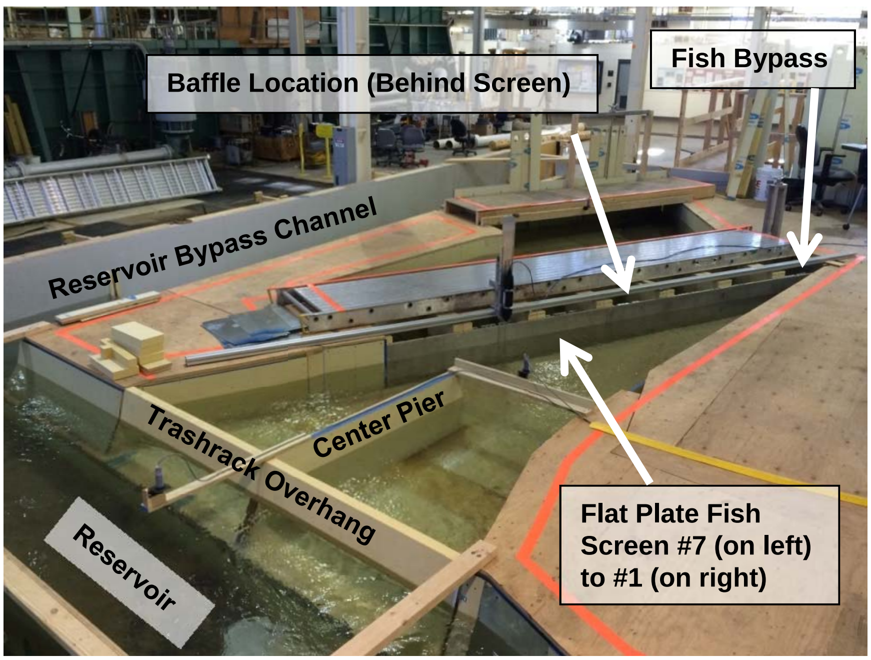

Figure 4. Overview of physical model in 7-screen bay configuration showing major model features.

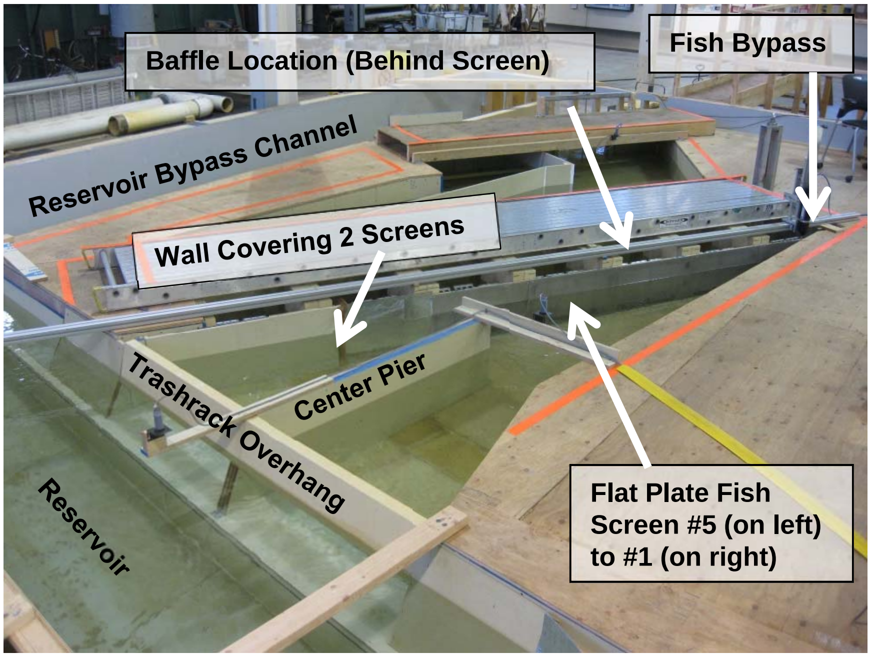

Figure 5. Overview of physical model in 5-screen bay configuration showing major model features.

Various screens were tested in the model to determine if the type of screen (wedgewire or perforated plate) and percent open area (33-58% open) affected velocity distributions at the screen face. Results showed that screens with 40% open area or less produced the best flow conditions at the screen face without interference from the support piers. The full test plan was conducted using a screen with 33% open area. Details of the screen percent open area tests can be found in Appendix A.

The fish screen was constructed of 14-gauge aluminum perforated plate with 3/32-in diameter holes staggered 5/64-in diagonally with an open area of 33%. Piers were constructed of high-density foam and shaped to the existing facility dimensions with the drum screen curvature. Flow baffles were placed 6 in (4 ft prototype) behind the fish screen between piers. Sheet metal isolation plates (1/8" thick model scale) were installed perpendicular to the screen face extending each pier to the back of the screen. Figure 6 provides a view of the downstream side of the fish screen including the metal isolation plate, curved piers, and flow baffles.

Both configurations (7-screen bay and 5-screen bay) were modeled with and without river velocity sweeping past the front of the trashrack. To easily switch between the two operational conditions, a removable wall (Figure 7) was built in the model reservoir. When the wall was in place, the velocity upstream of the trashrack was controlled by passing excess flow through a bypass channel to represent a situation where the dam is spilling water (Figure 8). When the wall was removed, a bulkhead was installed in the bypass channel to represent a condition where little or no flow is released from the dam. In this case, flow approaches the Roza Fish Screening Facility trashrack straight on.

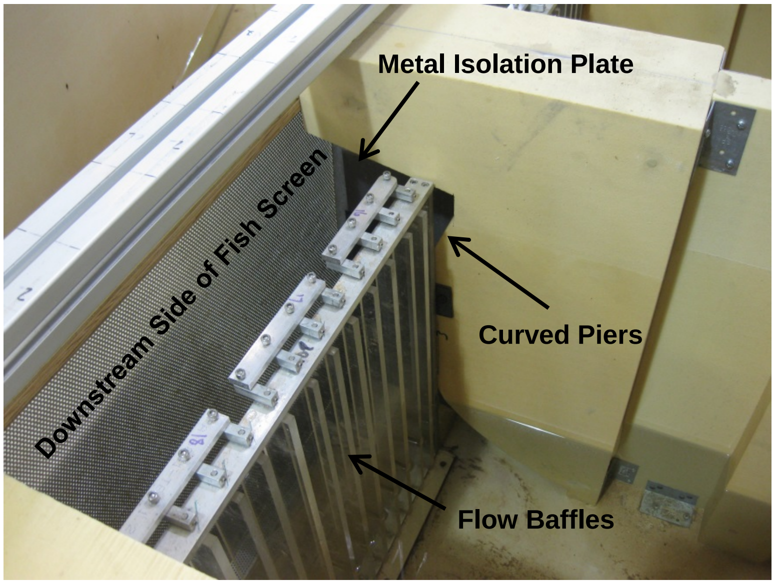

Figure 6. View of downstream side of the fish screen including flow baffles, curved piers, and isolation plates.

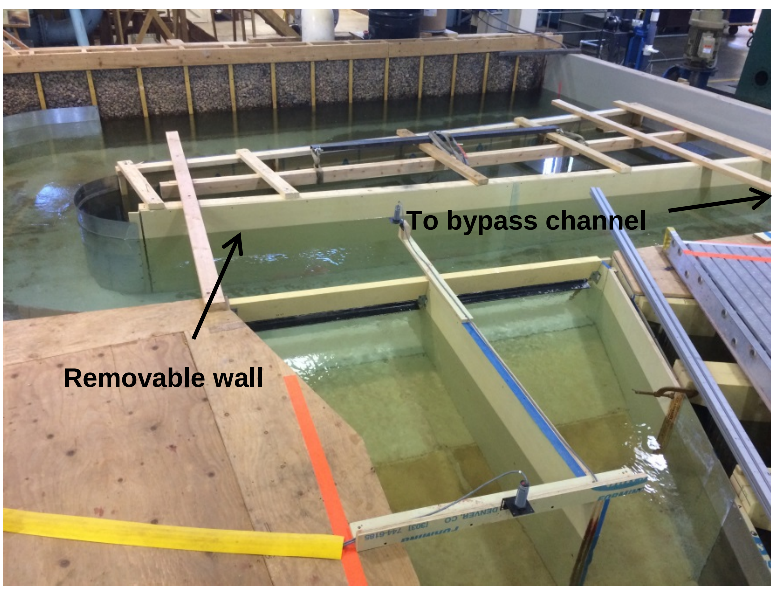

Figure 7. River velocity sweeping past the front of the trashrack was generated using a removable velocity wall.

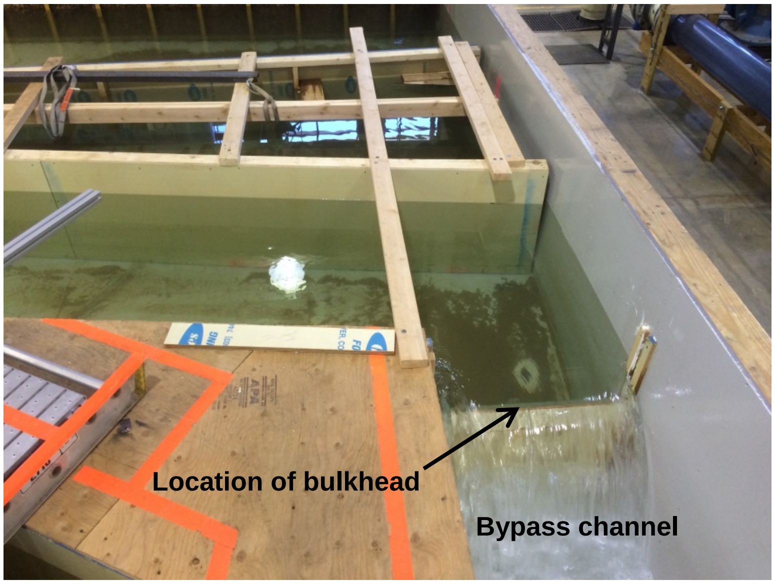

Figure 8. Location of the bypass channel and bulkhead. When the wall was removed and the bulkhead was installed, no river velocity swept past the front of the trashrack.

Instrumentation

A 240,000-gallon storage reservoir under the laboratory floor supplied water for the hydraulic model through an automated flow delivery and measurement system. Inflow to the model was measured with laboratory venturi meters. A 44,000 pound volumetric/weigh tank facility was used to calibrate the laboratory venturi meters at regular intervals to an accuracy of $\pm 0.25\%$.

Ultrasonic water level sensors (MASSA M-5000) were used to measure water surface elevations in the reservoir (Figure 9) and upstream and downstream of the fish screen to an accuracy of ±0.083 in (model scale). The target water surface elevation upstream of the fish screen was controlled by adjusting tailboards at the downstream end of the model.

Flow through the fish bypass was measured with a V-notch weir. A piezometer tap was placed in the sidewall of the fish bypass outflow box to measure the head on the weir. An ultrasonic water level sensor measured the water level in the attached stilling well (Figure 10).

To represent a river velocity of 2 ft/s, a temporary wall was installed in the model headbox to force flow past the trashrack. Flow sweeping past the front of the fish screen facility was measured with a ramp flume installed in the bypass channel accurate to ± 2%. A piezometer tap and stilling well with an ultrasonic water level sensor was used to measure the head on the ramp flume.

The canal discharge (diversion flow rate) was calculated as the inflow discharge minus the fish bypass flow. In the case where the river velocity was 2 ft/s, canal discharge was calculated as the inflow discharge minus the flow passing over ramp flume and through the fish bypass.

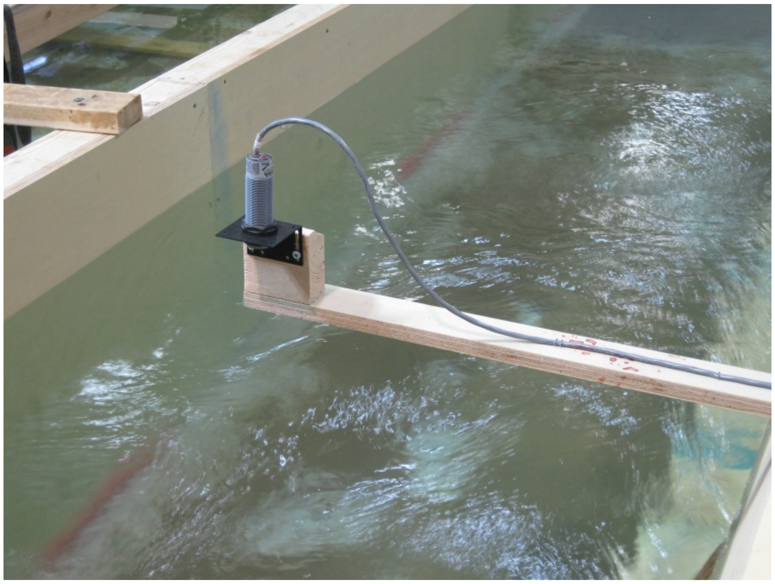

Figure 9. Ultrasonic water level sensor.

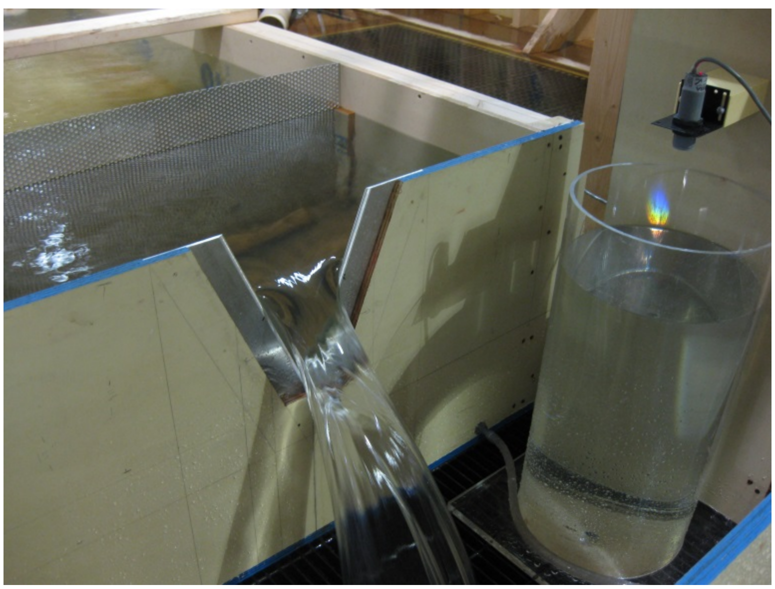

Figure 10. V-notch weir to measure fish bypass flow.

Three-dimensional velocity data were collected at the fish screen using a Nortek Vectrino+ 3-D velocimeter (Figure 11) with an accuracy of ± 0.5% of measured value. The approach velocity (perpendicular to the screen) and sweeping velocity (parallel to the screen) were measured at a location of 1.6875-in from the screen face in the model (13.5-in prototype). Screen measurements at a prototype distance of 3-in were not possible in the laboratory due to instrument limitations. It is expected, however, that velocity magnitudes in the prototype will be similar to velocity magnitudes in the model, and general flow patterns and velocity distributions will be representative of prototype performance. All velocity measurements in this report are referred to in prototype units unless noted otherwise.

Figure 11. Nortek Vectrino+ 3D velocimeter mounted in the model at 0.75 depth.

Model Test Plan

Velocity magnitude and direction of flow approaching the fish screening facility affects velocities directly in front of the screen. During large spills at the dam, flow velocity sweeping past the front of the trashrack can be up to 2 ft/s. The velocity decreases along the fish screening facility for each consecutive bay until, for the last bay, withdrawal is from a low velocity zone. At times of low or no spill, nearly all flow into the screening structure approaches the trashrack straight on. Therefore, the following reservoir conditions were modeled for both the 7-screen bay and 5-screen bay configurations:

1.) No river velocity (flow approaching straight toward the fish screen facility)
2.) River velocity sweeping past the front of the trashrack of 2 ft/s for 7-screen bay and 1.8 ft/s for 5-screen bay (since velocity decreases along the length of the trashrack)

The model study was conducted with a design flow of 2,000 ft^3/s which corresponds to 5% exceedence based on 25 year mean daily flow. The fish bypass was set to the normal bypass rate of 52 ft^3/s. The water surface elevation in the screen forebay (upstream of the screen but downstream of the trashrack) was set to the normal operating water level of 1220.45 ft.

Approach and sweeping velocities were measured at 0.25, 0.5, and 0.75 times the water depth from the water surface at 3 lateral locations on each screen bay and at the pier centerline to determine lateral and vertical distributions at the screen face. Data were first collected with the un-baffled configuration (baffles 100% open). Baffles were then adjusted to best achieve NMFS criteria (NMFS, 2011). Relevant criteria for this study are as follows:

1.) The approach velocity must not exceed 0.40 ft/s for active screens.

2.) The screen design must provide for nearly uniform flow distribution over the screen surface. Uniformity of approach velocity is defined as being achieved when no individual approach velocity measurement exceeds 110% of the criteria.

3.) Screens must have sweeping velocity greater than the approach velocity. Ideally, sweeping velocity should be at least 0.8 ft/s and less than 3 ft/s.

Headlosses across the fish screen and baffles were measured and dye was used to examine flow conditions throughout the model. Eddies, recirculation zones, and stagnant zones were noted if present.

Results

In the following graphs, flow is from left to right. The x-axis on each plot shows the screen and pier locations with screen 7 (closest to the trashrack) on the left side and screen 1 (closest to the fish bypass) on the right side and vertical lines indicating the centerline of the piers. Approach and sweeping velocity components are plotted on each graph along with the NMFS approach velocity criteria of 0.4 ft/s.

7-Screen Bay Configuration

No River Velocity

The first set of data was collected with no river velocity. Baffles were all set at 100% open (Figure 12). Without any baffling, approach velocities at mid-depth were near-uniform (mean = 0.41 ft/s, standard deviation = 0.051 ft/s). Approach velocities were just above criteria at the downstream end of the screen and below criteria at the upstream end.

Baffles were adjusted to improve approach velocity distributions while keeping head loss across the screen structure small (Figure 13). For each screen section, individual baffles located between piers were all set to one opening. Screen 1 was set at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open. Baffling slightly improved velocity uniformity (mid-depth mean = 0.40 ft/s, standard deviation = 0.042 ft/s); however, approach velocities at the screen closest to the fish bypass were still high. Even with the baffles at screen 1 completely closed, approach velocities exceeded NMFS criteria due to the restricted flow area in this part of the bay. Baffling increased head loss from 0.06 ft to 0.1 ft. Data collected at 4 depths showed that there was no significant vertical variation in screen velocities (Figure 13).

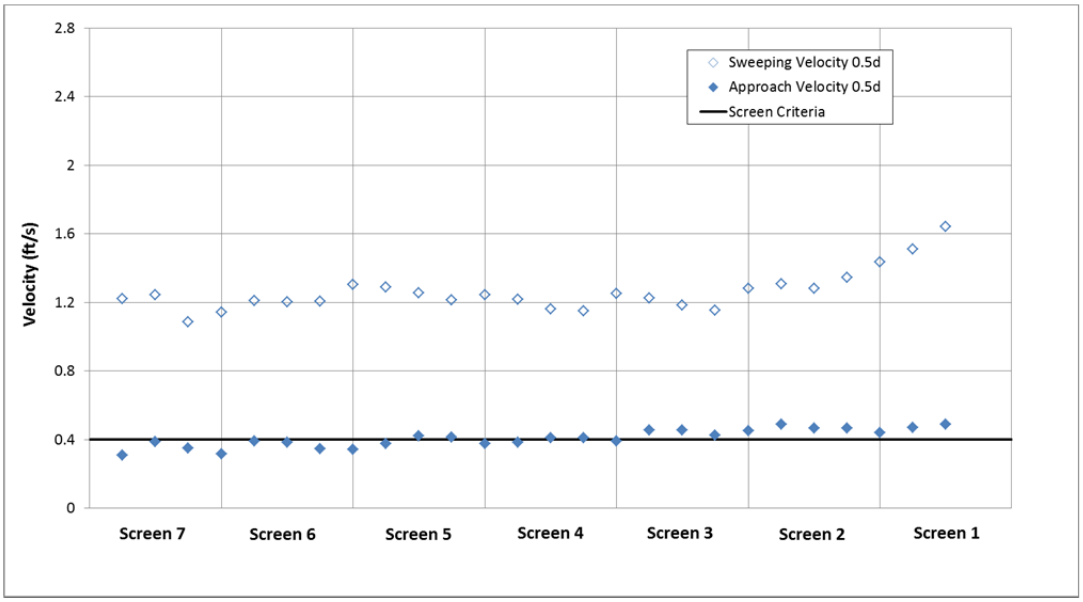

Figure 12. Approach and sweeping velocities along 7-screen bay with no river velocity. Piers were curved. Baffles were all 100% open. Head loss across the screen was 0.06 ft. Average approach velocity was 0.41 ft/s. Data were collected at 0.5 depth.

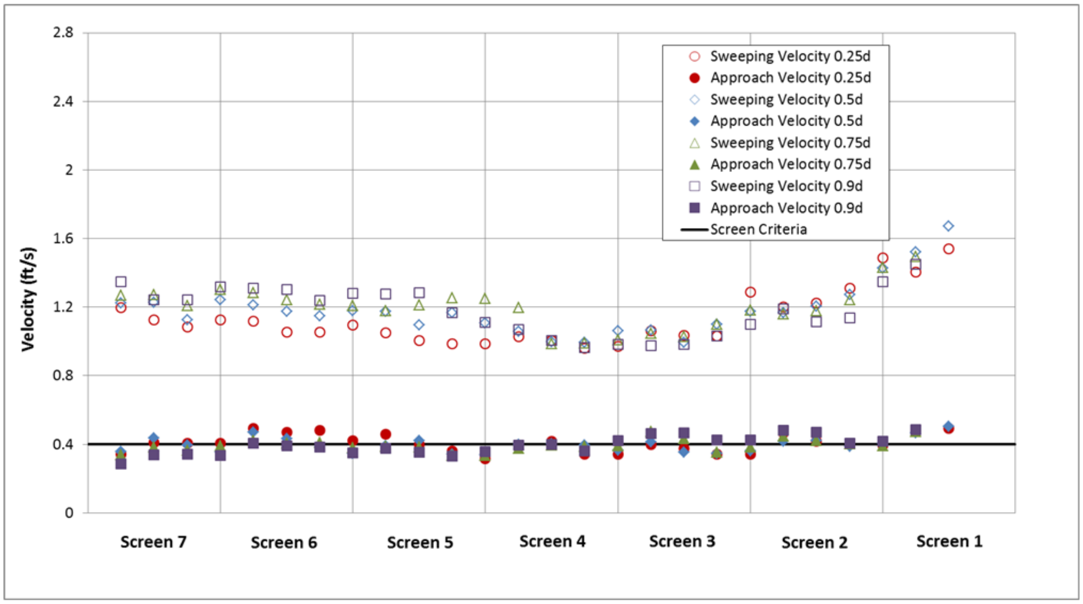

Figure 13. Approach and sweeping velocities along 7-screen bay with no river velocity. Piers were curved. Baffles were 33-100% open (screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open). Head loss across the screen was 0.10 ft. Average approach velocity was 0.40 ft/s. Data were collected at 0.25, 0.5, 0.75, and 0.9 depth.

With the existing drum screens, piers between screens are curved to the shape of the drum screen (Figure 6). The current design for the flat plate screens places the new screen in front of the piers such that the piers do not touch the back side of the screen. Baffles extend between piers. The shape of the pier provides an unobstructed flow path, particularly toward the channel bottom. Model testing was conducted with a vertical front face on the pier to determine if concrete should be added to the front of the existing piers to improve approach velocity vertical distributions at the screen face. Model testing shows that vertical piers did not have any advantage over a curved pier (mid-depth mean = 0.40 ft/s, standard deviation = 0.046, Figure 14).

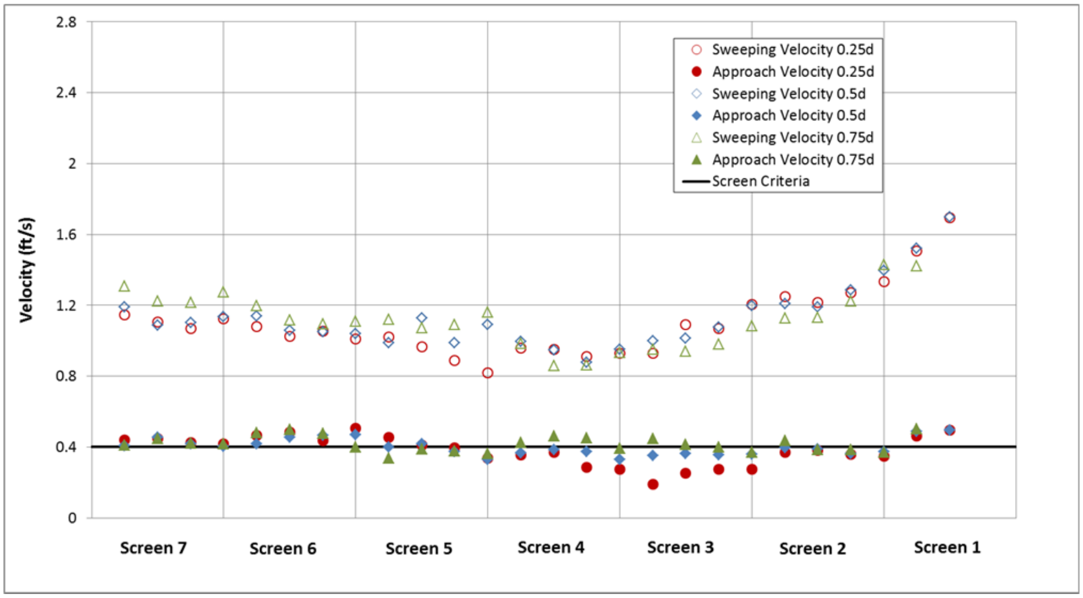

Figure 14. Approach and sweeping velocities along 7-screen bay with no river velocity. Piers were vertical. Baffles were 33-100% open (screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open). Head loss across the screen was 0.11 ft. Average approach velocity was 0.40 ft/s. Data were collected at 0.25, 0.5, and 0.75 depth.

River Velocity 2 ft/s

The second set of data was collected with a river velocity of 2 ft/s past the trashrack structure. Baffles were all set at 100% open (Figure 15). Sweeping velocities at the upstream side of the screen were higher when in the river velocity condition. Approach velocities were lower at the upstream end of the screen and higher at the downstream end. Non-uniform approach velocities were recorded when baffles were 100% open (mean = 0.38 ft/s, standard deviation = 0.122 ft/s).

Baffles were adjusted to 33-100% open (Screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open) to improve approach velocity uniformity while keeping head loss across the screen small (Figure 16). When screens were baffled by 33-100%, velocity uniformity improved (mean = 0.40 ft/s, standard deviation = 0.058 ft/s). As was the case with no river velocity, little vertical variation existed when data were collected at 3 depths on the screen.

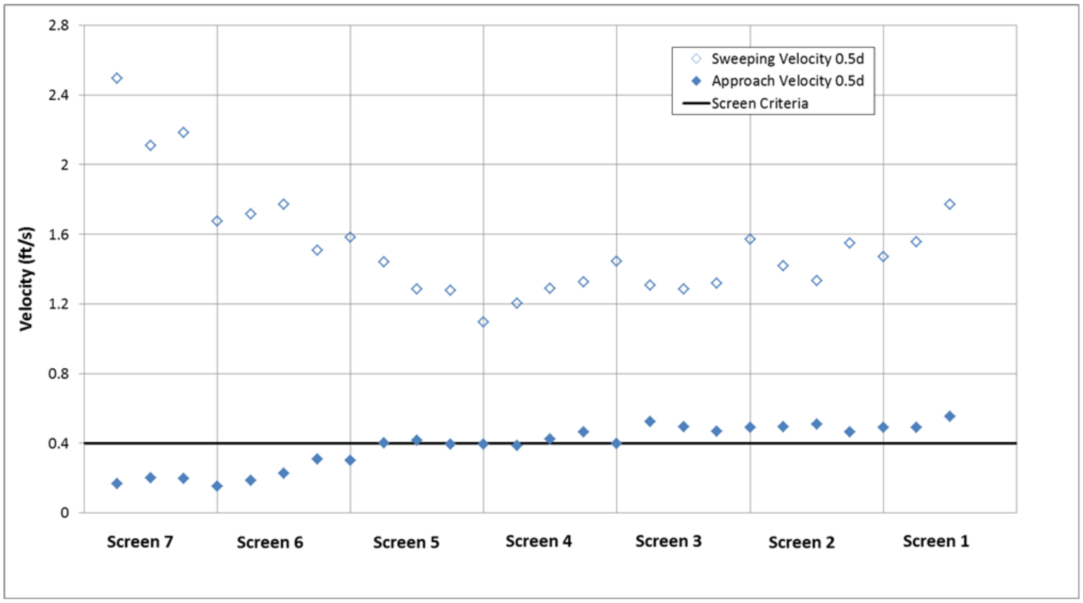

Figure 15. Approach and sweeping velocities along 7-screen bay with river velocity of 2 ft/s. Piers were curved. Baffles were all 100% open. Head loss across the screen was not recorded. Average approach velocity was 0.38 ft/s. Data were collected at 0.5 depth.

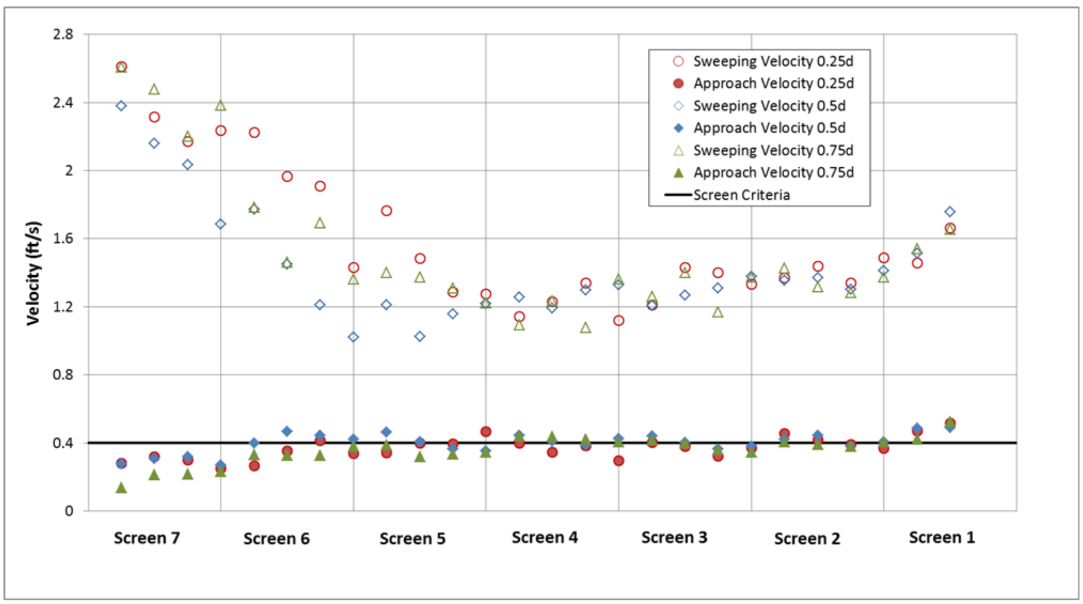

Figure 16. Approach and sweeping velocities along 7-screen bay with river velocity of 2 ft/s. Piers were curved. Baffles were 33-100% open (screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open). Head loss across the screen was 0.06 ft. Average approach velocity was 0.38 ft/s. Data were collected at 0.25, 0.5, and 0.75 depth.

Model testing was again conducted with a vertical front face on the pier at mid-depth (mean = 0.39 ft/s, standard deviation = 0.054 ft/s, Figure 17). Results show that data were similar between the curved and vertical piers; therefore, curved piers were used in the remainder of the model tests.

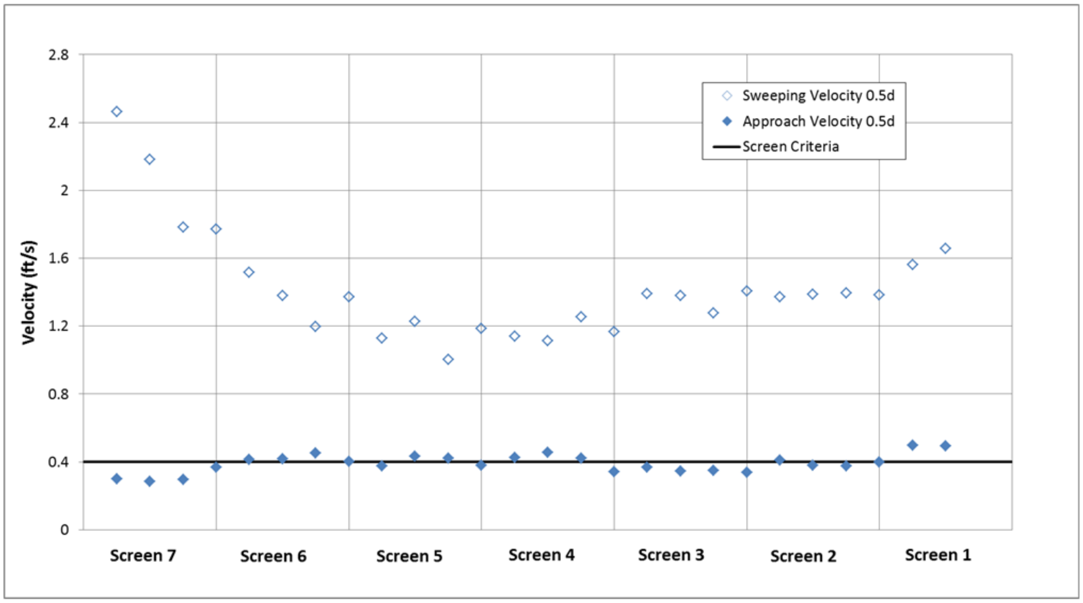

Figure 17. Approach and sweeping velocities along 7-screen bay with river velocity of 2 ft/s. Piers were vertical. Baffles were 33-100% open (screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open). Head loss was 0.09 ft. Average approach velocity was 0.39 ft/s. Data were collected at 0.5 depth.

Horizontal and vertical eddying occurred downstream of the center pier underneath of the trashrack deck (Figure 18). Turbulent fluctuations existed in front of screens 7 and 6. Velocity data showed more variability over time and greater vertical variability at these screens. No significant eddying, recirculation, or stagnant zones occurred elsewhere in the model.

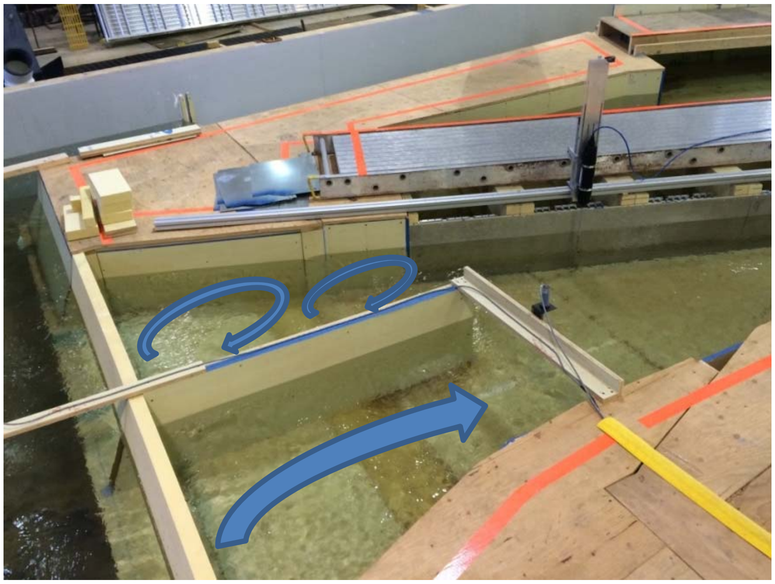

Figure 18. Eddying downstream of the center pier under the trashrack deck.

5-Screen Bay Configuration

No River Velocity

Velocities collected during the 7-screen bay investigation showed that there is no significant vertical variation in screen velocities, so screen velocities were only collected at 0.5 times the water depth for the 5-screen bay tests. The first set of data was collected with no river velocity. Baffles were all set at 100% open (Figure 19). Without any baffling, approach velocities at mid-depth were near-uniform (mean = 0.42 ft/s, standard deviation = 0.041 ft/s). There was no need to baffle the screen to improve approach velocity distributions.

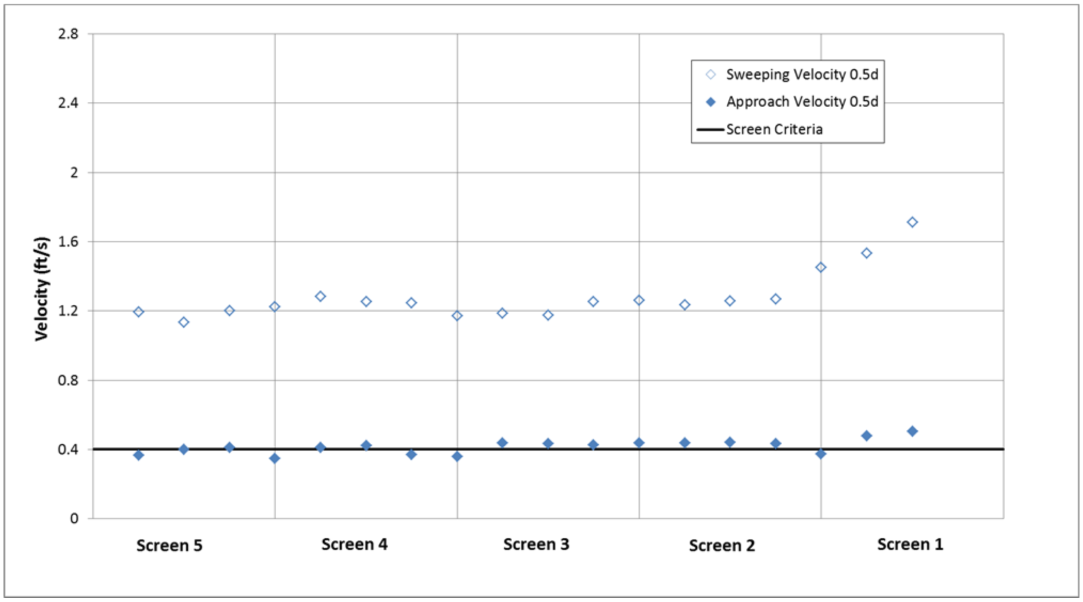

Figure 19. Approach and sweeping velocities along 5-screen bay with no river velocity. Piers were curved. Baffles were all 100% open. Head loss across the screen was 0.06 ft. Average approach velocity was 0.42 ft/s. Data were collected at 0.5 depth.

River Velocity 1.8 ft/s

Since river velocity sweeping past the front of the trashrack decreases along the length of the trashrack, river velocity was set to 1.8 ft/s for the 5-screen bay. Baffles were all set at 100% open (Figure 20). When the screen was unbaffled, near-uniform approach velocities were measured (mean = 0.40 ft/s, standard deviation = 0.052 ft/s, Figure 20).

Baffles were adjusted from 33-100% open in the following manner: screen 1 was set at 33% open, screens 2 and 3 at 44% open, screen 4 at 56% open, and screen 5 at 100% open to attempt to improve approach velocity uniformity while keeping head loss across the screen low (Figure 21). When screens were baffled from 33-100%, velocity distributions were similar (mean = 0.40 ft/s, standard deviation = 0.060 ft/s). In this situation, there was no advantage to baffling the fish screen.

No significant eddying, recirculation, or stagnant zones were observed in the 5-screen bay configuration.

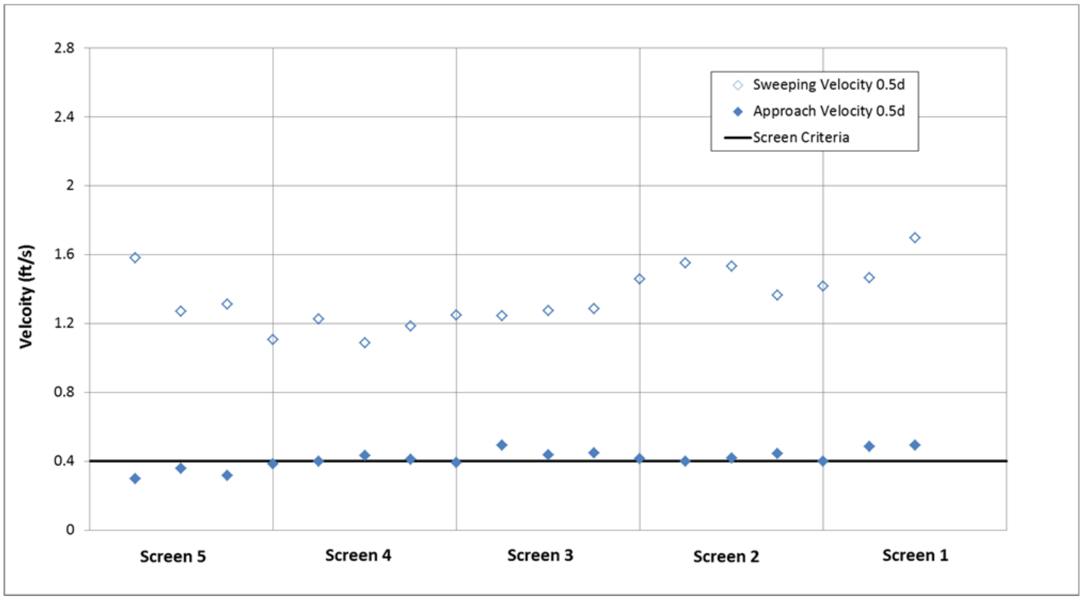

Figure 20. Approach and sweeping velocities along 5-screen bay with river velocity of 1.8 ft/s. Piers were curved. Baffles were all 100% open. Head loss across the screen was 0.09 ft. Average approach velocity was 0.41 ft/s. Data were collected at 0.5 depth.

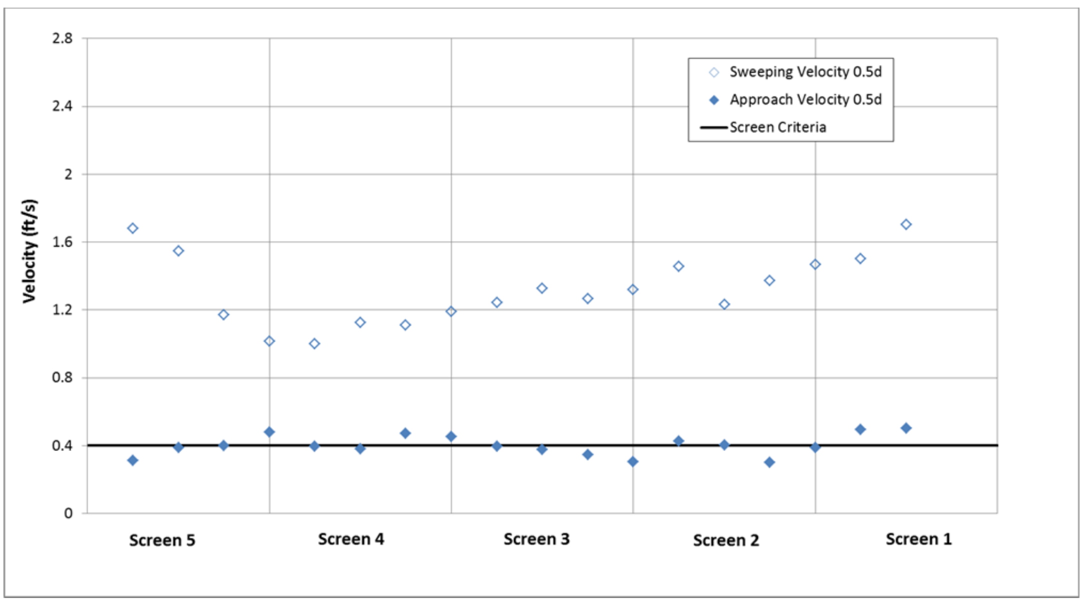

Figure 21. Approach and sweeping velocities along 5-screen bay with river velocity of 1.8 ft/s. Piers were curved. Baffles were 33-100% open (screen 1 at 33% open, screens 2 and 3 at 44% open, screen 4 at 56% open, and screen 5 at 100% open). Head loss across the screen was 0.10 ft. Average approach velocity was 0.40 ft/s. Data were collected at 0.5 depth.

Conclusions

Baffling was needed in the 7-screen bay configuration to improve approach velocities near the screen face. When there was no river velocity, baffling slightly improved conditions. When the river velocity was 2 ft/s, baffling screen 1 at 33% open, screens 2 and 3 at 44% open, screens 4 and 5 at 56% open, and screens 6 and 7 at 100% open was needed to produce acceptable approach velocity distributions. The proposed baffle location of 4 ft behind the screen face provided sufficient flow control at the screen face when the screen open area was at or below 40 percent. Baffles did not need to be moved forward to a more typical position of 1 ft behind the screen face.

Baffling was not needed in the 5-screen bays with or without river velocity when the screen open area was at or below 40 percent. To save construction costs, baffles could be omitted from the 4 bays that contain only 5 screens. These bays should be designed to accept baffles after construction if they are needed due to operational changes or other factors.

There were a few locations on the fish screen face where approach velocities were slightly above screen criteria (0.4 ft/s) and velocity uniformity requirements were not met (110% of criteria). In all conditions tested, approach velocities at the most downstream screen (near the fish bypass) exceeded criteria due to the restriction in flow width between the far wall and the screen. Baffling was not effective at reducing approach velocities in this area. With the existing curved piers, results show that there was no significant vertical variation in screen velocities. Therefore, curved piers did not need to be retrofitted with vertical piers.

Recommendations from this model study are applicable for screens with an open area of 40% or less. Model results show that screen open area should be 40% or less in the prototype to prevent localized lower velocities from occurring at screen locations in front of the piers. Screens with larger open areas showed lateral skewness of approach velocity across each screen panel which exceed screening criteria.

No significant eddying, recirculation, or stagnant zones were observed in the model. In the 7-screen bay, horizontal and vertical eddying occurred downstream of the center pier underneath of the trashrack deck, producing turbulent fluctuations in front of screens 7 and 6. Approach velocities, however, were not adversely affected at these screens.

References

Bureau of Reclamation. 2013. “Final Roza Fish Screen Modifications Appraisal Study, Yakima Project, Washington – For Official Use Only”. Pacific Northwest Region, Boise, Idaho.

National Marine Fisheries Service (NMFS). 2011. “Anadromous Salmonid Passage Facility Design”. NMFS, Northwest Region, Portland, Oregon.

Appendix – Screen Percent Open Area Tests

Various screens were tested in the model to determine if the type of screen (wedgewire or perforated plate) and percent open area (33-58%) affected velocity distributions at the screen face. All tests were conducted with the same baffle settings, curved support piers, and no river velocity. The following 6 screens were examined in the model:

1.) Wedgewire screen with 57% open area (0.069" wedgewires and 3/32" slot opening) with vertical backing bars for support
2.) Wedgewire screen with 57% open area (0.069" wedgewires and 3/32" slot opening) without vertical backing bars for support
3.) Perforated plate with open area 33% (14-gauge aluminum plate with 3/32-in diameter holes staggered 5/64-in diagonally)
4.) Perforated plate with open area 40% (22-gauge aluminum plate with 1/8-in diameter holes staggered 3/16-in diagonally)
5.) Perforated plate with open area 50% (22-gauge aluminum plate with 3/16-in diameter holes staggered 1/4-in diagonally)
6.) Perforated plate with open area 58% (22-gauge aluminum plate with 1/4-in diameter holes staggered 5/16-in diagonally)

When the 57% open area wedgewire screen was used, there was significant variability in approach velocities across each screen panel. On each screen, approach velocities were higher at the center of the screen and lower at the support piers (Figure A-1). To ensure that these velocity patterns were not caused by the vertical backing bars attached to the back of the screen for rigidity, the backing bars were removed. Data collected without backing bars showed the same laterally skewed velocity distributions across each screen (Figure A-2).

The wedgewire screen was replaced with a perforated plate of approximately the same open area. Approach velocities with the 58% open area perforated plate were very similar to the 57% open area wedgewire screen (Figure A-3). Velocity data collected with a 51% open area perforated plate showed that the lateral variability across each screen was reduced (Figure A-4). Data collected with 40% and 33% open area perforated plate screens showed even greater reduction in lateral skewness across each screen (Figures A-5 and A-6).

With a higher screen open area, it appears that flow passing through the screen interacted with the piers, producing lower screen approach velocities in this region. Vortex shedding was visually observed behind the screen face. When the open area was lower, flow through the screen was more evenly distributed and less turbulent. In this case, it appears that the piers did not adversely affect approach velocities in front of the screen. Results show that screen open area should be 40% or less in the prototype to prevent localized flow patterns from occurring at screen locations in front of the piers.

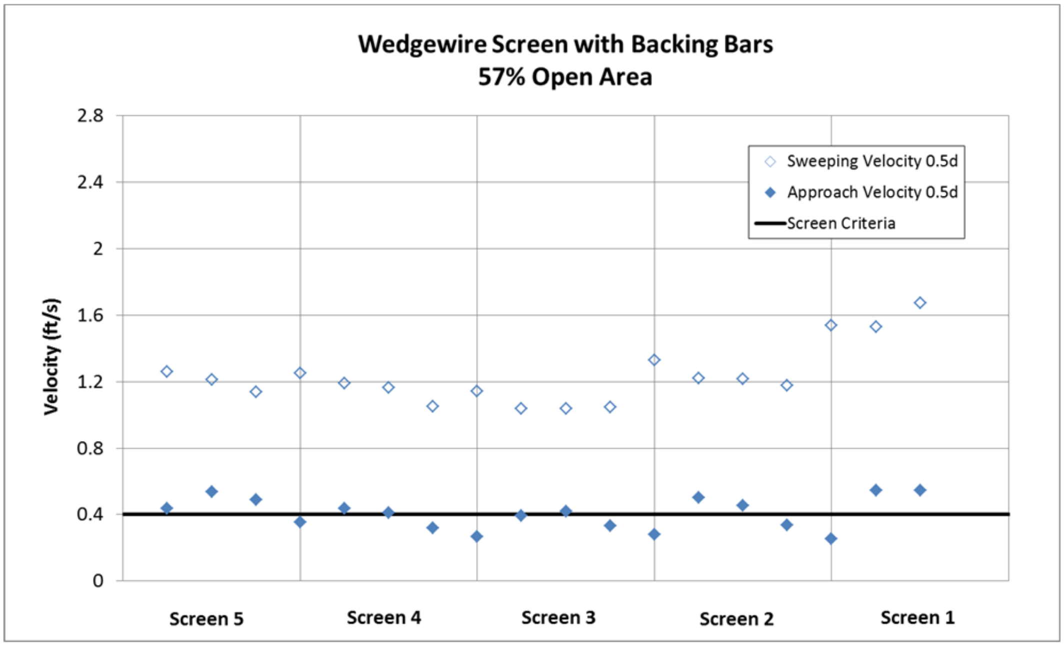

Figure A-1. Approach and sweeping velocities measured on a 57% open area wedgewire screen with backing bars.

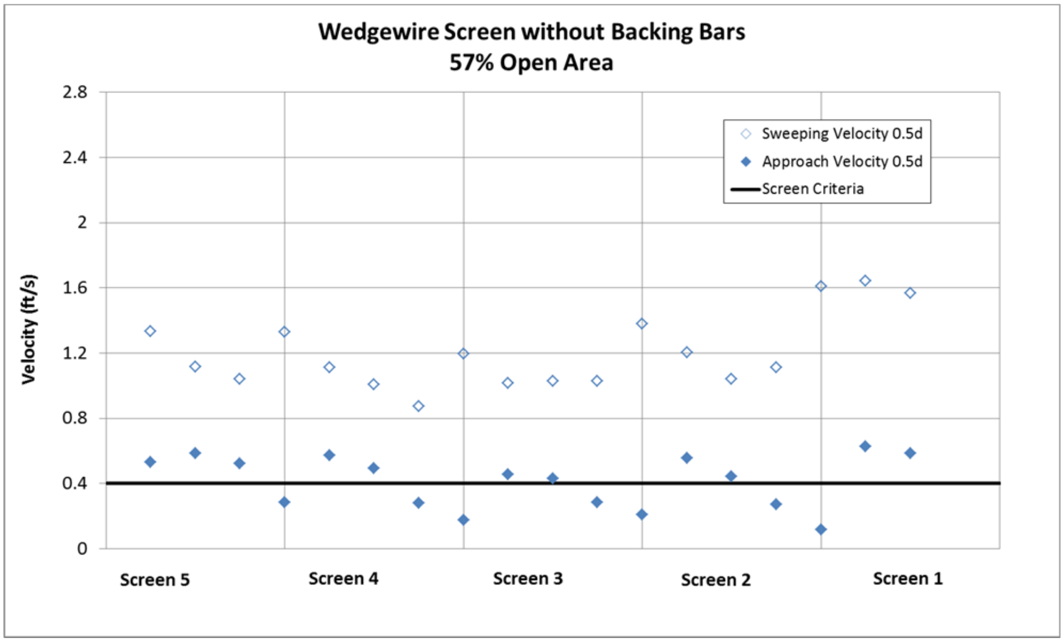

Figure A-2. Approach and sweeping velocities measured on a 57% open area wedgewire screen without backing bars.

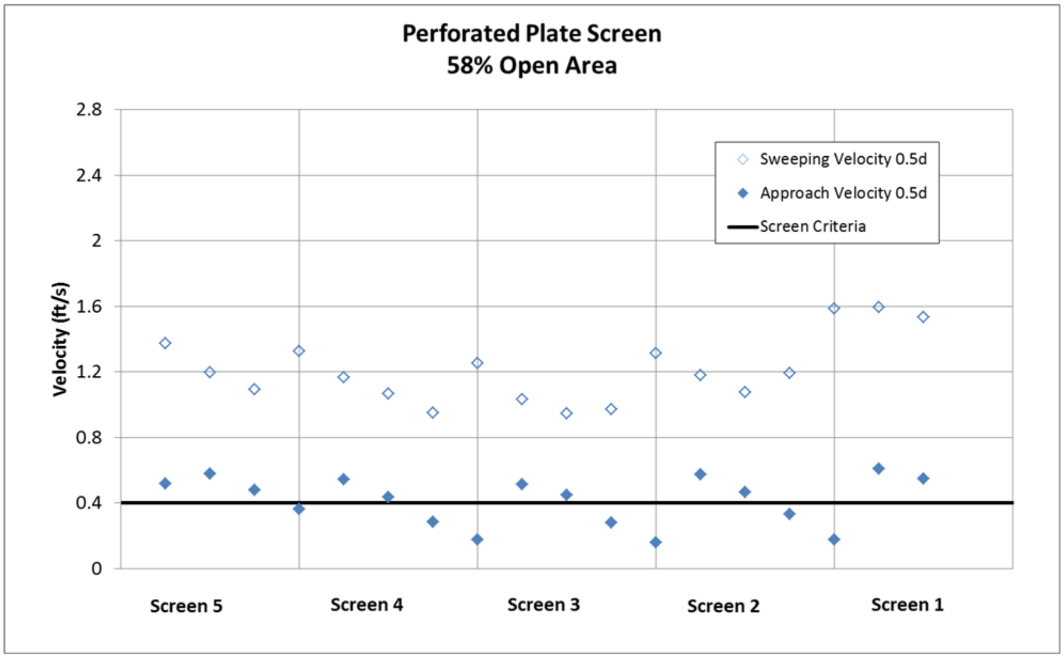

Figure A-3. Approach and sweeping velocities measured on a 58% open area perforated plate screen.

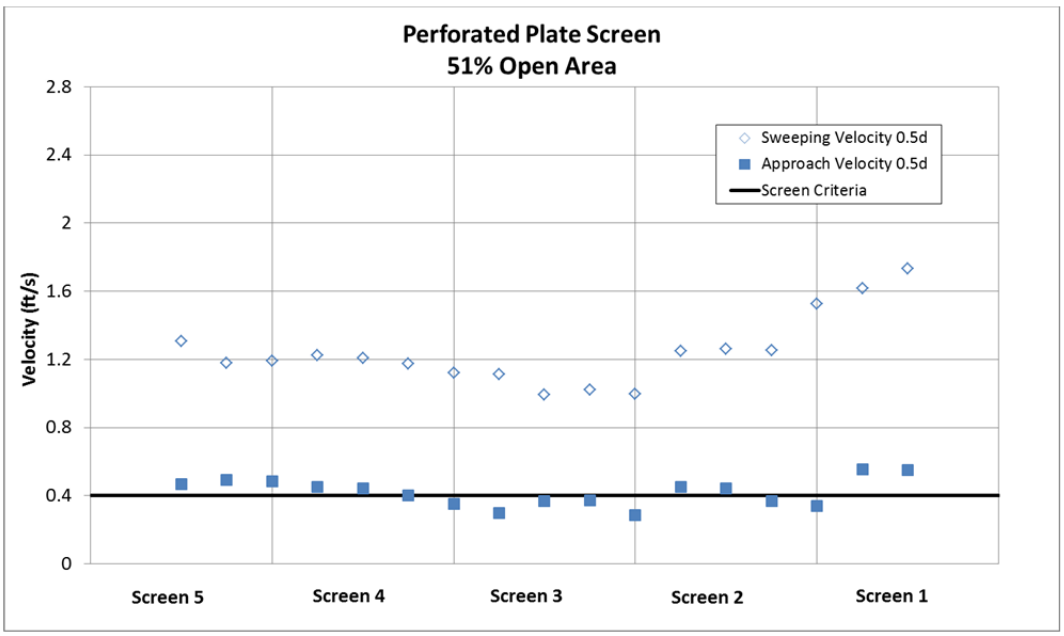

Figure A-4. Approach and sweeping velocities measured on a 51% open area perforated plate screen.

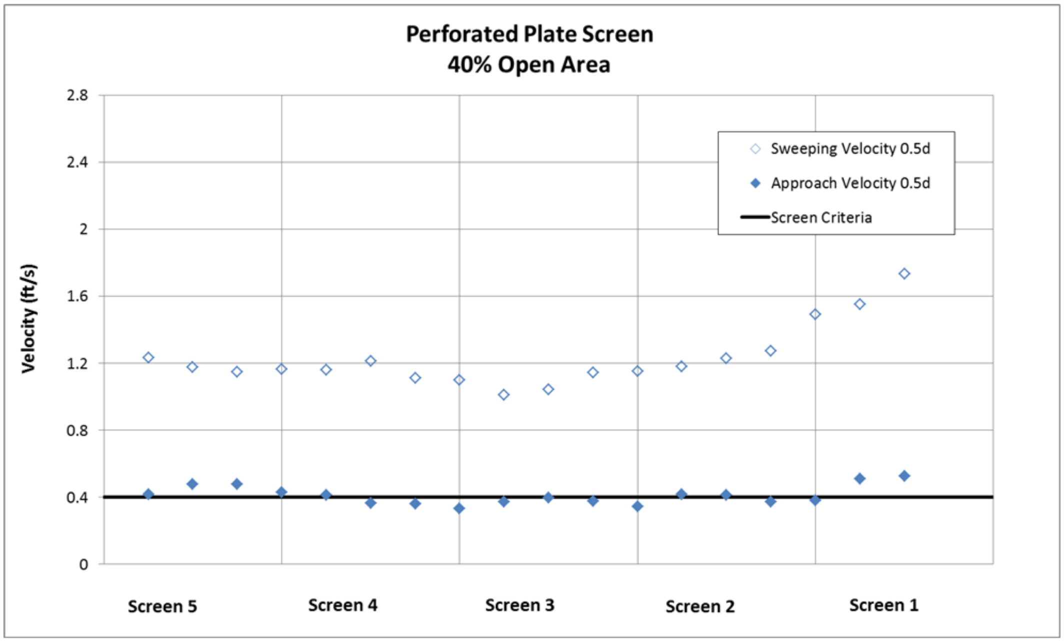

Figure A-5. Approach and sweeping velocities measured on a 40% open area perforated plate screen.

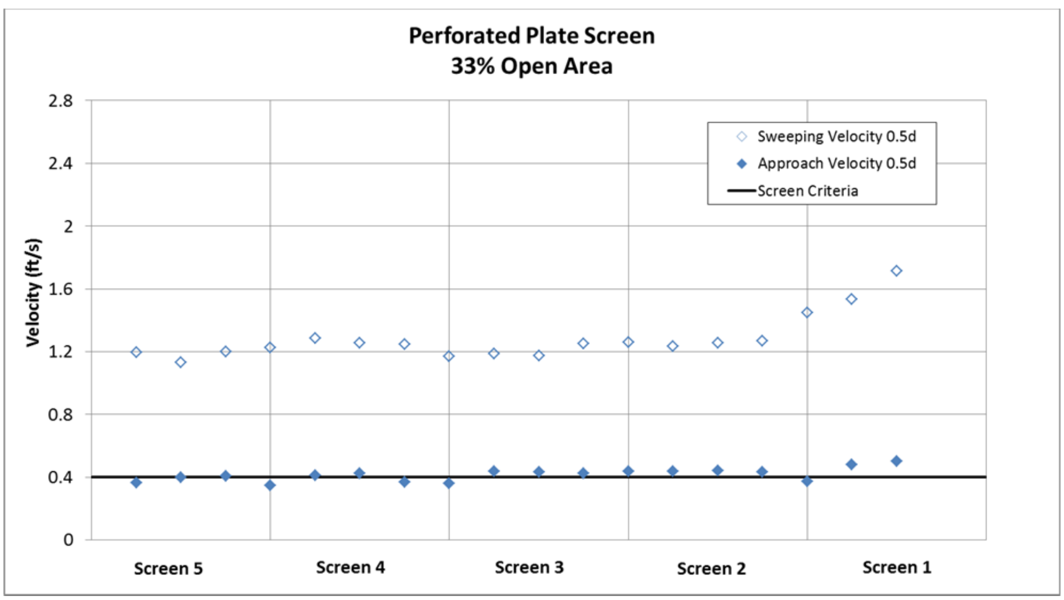

Figure A-6. Approach and sweeping velocities measured on a 33% open area perforated plate screen.