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Physical Hydraulic Modeling of Secondary Louver Replacement at the Tracy Fish Collection Facility

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14. ABSTRACT

The Tracy Fish Collection Facility (TFCF), located near Byron CA, was developed and built in the 1950's as part of the Central Valley Project to protect fish entering the Delta Mendota Canal. Although the facility was built with the best available technology at the time, many changes to laws, regulations, infrastructure, ecology, debris loads, delta operations and overall presence of fish have driven the TFCF to renovate and improve fish salvage processes. This study was conducted to support the replacement of the existing secondary louver with Hydrolox traveling screens. A partial full-scale hydraulic model of the secondary dewatering system was constructed to determine if the final designs for replacing the secondary louvers with traveling screens would operate as desired. Debris representative of that found at the TFCF was weighed and distributed throughout the inflow of the model and monitored to determine the Hydrolox debris removal efficiency. According to the model study results, it is anticipated that the replacement of existing secondary lovers with Hydrolox screens will provide a substantial amount of debris removal. Additional information regarding velocity profiles in front of the screens, clean water bypass and internal baffling were also collected during this study.

15. SUBJECT TERMS

Louvers, secondary dewatering, Tracy fish collection facility, Hydrolox, traveling screens, debris removal, fish salvage, debris

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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

TABLES

FIGURES

APPENDICES

GLOSSARY OF SYMBOLS

	Debris removal efficiency (percent)
	Total weight of debris released in the physical model (kg)
	Total weight of debris that entered the holding tank (kg)
Gpm	Gallons per minute
ft^3/sec	Cubic feet per second

Executive Summary

The Tracy Fish Collection Facility (TFCF) is located at the head of the Delta Mendota Canal just west of the town of Tracy, California. The purpose of the TFCF is to screen fish from water diverted into the Delta Mendota Canal and safely return them to the Sacramento-San Joaquin delta. Fish screening is accomplished by passing 4,600 ft^3/sec through primary and secondary louvers. Fish and approximately 12 ft^3/sec flow are diverted into fish holding tanks. Recent concern over damaging fish species listed under the state and federal Endangered Species Acts have increased the need for improved fish salvage at the TFCF. Studies of fish salvage directly related to operation of the secondary dewatering channel show three major deficiencies in the louver system including no automatic cleaning method being in place, no salvage during cleaning shutdowns, and highly variable louver efficiencies based on flow conditions and species.

In 2009 the National Marine Fisheries Service issued a biological opinion containing actions required at the TFCF to improve fish salvage efficiency. The study reported herein investigated one of the alternatives selected to address the biological opinion requirements for improving fish salvage in the secondary dewatering system and the reduction of debris in the holding tanks.

This report provides an evaluation of the final designs for replacing the louvers in the secondary channel at the Tracy Fish Collection Facility with Hydrolox traveling screens. A partial full-scale physical hydraulic model of the final design was constructed to determine the traveling screens debris removal effectiveness. Additional information regarding upstream velocity profiles, head loss and screened water bypass requirements were also collected during the model study.

The physical model contained the downstream half of the secondary channel modeled at full-scale but only partial depth. Due to the variable nature of debris loadings at the TFCF several types of debris were tested including Egeria, grass hay and saturated woody debris. Debris was weighed before and after each simulation and the debris removal efficiency was calculated for each data run.

Test simulations were conducted at channel velocities between 1.64 and 3.54 ft/sec which correspond with historical secondary channel velocities. Debris removal results were promising, with removal efficiencies between 83% and 99% yielding an average of 92% for all runs.

In addition to documenting debris removal, approach velocities and headloss across the screens were documented. Approach velocities ranged from 0.13 to 0.62 ft/sec for all measured conditions. The majority of measurements were uniform across the screens with an average approach velocity below 0.4 ft/sec. The uniformity of approach velocities across the screen reduces the need for internal baffling to reduce hot spots of velocity. Headloss for each screen was below 0.13 ft at a secondary channel velocity of 2.5 ft/sec, which is better than originally expected.

This study determined that the clean water bypass should normally be operated at or slightly above the secondary channel velocity to ensure maximum removal of aquatic plant debris with the Hydrolox traveling screens. Debris pegs should be mounted on the screen belt in staggered rows with 6-in between pegs and 10-in between each row. The screen belt speed should be approximately 4 to 5 ft/min. It is also recommended that the clean water bypass pump at Tracy be pulled, inspected, and refurbished or replaced to ensure that clean water bypass velocities (flow of approximately 9000 gpm) can be at or above the average secondary channel velocity.

Introduction and Purpose

The Tracy Fish Collection Facility (TFCF) is located at the head of the Delta Mendota Canal just west of the town of Tracy, California. The canal was constructed by the Bureau of Reclamation in the late 1940's and early 1950's to divert and convey waters of the Sacramento and San Joaquin Rivers to the southern Central Valley. The canal has a design capacity of 4,600 ft^3/sec. The purpose of the TFCF is to screen fish from water diverted into the Delta Mendota Canal and safely return them to the Sacramento-San Joaquin delta away from the hydraulic influence of the diversion facility. Fish screening is accomplished using a primary dewatering system consisting of a 320-ft-long louver angled at 15 degrees to the flow. The primary dewatering louver contains four fish bypasses spaced along the louver line that direct fish and approximately 140 ft^3/sec (maximum) of flow to the secondary dewatering channel. The secondary channel provides further dewatering and concentration of fish into a flow of about 12 ft^3/sec that transports fish to the holding tanks. Secondary dewatering is performed by passing the primary bypass flow through two parallel sets of louvers. Two louver lines were implemented in the original secondary channel design to maximize louver fish screening efficiency for small-bodied fish that can pass through the 1.0 inch louver bar spacing.

This study investigated secondary channel flow conditions and the debris removal efficiency of the Hydrolox[1] vertical traveling screens with debris pegs that will replace the secondary louver system. This alternative for improving secondary channel fish salvage was selected over other types of automated louver cleaners previously studied including submerged spray washing, raking and vacuum cleaning.

[1] Hydrolox is a manufacturer of plastic and nylon belted vertical traveling screens

A single line of four traveling screens totaling about 46 ft in length will replace the two secondary louver lines. The traveling screens have a screen slot width of 1.75 mm, 32 percent porosity and are self-cleaning. The screens tested were customized by adding 0.75-in-long debris pegs mounted on the screen belting. The pegs were specifically designed to catch and remove pond weed and other stringy debris passing in front of the screens prior to it entering the fish holding tanks. Egeria, a common pond weed, is the primary debris load encountered at the TFCF.

Background

Concern over a general decline in fish populations in the delta and its tributaries and the listing of chinook salmon, central valley steelhead, delta smelt and green sturgeon under the state and federal Endangered Species Acts have increased the need for improved fish salvage at the TFCF (Service, 2011). Studies of fish salvage directly related to operation of the secondary dewatering channel show three major deficiencies in the louver system that impact fish salvage.

First, the secondary louvers do not have an automated cleaning method. Cleaning requires dewatering the secondary channel and hand raking the louver bars. During cleaning, flow diversion through the primary louvers continues with no bypass flow and no fish salvage, resulting in increased fish loss through the primary louvers.

Second, debris buildup on the louvers over time reduces louver flow area increasing louver approach velocity and the debris load passed into the fish holding tanks. Debris loads can plug large areas of the louvers in a few hours during the spring and fall when debris levels are highest.

Third, fish guidance efficiency studies of the secondary show fish salvage varies widely between species and with secondary channel flow velocity. Studies conducted at the TFCF found louver efficiency varied widely between the 32 fish species identified in the salvage (Bowen, et al., 2004). The studies show that setting secondary channel velocity to achieve peak louver efficiency for one species can result in decreased louver efficiency for other species.

In 2009 the National Marine Fisheries Service (NMFS) issued a biological opinion containing actions required at the TFCF to improve fish salvage efficiency. Action IV.4.1 entitled “Tracy Fish Collection Facility Improvements” describes the following actions pertaining to the secondary dewatering channel:

> *“By December 31, 2012, improve the whole facility efficiency for the salvage of Chinook salmon, CV steelhead, and Southern DPS of green sturgeon so that overall survival is greater than 75 percent for each species.*

By March 31, 2011, Reclamation shall complete studies for the re-design of the secondary channel to enhance the efficiency of screening, fish survival, and reduction of predation within the secondary channel structure and report study findings to NMFS. NMFS shall review study findings and if changes are deemed feasible, Reclamation shall initiate the implementation of the study findings by January 31, 2012.

No later than 12 months from the date of issuance of this Opinion, Reclamation shall submit to NMFS for approval, one or more solutions to the loss of Chinook salmon and green sturgeon associated with the cleaning and maintenance of the primary louver and secondary louver systems at the TFCF. In the event that a solution is not in place within 24 months after the issuance of this document, pumping at the Tracy Pumping Plant shall cease during louver cleaning and maintenance operations to protect fish from loss during these actions."

The study described in this report was conducted as a partial full-scale test of the alternative selected to address the biological opinion requirements for improving fish salvage in the secondary dewatering system and the reduction of debris in the holding tanks.

Model Description

Test Facility

Testing was conducted in Reclamation's hydraulic laboratory located in Denver, CO USA. A partial height full-scale model of the downstream half of the secondary channel was constructed in an existing 60-ft-long 10-ft-wide and 4-ft-deep flume. The flume has the ability to pass approximately 30 ft^3/sec of flow from 4 sources. All sources draw water from a 250,000 gallon sump which is refilled by the return flow from the model. All flows were measured using either a calibrated venturi meter or an ultrasonic flow meter allowing inflow to be monitored to around 1 percent accuracy overall.

Physical Model Features

The physical model contained the entire width of the secondary channel (Figure 1) but only modeled part of the channel length and depth. Due to laboratory flume length limitations, only the downstream two of the four prototype screens were modeled. Prototype flow conditions approaching the screens were simulated using a bullnose transition (Figure 2). Depth limitations were set to a maximum of 4 feet due to the wall height of the flume. Figure 3 contains an overview of some of the important model features. These include:

- *Headbox* – including a rock baffle to calm and uniformly distribute incoming flow from three 12-inch pipes (Inflow 1-3)

- *Clean water bypass* – supplied by an additional 12-inch pipe (Inflow 4)

- *Bullnose transition* – used to simulate prototype approach flow conditions from the upper screens which are not modeled.

- *Traveling screens 1-4* – Two screens are used in the model to represent one prototype screen. The screens were fabricated using the same Hydrolox screen material and debris pegs that will be used in the prototype. Variable frequency drive motor controls allowed the travel speed of the screens to be adjusted if needed. Due to electrical supply constraints Screen 1 was on an independent speed controller from Screens 2-4. Generally, all screens were operated at approximately the same belt speed.

- *6" holding tank bypass* – allows inflow of debris and flow from the secondary channel into the holding tank

- *Holding tank* – has screened outlets to accumulate and collect all entering debris

- *Removable tailboards* – adjustable to meet target velocities upstream of Screen 1.

- *Tailbox* – has screed outflow to collect all debris that passes over the traveling screens.

- *Walkway* – to allow access to instrumentation, controls and screens.

In addition to the above features, the traveling screens were raised 1-inch off the bottom of the flume to allow room for debris pegs to pass without damage. The one inch gap also allowed passage of debris traveling along the bottom of the secondary channel. The debris pegs were designed to be easily removable so that the best pattern and spacing for removing debris could be determined.

For detailed pictures of the model refer to Appendix A.

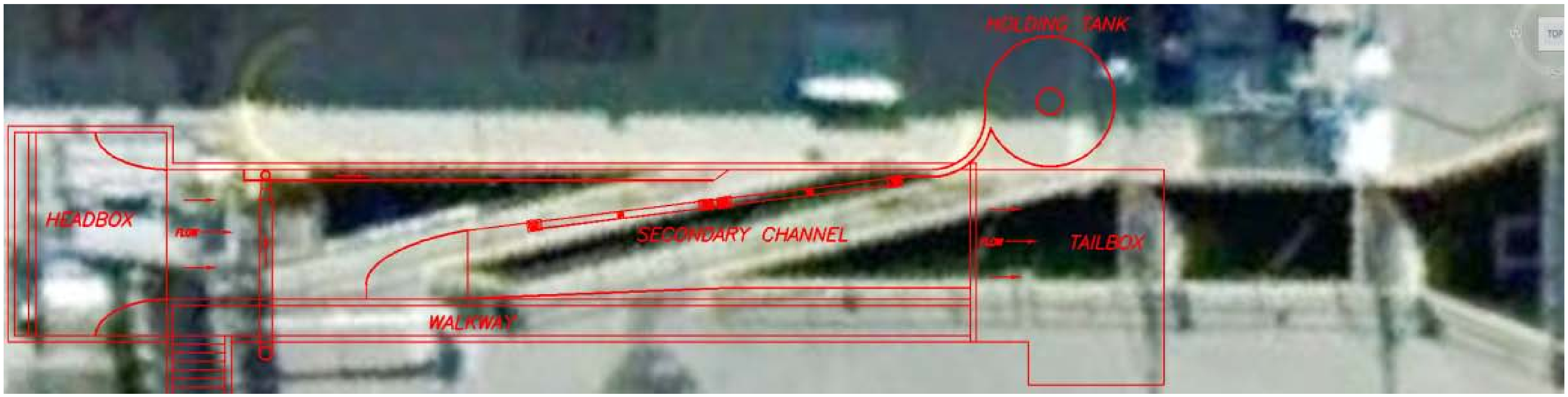

Figure 1 - Physical model extents overlaid on an aerial image of the secondary channel (flow from left to right)

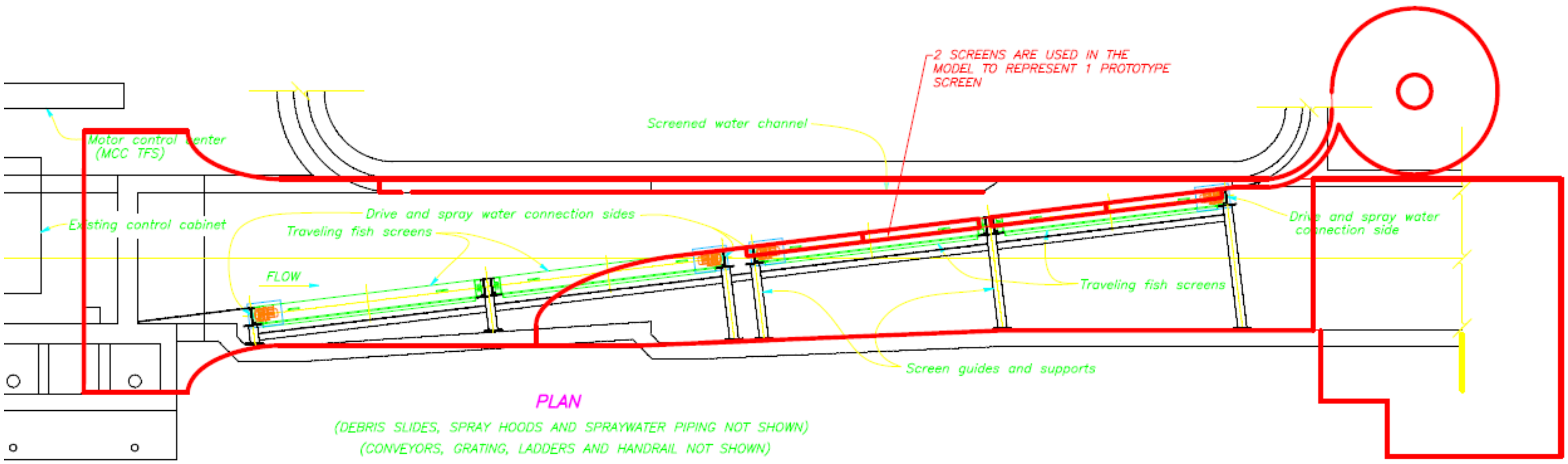

Figure 2 - Physical model extents overlaid on the final design specification drawings (flow from left to right)

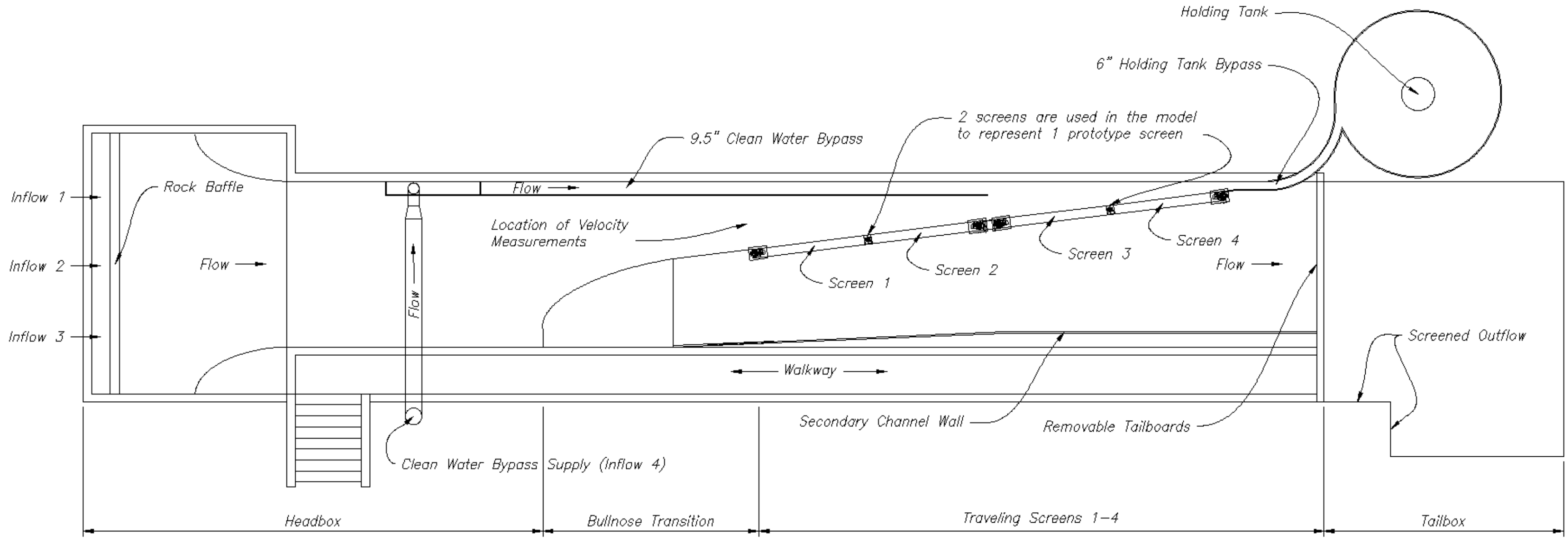

Figure 3 - Overview and description of physical model features (flow from left to right)

Test Description

Debris Monitoring

The character of the debris at the TFCF changes seasonally with woody debris (sticks, culms from riparian plants, and bark) being dominant during January through April. Starting in June, Egeria begins to dominate and continually increases through December (Boutwell, et al., 2007). Considering the variable nature of the debris loading at the TFCF, tests were conducted with both woody debris and Egeria to ensure adequate removal during all times of the year. During testing Egeria supplies quickly disintegrated into non-usable pieces and saturated grass hay was used as a surrogate due to its similar size, characteristics, and local availability.

Prior to testing, the debris was soaked in water and disinfectant for at least 24 hours to allow it to reach full saturation. Once saturated, the debris was ready to be introduced into the physical model. Debris used in each test was quantified by measuring debris weight. To remove excess water from the samples, debris was spun 10 revolutions with an industrial hand spinner prior to being weighed. This process was conducted prior to introducing debris at the head of the model and following debris recovery from the bypass holding tank and channel downstream of the screens.

Test Procedure

Test procedures were designed to allow varying debris loading and historical secondary channel velocities to be modeled. Records indicate that velocities in the secondary channel can range from 0.25 to 6.76 ft/sec with a yearly average of 2.41(Mortensen, 2011). To adequately match historical velocities, the model velocities directly upstream of the first screen were set between 1.5-3.5 ft/sec. Direct measurement of the channel velocity during testing was not feasible due to the amount of debris that was introduced to the flow. As such, water depths were measured directly upstream of the first screen and the total discharge from inflows 1-3 (Figure 3) was divided by the cross sectional area at that location to obtain the average channel velocity. Velocities of the clean water bypass were measured using a similar technique at the end of the clean water channel using only inflow 4 (Figure 3). The two flows were added to obtain the total model flow.

Once the total model flow was set and stabilized the four traveling screens were initialized and set to the same speed. After documenting the flow rates, depths and screen travel speeds, a known mass of debris was introduced into the model. Between 8 to 21 kg of debris was introduced throughout the water column over approximately 5 minutes per simulation. After all the debris was released the model was allowed to run for a few more minutes to allow all the debris to pass through the model and into either the tailbox or the holding tank before the flow was shut off. Once shut down, the debris was collected and re-weighed from both the holding tank and tailbox. A comparison between the total debris released and that recovered from both the holding tank and tailbox was conducted to ensure that all debris was accounted for.

During some simulations debris was lost over the tailbox screen and into the sump recirculation tank. For that reason, debris removal efficiency was calculated based on the amount of debris entering the holding tank using Equation 1:

$$DRE = \frac{(DB_{in} - DB_{HT})}{DB_{in}} \times 100 \qquad (1)$$

where DRE is the debris removal efficiency in percent, DB_{in} is the total weight of debris released in kg (after removing surface water), DB_{HT} is the total weight of debris that entered the holding tank in kg (after removing surface water).

During most of the simulations video and still photography was used to document and record the testing. Video footage allowed researchers to re-visit the debris impingement and removal process in greater detail.

Results

Debris Removal

Table 1 contains a summary of the model results from 14 test simulations. Channel velocities ranged from 1.67-3.54 ft/sec and clean water velocities ranged from 0.00-3.27 ft/sec. Screen speeds ranged from 3.74-6.83 ft/min. Considering that multiple types of debris can be present at different times of the year tests were conducted with both individual and combined debris types. Debris removal for the tests ranged from 83-99 percent with an average debris removal of 92 percent for all simulations.

Table 1 - Summary of debris removal data for 14 test simulations

Test (#)	Channel Velocity (ft/sec)	Clean Water Velocity (ft/sec)	Screen Speed [#1]/[#2-4] (ft/min)	Type of Debris	Debris Removal (%)
1	2.54	1.00	5.77 / 6.83	Egeria*	83
2	2.35	0.80	3.74 / 5.85	Egeria*[+]	88
3	2.64	2.00	3.74 / 5.85	Egeria*[n]	88
4	2.44	1.86	4.23 / 5.82	Grass hay	94
5	2.58	2.04	4.52 / 5.82	Wood & Hay	96
6	2.60	2.04	4.52 / 4.51	Grass Hay	95
7	2.59	2.02	4.52 / 4.51	Wood	93
8	1.67	2.47	4.52 / 4.51	Grass hay	99
9	1.81	0.00	4.52 / 4.51	Grass hay	83
10	3.09	2.19	4.43 / 4.51	Grass hay	99
11	3.52	0.00	4.23 / 4.51	Grass hay	92
12	3.24	3.27	4.23 / 4.51	Grass hay	94
13	3.54	0.00	4.23 / 4.51	Wood	93
14	3.06	3.09	4.23 / 4.51	Wood	86
				Average Removal:	92

** Debris was fairly deteriorated compared to material entering TFCF*

[+] Loss of tailwater control before test was completed

[n] Problems with loss of fine debris from holding tank drain

Velocity Profiles

Velocity measurements were collected at 4 locations on each screen for 3 conditions where the average channel velocities were 1.5, 2.5 and 3.0 ft/sec respectively. Figure 4 shows that velocity measurements were made at the third points along each screen shown as locations A and B. At each longitudinal location, velocity was measured at both mid-depth and 1 inch off the invert (low depth). Mid-depth measurements were located 0.4 times the water depth up from the channel bottom. All measurements were taken 3 inches in front of the upstream face of the screen according to the Bureau of Reclamation screen testing standards (Reclamation, 2009) using a 10-MHz Acoustic Doppler Velocimeter (ADV). As each screen was measured in the same location, Tables 2-4 and Figures 5-6 clarify velocity measurements by putting the screen number before the measurement location (1A indicates screen 1 measured at the A location).

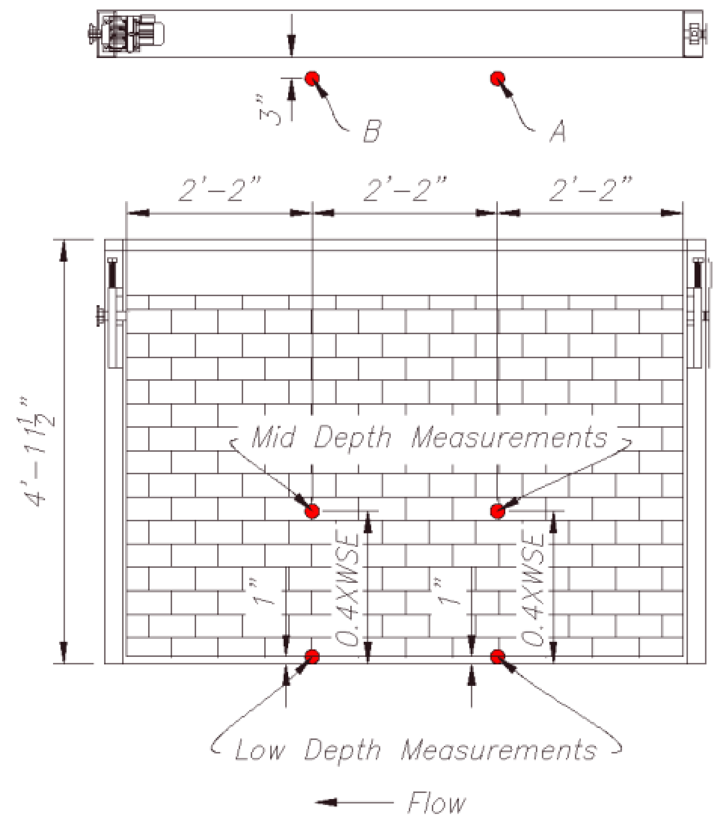

Figure 4 - Locations for velocity measurements on each screen

Table 2 - Approach and sweeping velocity data (channel velocity = 3.0 ft/sec)

Screen Location	**Channel Velocity of 3.0 ft/sec**			
	Approach Velocity (ft/sec)		*Sweep Velocity (ft/sec)*	
	Mid Depth	*Low Depth*	*Mid Depth*	*Low Depth*
1A	0.37	0.36	3.08	3.04
1B	0.39	0.32	3.02	2.90
2A	0.35	0.60	3.12	2.61
2B	0.32	0.62	3.08	2.74
3A	0.36	0.54	3.49	2.99
3B	0.35	0.50	3.51	3.17
4A	0.32	0.39	3.16	2.66
4B	0.37	0.28	2.35	2.38
Average	0.36	0.45	3.10	2.81

Table 3 - Approach and sweeping velocity data (channel velocity = 2.5 ft/sec)

Screen Location	**Channel Velocity of 2.5 ft/sec**			
	Approach Velocity (ft/sec)		*Sweep Velocity (ft/sec)*	
	Mid Depth	*Low Depth*	*Mid Depth*	*Low Depth*
1A	0.29	0.32	2.66	2.52
1B	0.30	0.29	2.67	2.53
2A	0.25	0.45	2.70	2.32
2B	0.28	0.37	2.74	2.28
3A	0.25	0.40	2.89	2.30
3B	0.26	0.46	2.94	2.54
4A	0.28	0.38	2.74	2.02
4B	0.32	0.34	2.35	1.57
Average	0.28	0.38	2.71	2.26

Table 4 - Approach and sweeping velocity data (channel velocity = 1.5 ft/sec)

Screen Location	**Channel Velocity of 1.5 ft/sec**			
	Approach Velocity (ft/sec)		*Sweep Velocity (ft/sec)*	
	Mid Depth	*Low Depth*	*Mid Depth*	*Low Depth*
1A	0.19	0.26	1.72	1.76
1B	0.15	0.19	1.71	1.77
2A	0.17	0.25	1.74	1.69
2B	0.16	0.28	1.76	1.58
3A	0.13	0.35	1.90	1.65
3B	0.13	0.38	1.90	1.73
4A	0.15	0.32	1.94	1.45
4B	0.23	0.33	1.90	1.45
Average	0.16	0.29	1.82	1.64

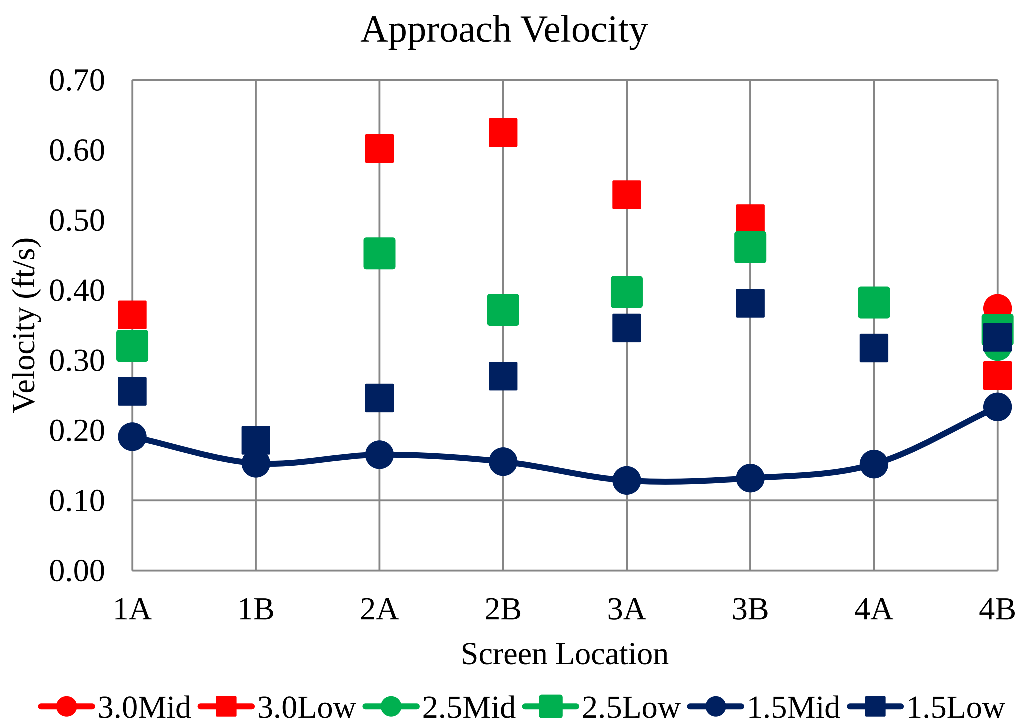

Figure 5 - Mid and low depth approach velocities (channel vel. of 3.0, 2.5 & 1.5 ft/sec)

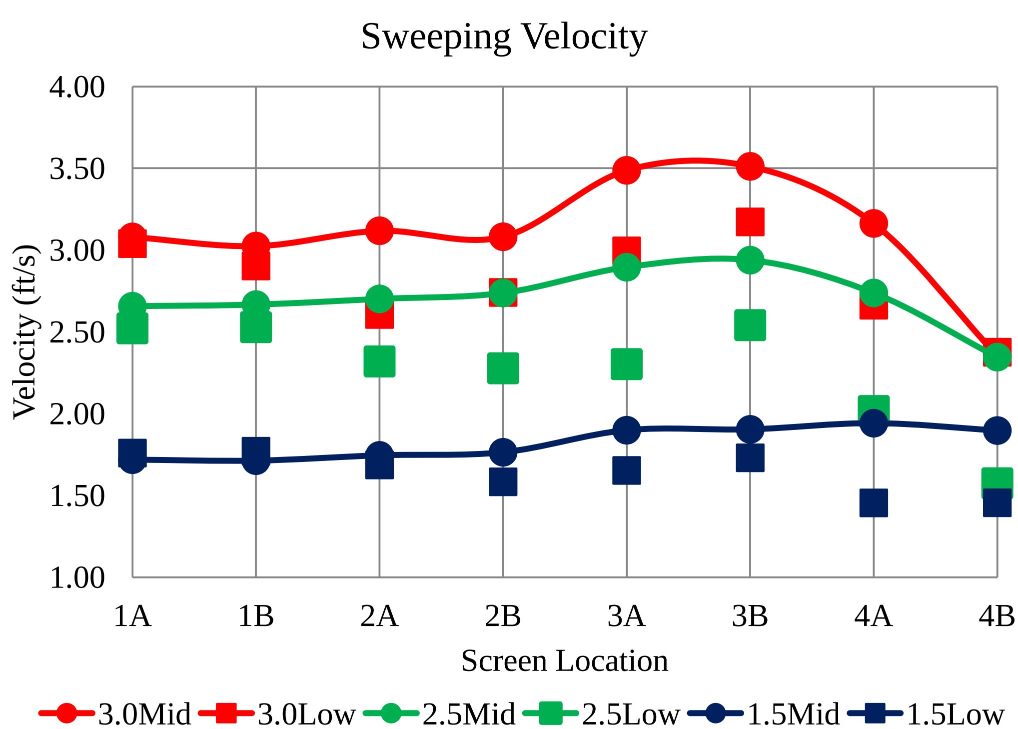

Figure 6 - Mid and low depth sweeping velocities (channel vel. of 3.0, 2.5 and 1.5 ft/sec)

Headloss

Headloss calculations were done by measuring the difference between the water surface elevation in front and behind of each screen. Average depths were measured for 2 minutes at the center of each screen. Table 1 provides the upstream (U/S) and downstream (D/S) depths that were measured with a channel velocity of 2.5 ft/sec and the calculated headloss in feet. Measurements were taken while the screens were free of debris and not traveling. The maximum differential was calculated at screen number 4 with 0.13 feet of loss. Due to the small amount of loss at the 2.5 ft/sec channel velocity no other measurements were taken. Visual inspection during testing confirmed that any additional headloss caused due to higher velocities and debris loading was undetectable.

Table 5 - Headloss calculations for each traveling screen (channel velocity = 2.5 ft/sec)

Location	Average Screen Depth (ft)			
	1	2	3	4
U/S screen	2.78	2.74	2.68	2.78
D/S screen	2.70	2.66	2.66	2.65
Headloss (U/S-D/S)	0.08	0.08	0.02	0.13

Discussion

Debris Removal

As indicated in the Tracy Series Volume 33 report (Boutwell, et al., 2007), debris loading at the TFCF can be severe during many parts of the year. According to Boutwell the Chinese mitten crab removal screen could be used to remove approximately 50 percent of debris loads entering the secondary channel. Even with promising results from field tests the screen was rarely used and debris continues to be an issue at the TFCF. To help mitigate some of the problems arising from large debris loads, the secondary channel must be shut down and cleaned on a regular basis. Cleaning procedures include draining and lowering several individuals into the secondary channel to manually remove debris that has collected on the louvers and channel floor. Not only is this process labor intensive and dangerous for TFCF employees but it also prevents fish salvage for an extended period of time when the secondary channel is drained. Realizing the issues with debris, periodic shutdown of the secondary and the resulting fish loss the National Marine Fisheries Service issued a ruling that the TFCF must decrease fish loss associated with the secondary and primary channel cleaning operations (National Marine Fisheries Service, 2009).

To help meet the biological opinion and reduce the loss of fish associated with debris accumulation and cleaning the secondary channel louvers, the TFCF is planning on replacing the secondary louvers with traveling Hydrolox fish screens. Due to the small openings in the new screens, one long linear screen will replace both sets of existing secondary louvers. To accomplish this and still meet design requirements the approach angle of the screen was changed from 15 degrees to 7. Changes in the approach angle and the development of new debris pegs warranted a physical model study to provide evidence that the screens would be both fish-friendly and remove debris adequately.

Without knowing the true debris loads entering the secondary channel at the TFCF it is difficult to predict the total amount of debris that will be removed by the new traveling screens. Model results were encouraging, showing an average removal of 92 percent with all types of debris tested. It is expected that field removal will be of the same magnitude.

The traveling screens were tested at speeds around 4 to 5 ft/min for the majority of the tests. During initial testing Screen 1 was inadvertently set at a slower speed than Screens 2-4. The slower speed at Screen 1 did not seem to be the cause of the lower debris removal during those tests. Belt speed was selected based on manufacturers' recommendations and observations of debris removal effectiveness. Increasing the speed of the screen is possible and will clear debris more quickly but could increase wear and maintenance costs. Depending on actual debris loading, the screens could be operated intermittently based on water surface differential across the screen or a set schedule.

In addition to considering screen travel speed to optimize debris removal the spacing of the debris pegs was adjustable. Initially it was the researchers' intent to test several peg layouts. However, modifications to the initial layout (Figure 7) were not necessary to obtain a high percentage of debris removal and no modifications were made. Visual observations of the tests did suggest that increasing the peg density of screen 4 near the bypass entrance may further increase debris removal effectiveness for high debris loads. This assumption was not tested in the laboratory tests and should be evaluated along with impacts to fish movement into the bypass entrance.

Debris pegs (Figure 8) are ½-in wide by 2-in tall and protrude from the Hydrolox screens ¾-in. To allow adequate clearance while the screens are in motion the bottom of each screen was raised off the floor one inch (Figure 9). In addition to allowing the debris pegs to pass, the gap also enables small woody debris, sand and small shells traveling along the bottom of the channel to pass under the screens. The 1 inch bottom gap is similar to the spacing between the louver bars and increases the potential for loss of small fish. To maximize fish salvage a removable brush could be mounted to cover the gap while allowing passage of the debris pegs during periods of low entrainment of bed debris. This idea was not tested in the model.

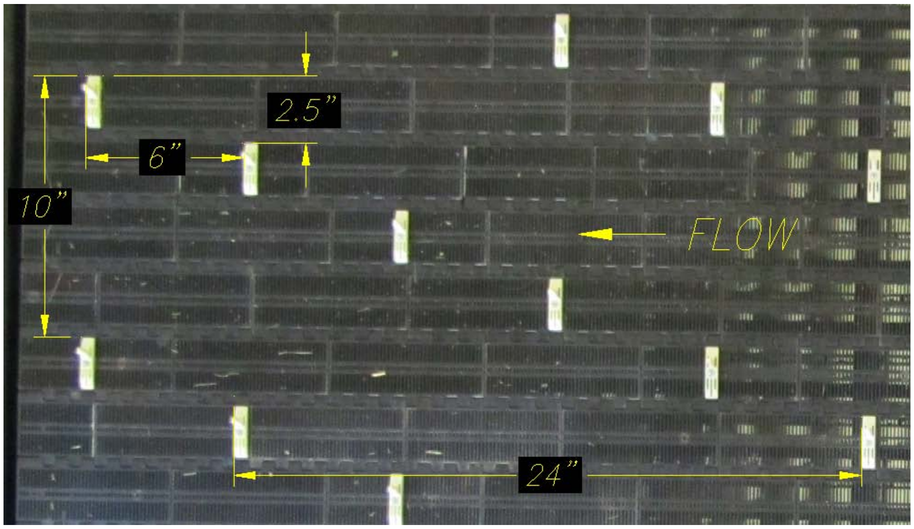

Figure 7 - Debris peg layout and spacing (flow is from right to left)

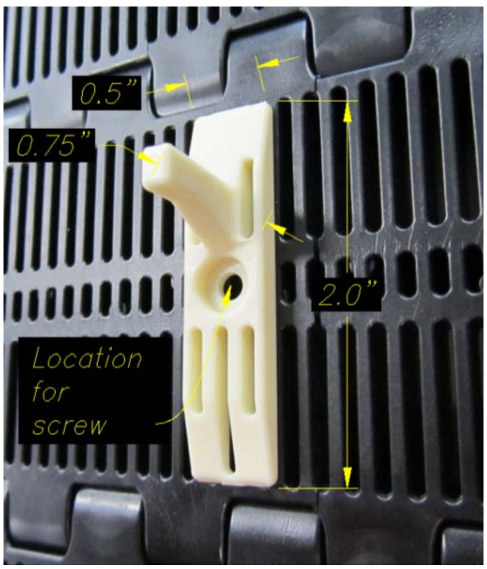

Figure 8 - Debris removal pegs without screw to permanently attach to screen

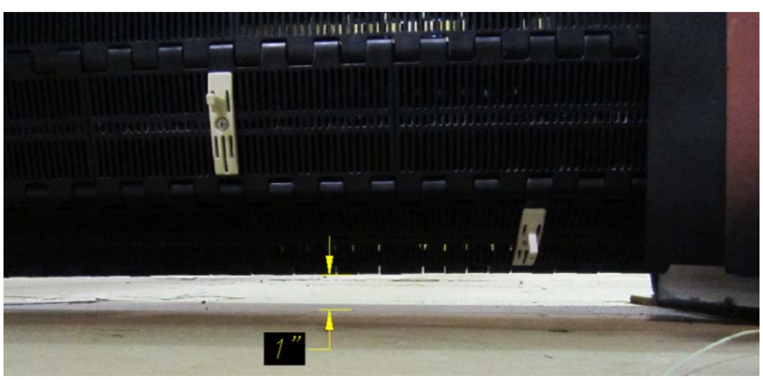

Figure 9 - 1 inch space along bottom of traveling screen

Velocities

Approach Velocities

Figure 10 contains a comparison of average approach velocities and secondary channel velocities recorded by TFCF personnel from 2005-2007. The solid black line is a linear best fit trend line showing average historical values. Any data below the black solid line indicates approach velocities that are below normal historical values. Due to the different approach angle, the new Hydrolox screens are longer than the existing louvers and will reduce the overall approach velocity as is indicated by average mid (pink) and low (yellow) depth data included in Figure 10.

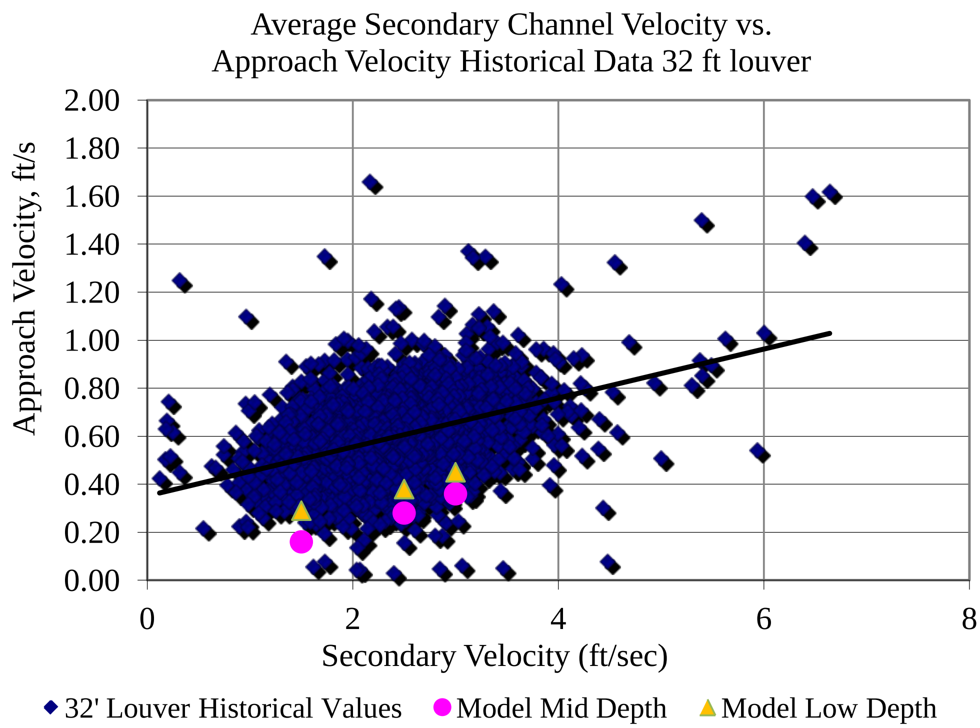

Figure 10 - Model and historical 32-ft louver approach velocities vs secondary channel velocity

Internal Baffling

Another benefit to evaluating the approach velocities along the screen was to determine if internal baffling is necessary in the prototype design to reduce hot spot velocities that could impinge fish against the screens. No alarming hot spots were discovered during the velocity profiling. Near the channel invert, where the screens are mounted 1 inch above the bed, approach velocities were generally higher than at mid-depth as shown in Tables 2-4. The model velocity data does not indicate a need for additional baffling of the traveling screens. However, understanding that inflow conditions from the primary bypass lines are not uniform, it is expected that inflow velocity profiles could skew the approach velocities across the screen. For this reason it is recommended that the ability to install baffling in the future should be incorporated in the screen design.

Clean Water Supply

As shown in Table 1, clean water velocities from 0.00-3.30 ft/sec were tested in the physical model. The tests results show a decrease in aquatic plant debris in the holding tank with increased clean water velocity. Operating the clean water channel at or above the secondary channel velocity was found to effectively move debris traveling along the wall opposite the screens toward the screen face, enabling greater recovery. The impact of clean water flow on removal of bottom oriented debris was less clear. It appeared that operating the clean water flow system at velocities above the channel velocity could reduce removal of bottom materials by creating sufficient turbulence where the flows merge to entrain the material up into the flow column. The material would then bounce along the screen face entering the bypass as opposed to passing under the screen near the bottom.

Currently, the clean water bypass supply is pumped from downstream of the secondary louvers by a 20-in Peerless vertical turbine pump. The pump curve and design specifications of the pump plate indicate that the pump can operate at 8080 gallons per minute (gpm) at 8 feet of total dynamic head. Field measurements were taken to verify the actual flow rates available from the clean water bypass. When pumping against 2.58 ft of head the pump was able to supply 12.8 ft^3/sec (5745 gpm), which is approximately half of that given from the pump curve. This is probably due to degradation of the pump impeller from many years of being submerged with minimal use.

Historically, the clean water bypass has not been routinely operated for several reasons, including problems with debris downstream of the secondary louvers clogging the screened inlet to the clean water pump and the flow meter for measuring clean water bypass flow was never fully installed so personnel could not properly set the clean water bypass flow.

To enable the clean water bypass to be fully operational, when the secondary louvers are replaced with traveling screens, the inlet screen to the clean water pump will be replaced with a similar self-cleaning traveling screen (without pegs). To ensure that adequate flow is available from the clean water bypass, the existing pump will need to be rebuilt or replaced to achieve about 20 ft^3/sec (~9000 gpm) at 9 feet of total dynamic head. This value was determined based on historical secondary channel flow and depths and amount of flow needed from the 10-inch clean water bypass to match the historical values.

It is recommended that the clean water bypass velocity be set to match the secondary channel average velocity at all times. For this reason, a control valve and variable frequency drive motor should be incorporated into the clean water pump to enable automated control of clean water flow. Understanding the need to accurately match the secondary channel velocities, research engineers asked that a new flow meter be installed on the clean water bypass pipe. In early 2011, TFCF met this request by installing a GE-Panemetrics Ultrasonic flow meter that can be used to monitor the flow in the clean water bypass from within the holding tank building.

Conclusions and Recommendations

The research described in this report summarizes the findings of debris removal tests of the proposed new secondary channel traveling screens at the Tracy Fish Collection Facility. The existing series of louvers will be replaced with a single line of Hydrolox traveling screens with debris pegs. Test simulations were conducted that matched historical secondary channel velocities. Debris representative of that found at the TFCF was tested. Results of the study indicate that the new screens will continuously remove 90 to 95 percent of the debris in the secondary channel when operated with the clean water system. Fish salvage is expected to increase as the new screens provide a lower approach velocity and significantly smaller screen orifice size than the existing secondary louvers.

To ensure that the prototype installation operates similar to the physical model results it is recommended that the following items be considered during construction and operation of the new Hydrolox traveling screens:

- Screen travel speed should be around 4 to 5 ft/min.
- Travel time and duration should be determined based on screen differential, debris loading and listed species present. After the screens are installed, actual approach velocities should be collected to ensure no hot spots are present.
- Accommodations to add internal baffling in the field should be included in the screen design in the event field tests show baffling would improve fish salvage performance.
- Following installation, field tests to evaluate the performance of the downstream screen with a greater peg density should be conducted. *Note: these tests were not conducted in the laboratory as the impact of peg density near the bypass entrance also requires evaluation of peg density impacts on fish movement into the bypass entrance.*
- The existing clean water bypass pump should be rebuilt or replaced with one capable of pumping 20 ft^3/sec (~9000 gpm) at 9 feet of total dynamic head.
- The clean water bypass should be operated to optimize removal of the dominant debris from entering the facility. From laboratory test results, clean water bypass velocities should be at or above the channel velocity.

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APPENDIX A
Photographs

Figure A-1 - Close up overview of model (flow from bottom to top)

Figure A-2 - Overview of model (flow from bottom to top)

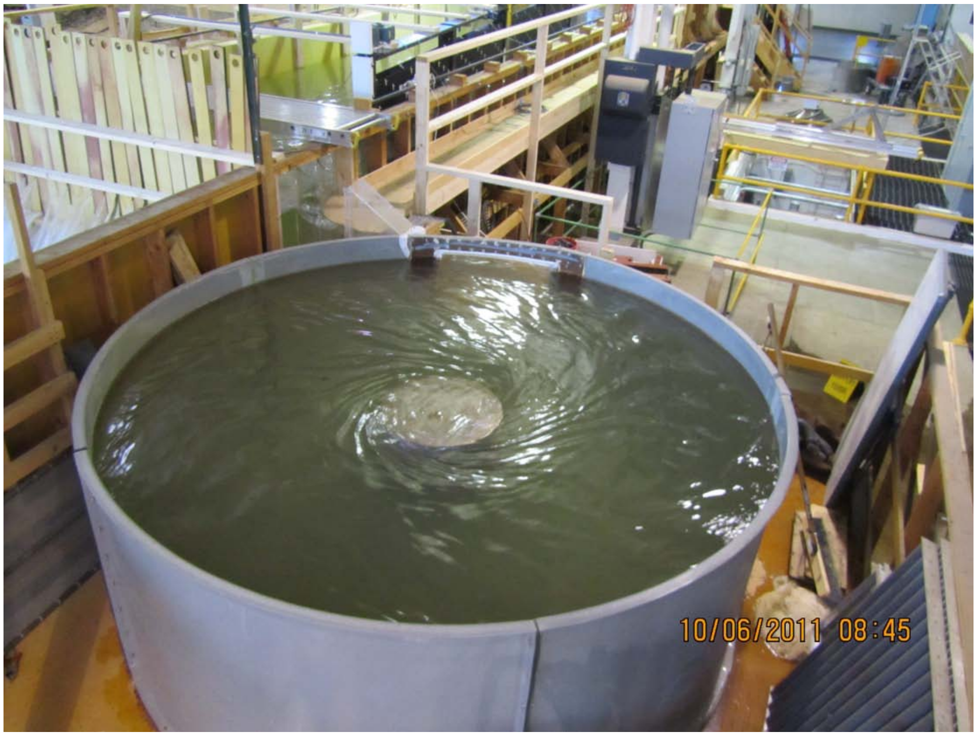

Figure A-3 - Holding tank during a test (flow entering the tank from the top)

Figure A-4 - Tailbox during a test (flow from bottom to top)

Figure A-5 - Tailbox during a test (flow towards reader)

Figure A-6 - Ultrasonic flow meter on two inflow pipes (flow from right to left)

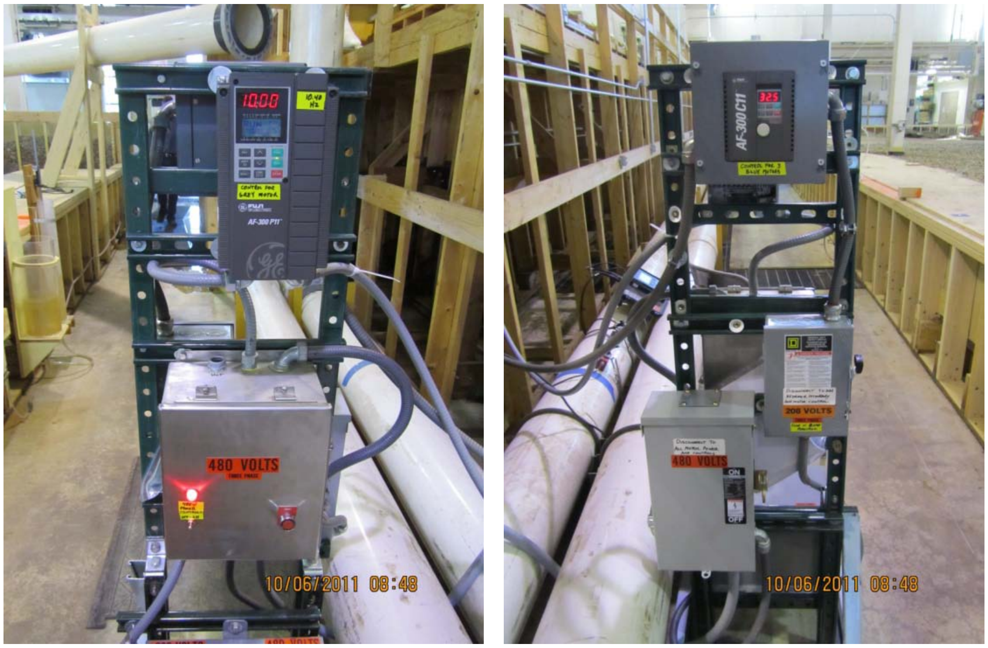

Figure A-7 - Variable frequency drive for screens

Figure A-8 - Headbox and inflow pipes 1 and 2 (flow from bottom to top)

Figure A-9 - Close up of hay and woody debris collected downstream of the traveling screens

Figure A-10 - Collection of hay and woody debris in the tailbox downstream of the traveling screens

Figure A-11 - Hay and woody debris in the holding tank after a test is complete.

Figure A-12 - Inflow 4 into the clean water bypass (flow from right to left)

Figure A-13 - Clean water bypass (flow from top to bottom)

Figure A-14 - Ultrasonic downlooker to determine flow depth (1 of many)

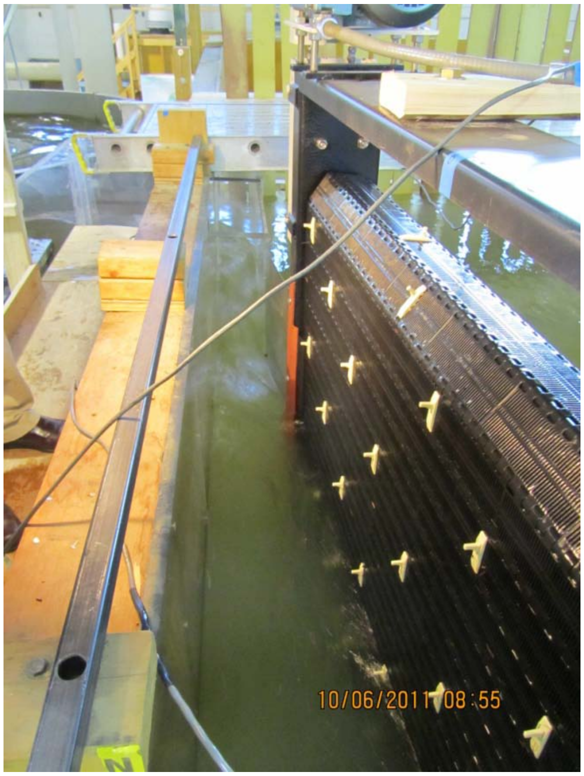

Figure A-15 - Close up of holding tank bypass entrance (flow from bottom to top)

Figure A-16 - Debris peg layout on upstream side of screen (flow from right to left)

Figure A-17 - Debris weigh station