

DRAFT

Data Report

**Evaluation of Overshot Horizontal
Flat Plate Fish Screen,
Farmers Canal, Hood River, Oregon**

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1.0 INTRODUCTION

Hydraulic and fish tests (injury and mortality) on the prototype horizontal flat plate fish screen were conducted and results presented in 2000 and 2001. Based on the tests, Farmers Irrigation District (FID) was allowed by the Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife Service (USFWS), and NOAA Fisheries to install a full-sized screen in the Farmers Canal and to conduct various hydraulic analyses and biological tests to determine injury and mortality to juvenile fish. Tests were conducted during spring 2003.

2.0 OBJECTIVES

The preliminary results for the tests of the Overshot Horizontal Flat Plate Fish Screen installed in the Farmers Canal are presented in this report. The report is intended to be a description of the screen, a summary of the test conditions, preliminary test results, and the raw data. The objective of presenting preliminary results is to allow the reviewers to quickly review and provide preliminary comments on the test conditions and results to date.

3.0 DESCRIPTION OF OVERSHOT HORIZONTAL FLAT PLATE FISH SCREEN

Plan and section views and photographs of the fish screen are shown in Appendix A. Screen parameters and hydraulics characteristics during tests are provided in Table 1. The screen is 160 feet long and tapers from 9 feet wide at the upstream end to 2 feet wide at the downstream end where bypass flows exit the screen to a receiving pool for water and bypassed fish.

The overshot horizontal flat plate fish screen is a perforated plate stainless steel screen with 3/32-inch openings. The water depth over the screen is controlled by an adjustable stop log weir and adjustable taper wall to regulate width in the lower 20 feet of the canal. The theoretical velocity through the screen openings (V_a) is 0.083 feet per second (ft/s) based on gross screen area. The theoretical value of V_a based on net free area (33%) of the screen is 0.251. This value is similar to 0.3 ft/s measured with an Acoustic Doppler flow meter by ODFW during biological testing.

Total flow in the canal during the tests was approximately 83 cubic feet per second (cfs). The system can be operated up to approximately 95 cfs. Of the 83 cfs, approximately 65 cfs was delivered to the irrigation system while 18 cfs was bypassed to the receiving pool and Hood River via Joe's Creek. Depth of water over the screen was 2.1 feet for 150 feet of screen length. For the remaining 10 feet in the bypass throat, the depth was 1.25 feet. Velocities were in the range of 3.91 to 4.40 ft/s, except in the bypass throat where velocity increased to 7.46 ft/s to provide a capture velocity.

Table 1. Screen Hydraulics for the Horizontal Overshot Flat Plate Fish Screen Tests in Spring 2003.

Parameter	Value	Parameter	Value
Q total, cfs	83.07	Mannings, n	0.014
Q diverted, cfs	64.41	Bed Slope, s	0.0001
Q bypassed, cfs	18.65	Va, ft/s based on Net Free Area	0.251
Bypass width, ft	2.00	Va, ft/s, based on Gross Screen Area	0.083
Channel width, ft	9	Net Free Area, %	33
Screen length, ft	160	Screen Area (ft ²)	775
Wall angle, deg	3	Net Screen Area	255.75

Length (feet)	Depth (feet)	Velocity (ft/s)	Froude #
0.00	2.10	4.40	0.53
10.00	2.10	4.30	0.52
20.00	2.10	4.28	0.52
30.00	2.10	4.22	0.51
40.00	2.10	4.29	0.52
50.00	2.10	4.25	0.52
60.00	2.10	4.30	0.52
70.00	2.10	4.32	0.53
80.00	2.10	4.30	0.52
90.00	2.10	4.22	0.51
100.00	2.10	4.14	0.50
110.00	2.10	4.14	0.50
120.00	2.10	4.15	0.50
130.00	2.10	4.27	0.52
140.00	2.10	3.91	0.48
150.00	2.10	4.10	0.50
160.00	1.25	7.46	1.18
Average	2.05	4.41	0.55
Minimum	1.25	3.91	0.48
Maximum	2.10	7.46	1.18

The plan and section views show a vertical screen in the lower 10 feet of the bypass and a screened horizontal ramp that extends to the receiving pool. Preliminary tests conducted without the vertical screen and ramp resulted in significant injuries to fish in the retrieval net due to excessive turbulence. The vertical screen and ramp were installed to allow dissipation of flows into the receiving pool and away from the fish collection net to prevent injury and mortality to fish collected in the net. The use of the vertical screen and ramp reduced the bypass flows into the net from an unacceptable nearly 19 cfs to approximately 1 cfs. The bypass of 19 cfs into the net resulted in excessive churning and turbulence that resulted in injury and mortality to fish. Previous memos have described the necessity for the vertical screen and ramp for the fish tests. Under normal operation the vertical screen and ramp are not necessary.

4.0 TEST FISH

Table 2 summarizes details of fish source and other experimental conditions.

Table 2. Test Fish Sources and General Experimental Design.

Test Fish	Fish Source	Acclimation Period	Test Fish	Control Fish	Latent Mortality Period
Winter steelhead smolts (Hood River stock)	Oak Springs Fish Hatchery	120-144 hours	750 (30 groups of 25)	250 (10 groups of 25)	96 hours
Summer steelhead fry (Skamania stock)	Oak Springs Fish Hatchery	96 hours	750 (15 groups of 50)	250 (5 groups of 50)	96 hours
Spring Chinook fry (Deschutes stock)	Round Butte Fish Hatchery	96 hours	300 (6 groups of 50)	150 (3 groups of 50)	96 hours

4.1 Fish Source, Species, and Test Dates

Fish sources were Oak Springs Fish Hatchery and Round Butte Fish Hatchery. Summer steelhead fry, winter steelhead smolts, and spring Chinook fry were the experimental and control fish. Steelhead smolt tests occurred on May 27 and 28, 2003. Steelhead and Chinook fry tests occurred on June 2 and 3, 2003. Sizes of fish used in the tests were as follows:

	<u>Chinook Fry</u>	<u>Steelhead Fry</u>	<u>Steelhead Smolts</u>
Average (millimeters)	70	63	207
Range (millimeters)	51-84	48-75	148-264

4.2 Delivery, Holding Facilities, and Acclimation

All fish were delivered to the site several days prior to actual tests. Fish were acclimated and unfed for at least 96 hours in net pens in the canal water prior to tests. Net pens were sited within the canal system so that clean, cool flows were passed through the net pens. Mortality in the net pens during acclimation was limited to less than 10 fish for all net pens combined.

4.3 Latent Mortality

Latent mortality was evaluated. After each test was conducted, fish recovered were evaluated and placed in a net pen. All fish of the same species tested on a given day were placed in the same net pen or net pens, depending on density of fish in the pen. Daily evaluation was made of latent mortality in the net pens by observing the number of dead fish in the net pens each morning for four days.

5.0 TEST PROCEDURE

The test procedure will be discussed as it was sequentially implemented in the field. Test evaluations were conducted by subjecting the fish to passage over the screen and collection in the retrieval net in the receiving pool. Control tests also were conducted by releasing fish directly into the distal end of the bypass throat so that the fish were not subjected to passage over the screen to attempt to account for any injuries or mortalities that might be attributable to the retrieval net.

5.1 Smolt Pre-Test Evaluation

- Smolts were taken from the net pens in the canal to the processing station adjacent to the canal. At the processing station, the fish were anesthetized with MS222.
- After anesthetization, each smolt was evaluated for scale loss and other injuries and results were recorded before they were included in the experiment. The characteristics evaluated were:
 - Scale Loss - One observer was used for the entire study to ensure consistency in the estimation of scale loss. Prior to the experiment, the observer evaluated approximately 300 fish to obtain a "standardized eye" with regards to scale loss and other injuries. U.S. Army Corps of Engineers, NOAA technical memorandum, and National Marine Fisheries Service scale loss criteria were referenced for visual evaluation methodology. Each side of the fish, left and right, was recorded separately. The entire body of the fish except for the ventral surface from the pectoral fins to the vent was evaluated. Fish were classified as 0, 5, 10, or 15% scale loss, based upon visual inspection. The visual inspection consisted of an estimation of scales that were apparently missing from the fish body in proportion to the amount of scales that were intact. All visual estimations were performed using the naked eye. Any fish with more than 15% scale loss was not used in the experiment.
 - Eye injuries - Fish with eye abrasions or injuries were not included in the experiment.
 - Abrasions and bruises - Smolts with abrasions and/or bruises were not included in the experiment.
 - Gill injuries - Smolts with gill injuries were not included in the experiment.

- Deformities - Fish with deformities were not included in the experiment.
 - Fungus - Smolts with fungus on any body part and/or badly eroded snouts were not included in the experiment.
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- After the smolts were characterized for injuries, they were placed in clean water to revive from the effects of MS222. After revival (using 5 to 10 minutes), the fish were taken to the upstream end of the fish screen for release over the screen.
 - A decision was made to release only 25 fish at one time for each test. This was based on preliminary experimentation with releasing 50 fish per test in which a significant amount of injury occurred. The injury was attributed to crowding in the capture net during net retrieval. The decrease to 25 fish per test resolved the injury problem attributed to the net.
 - The release of fish over the screen occurred to evaluate impingement, injury, and mortality. Fish were transported in a 5-gallon bucket to the release location and then carefully poured with the water into the flow of the canal by partially submerging the bucket in the water column. Then, fish were observed (as possible) as they moved down the screen and into the collection net in the receiving pool.
 - A decision was made on how long to leave the retrieval net in the receiving pool before retrieval. The retrieval net was pulled out of the bypass flow 10 minutes after the first fish was observed entering the net after passing over the screen. To standardize the time in the retrieval net, the control fish were released at the vertical screen, in the middle of the water column, exposing the fish to the retrieval net for the corresponding length of time (10 minutes). Ten minutes was allowed because of the ability of the smolt to swim upstream or to slowly move downstream to the retrieval net. The control fish were released at the vertical screen, in the middle of the water column, and retrieved after ten minutes.
 - Fish captured in the receiving net were placed in a 5-gallon bucket of water from the receiving pool and transported to the fish processing station.

5.2 Smolt Post-Test Evaluation

Fish were again anesthetized with MS222 and evaluated for number of recoveries, injuries, and mortality. The results of the tests are in Appendix B and are summarized in Tables 3, 4 and 5. After the evaluation, the fish were put into a net pen to evaluate latent mortality for 96 hours (Table 6 and Appendix F).

Table 3. Summary of Number of Tests, Number of Fish per Test, and Number Not Recovered for the evaluation of the Overshot Horizontal Flat Plate Fish Screen for Year 2003.

Parameter	Chinook Fry	Steelhead Fry	Steelhead Smolts
1. Number of Tests	9	21	40
a) No. of Tests	6	15	30
b) No. of Controls	3	6	10
2. Number of Fish per Test	50	50	25
3. Total No. of Fish	450	1,050	1,000
a) No. in Tests	300	750	750
b) No. in Controls	150	300	250
4. Fish Not Recovered	4	46	117
a) Tests	4	46	91
b) Controls	0	0	26
5. Average Size of Fish (millimeters)	70	63	207
6. Size Range (millimeters)	51 to 84	48 to 75	148 to 264

Table 4. Injury Data for Chinook and Steelhead Fry for the Overshot Horizontal Flat Plate Fish Screen Evaluation for Year 2003.

Species	INJURY					
	Fin		Gill/Eye		Bruise	
	Test	Control	Test	Control	Test	Control
Chinook Fry	0	0	0	0	0	0
Steelhead Fry	0	0	5	1	0	0

Table 5. Average Scattered Scale Loss for Steelhead Smolts for the Overshot Horizontal Flat Plate Fish Screen Evaluation for Year 2003.

Test	Average Scattered Scale Loss (%)	Delta Scattered Scale Loss (%)
Pre-Test	9.39	0.01
Post-Test	9.41	
Pre-Control	8.84	1.52
Post-Control	10.36	

Table 6. Latent Mortality Data for Steelhead and Chinook Fry, and Steelhead Smolts for Spring 2003 Tests.

Holding Time (hrs)	Chinook Fry		Steelhead Fry		Steelhead Smolts	
	Test	Control	Test	Control	Test	Control
24	0	0	0	0	0	0
48	0	0	0	0	0	1
72	0	0	0	0	0	0
96	0	0	0	0	4	3
Total Count	0	0	0	0	4	4
Fish Held	296	150	704	300	659	224
% Mortality	0.0%	0.0%	0.0%	0.0%	0.6%	1.8%

Retrieval of Test and Control Fish – Retrieval of test and control fish was considered excellent given the size of the screen area (160 feet long). Only 91 steelhead smolt test fish (out of 750 fish) were not recovered. For control fish (250 fish), 26 fish were not recovered. The non-recovery of control fish reflects the ability of smolt to swim upstream in the throat of the bypass flow even when the fish are released in relatively high velocity flow (7.46 ft/s). Fish that were not recovered were not seen on the screen during numerous observations. They may have escaped via the bypass when the retrieval net was raised or they may have escaped upstream.

Injuries and Mortalities – No fin, gill/eye, or bruises were observed for steelhead smolt. Scale loss was virtually identical for pre- and post-test smolt (0.01% difference). For the control fish the difference in pre- and post-test results was 1.52%. The higher percentage in control fish is attributed to an artifact of the way the control fish were released. The way the releases were made was observed to basically crowd the fish into the bypass throat and into the net virtually at the same time. This likely resulted in loss of scales.

Latent Mortality – Latent mortality occurred equally in the test (4 fish – 0.6%) and control net pens (4 fish – 1.8%).

5.3 Steelhead and Chinook Fry Pre-Test Evaluation

The steelhead and Chinook fry were evaluated and results recorded before they were included in the experiment. Scale development on the fry was virtually non-existent, but other characteristics evaluated were:

- Eye injuries - Steelhead fry with eye injuries were not included in the experiment. Chinook with eye injuries were noted and included in the experiment due to the limited number of Chinook available for the tests.
- Gill injuries - Fish with gill injuries or deformities were not included in the experiment.
- Fin injuries - Fish with fin injuries were noted and included in the experiment.

- Abrasions/bruises - Fish with large abrasions and/or bruises were not included in the experiment.
- Deformities - Fish with deformities were not included in the experiment.

The procedure for the tests was virtually the same as for the steelhead smolts. The only exception was the number of fish released. Because of the small size of the fry (Table 3), releases were made in groups of 50 fish.

The retrieval net was pulled out of the receiving pool approximately five minutes after the first fish showed up in the net during the fry experiments. The control fish were released at the vertical screen, in the middle of the water column, exposing the fish to the retrieval net for the corresponding length of time to standardize the amount of time fish were in the net.

5.4 Fry Post-Test Evaluation

The results are in Appendix C and D and are summarized in Tables 3, 4, and 5. No injuries were observed to either Chinook or steelhead fry by passing them over the fish screen or into the retrieval net. In addition, there was no latent mortality recorded.

Recoveries – Recovery of test and control fish was considered excellent given the size of the screen length. Only 4 Chinook test fish (out of 300 fish) were not recovered. All control fish (150 fish) were recovered. For steelhead, 46 test fish (out of 750 fish) were not recovered. All control fish (300) were recovered. The recovery of all control fish reflects the limited ability of fry to swim upstream in the throat of the bypass flow.

Injuries and Mortalities – Fin and bruise injuries did not occur for either Chinook or steelhead fry. No gill and/or eye injuries were documented for Chinook fry. For steelhead fry, 5 test fish (0.67%) and 1 control fish (0.33%) had gill/eye injuries.

Latent Mortality – Latent mortality did not occur for either steelhead or Chinook fry.

6.0 PRELIMINARY SUMMARY

6.1 Hydraulic Tests

- uniform water surface elevation across entire screen
- sub-critical flow at steady-state (except exit throat)
- no vortical flow
- velocity through screen openings (V_a) based on gross screen area - 0.083 ft/s
- velocity through screen openings (V_a) based on net free area of 33% - 0.251
- average sweeping velocity - 3.6 ft/s
- total system inflow - 83.07 cfs
- diverted flow - 64.41 cfs
- bypass flow - 18.65 cfs

6.2 Biological

- Fry passed across the screen with no apparent impingement.
- Smolt desired to swim against the current or moved down the screen without difficulty.
- Injuries to Chinook and steelhead fry and steelhead smolt were either non-existent or very minimal and not attributable to the fish screen.
- Scale loss for steelhead smolt did not appear to be increased by passing fish over the screen (as compared to controls not passed over the screen). Fry did not have developed scales and there was no apparent loss.
- No latent mortality occurred with Chinook and steelhead fry. For steelhead smolts, latent mortality was minimal and equivalent in both test and control fish.

7.0 FUNDING ENTITIES

A number of agencies have contributed to the success of the project to date. Since the inception of this fish screening concept, ODFW and Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO) representatives have worked directly with FID staff to continually refine the evaluation process. Once these local resource managers felt the concepts were sound, ODFW, CTWSRO, and FID made presentations to regional NOAA Fisheries and USFWS representatives. NOAA Fisheries and USFWS representatives encouraged FID, CTWSRO, and ODFW to complete two biological tests across the prototype screen installed at one of FID's hydropower facilities. The results from these tests were very positive.

Furthermore, the United States Bureau of Reclamation (USBR) has historically shown a strong interest in FID screen concepts and conducted additional hydraulic and biological testing in its Denver, Colorado hydraulics laboratory with the support of Colorado State University. Very favorable results also were obtained in these tests and, consequently, approval to proceed with construction of a full-scale version of the screen was received from NOAA Fisheries, USFWS, ODFW, and CTWSRO. FID began design and construction of a screen for FID's Farmers Canal diversion from the Hood River in fall 2001.

With the strong support of the Hood River Watershed Group, CTWSRO, USFWS, and NOAA Fisheries, FID has received grant funding from Bonneville Power Administration (BPA), CTWSRO, Oregon Watershed Enhancement Board (OWEB), National Fish and Wildlife Foundation (NFWF), United States Department of Agriculture (USDA), and Pacific Coastal Salmon Recovery Fund (through Columbia River Intertribal Fish Commission). Without the support and thinking of all of the representatives of the aforementioned agencies, this project would never have moved ahead. The dedicated consultants and agency personnel associated with this project have helped to develop what appears to be a very promising alternative technology to address fish screen and passage issues.

APPENDIX A

Plan and Section Views of Fish Screen for Year 2003

APPENDIX B

Steelhead Smolt Test Data for Year 2003

APPENDIX C

Chinook Fry Test Data for Year 2003

APPENDIX D

Steelhead Fry Test Data for Year 2003

APPENDIX E

Length – Weight Data for Year 2003

APPENDIX F

Latent Mortality Data for Year 2003