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Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

Walla Walla River Basin Fish Screen Evaluations, 2003: Nursery Bridge Fishway and Garden City/Lowden II

J. A. Vucelick
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Prepared for the U.S. Department of Energy
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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Pacific Northwest National Laboratory evaluated the fish screens at the Nursery Bridge Fishway and the newly constructed Garden City/Lowden II site west of Walla Walla, Washington, in the Walla Walla River Basin during spring and summer 2003. Both fish-screen facilities were examined to determine if they were being effectively operated and maintained to provide for safe fish passage. At the Nursery Bridge Fishway, the screens were evaluated specifically to determine whether the louvers that aid in controlling water flow from behind the screens could be adjusted so that the screens would meet fish-protection criteria. Data were collected to determine whether velocities in front of the screens and in the bypasses met current National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) (formerly National Marine Fisheries Service [NMFS]) criteria to promote safe and timely fish passage before and after changing the louver settings. Rock weirs downstream of the dam were also evaluated to determine whether they might impede upstream migration of juvenile salmonids during low-flow conditions. At the Garden City/Lowden II site, data were collected to establish a baseline for operating conditions and to determine whether any changes in the baffle settings were needed.

The following conclusions are based on the results of the 2003 studies:

Nursery Bridge Site:

- A total of 68% of the initial velocity measurements on the west screen exceeded the NOAA Fisheries criteria of 12.2 cm/s (0.4 ft/s) for approach velocity

- A simple adjustment of the existing louvers was not sufficient to fix the problem

- The sediment and debris load in the river upstream of the screens exceeded the design criteria for the site, which had frequent breakdowns in the screen-cleaning systems

- The rock weirs downstream of the dam would not be expected to impede upstream movement of juvenile fish during low-flow conditions.

Garden City/Lowden II:

- The flat inclined-plate screen design appeared to be efficiently protecting juvenile fish from entrainment, impingement, and migration delay

- Approach velocities met the NOAA Fisheries criteria of less than 12.2 cm/s (0.4 ft/s) in June, and no change in baffle settings was needed

- Sweep velocities were generally lower than approach velocities and did not increase toward the downstream end of the site

- The automated cleaning system at the Garden City/Lowden II site works adequately when sediment loads are low, though its effectiveness at cleaning the screens decreases as sediment and debris loads and algal growth increase.

Acknowledgments

We are thankful for the support of Brian Zimmerman, Confederated Tribes of the Umatilla Indian Reservation, and Ben Zelinsky, Bonneville Power Administration, in securing funding for this work. We also appreciate the gracious treatment we received from Jon Brough and Gary Harris, Hudson Bay District Improvement Co., and Stuart Durfee, Gardena Farms Irrigation District, while conducting the field assessments. Scott Abernethy, Traci Degerman, and Corey Duberstein of Pacific Northwest National Laboratory assisted in the field work.

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1.0 Introduction

Over the years, irrigation has played an important role in the development of the middle Columbia River Basin. Water has been diverted from western rivers since the mid-1850s to irrigate crops. During the 1920s, some of these diversions were equipped with fish-protection devices, but it was not until the *Mitchell Act of 1938* provided funding to protect fish that screening irrigation diversions and evaluating their effectiveness truly got underway (Bryant and Parkhurst 1950).

More recently, the Bonneville Power Administration (BPA) and the Northwest Power Planning Council (NPPC) expanded screening efforts to protect and enhance fish populations. The Council's Columbia River Fish and Wildlife Program lists fish protection through effective screening of irrigation diversions as an essential element in its plan to restore declining steelhead and salmon runs (NPPC 1984, 1987, 1994).

Research on the effectiveness of fish-screening devices initiated changes in design and operating procedures of screening facilities over the years. For example, maximum allowable screen-size openings decreased, as protecting fish at their earliest developmental stages became a concern. These and other new requirements for fish protection are developed by the National Oceanic and Atmospheric Administration Fisheries (NOAA Fisheries) (formerly National Marine Fisheries Service [NMFS]) and adopted by individual state agencies. Changes in the regulations require that older, less-efficient screening facilities be updated or replaced. In addition, BPA has established a monitoring and evaluation program to ensure that new and updated screening facilities meet current fish-protection standards.

The evaluation of existing screen sites is important to ensure that the sites achieve the goal of protecting fish from entrainment into the irrigation systems. The screens at the Nursery Bridge Fishway were evaluated during spring 2003 to determine whether conditions at these sites were conducive to safe fish passage and whether the site was operating within criteria developed by the NOAA Fisheries. Rock weirs downstream of the dam were evaluated in summer 2003 to determine whether they might impede upstream migration of juvenile salmonids during low-flow conditions. The Nursery Bridge Fish Ladder is located on the east bank (river right) of the Walla Walla River near the town of Milton-Freewater (Figure 1.1). The fish-screen facility is located at the upstream end of the ladder and is used to draw water from upstream to increase attraction flow at the ladder entrances. This facility consists of two vertical-bar screens facing each other with a channel in between (Figure 1.2).

The Garden City/Lowden II site is located about 3.2 km (2 mi) east of the town of Lowden off Highway 12 (Figure 1.1). The site is an inclined plate screen with eight 1.8-m (6-ft) high × 1.2-m (4-ft) wide screen panels (Figure 1.3). The site was evaluated in June 2003 to establish a baseline of operations and also to determine whether any changes in the baffle settings were needed, based on velocity measurements, to put the site within the NMFS criteria.

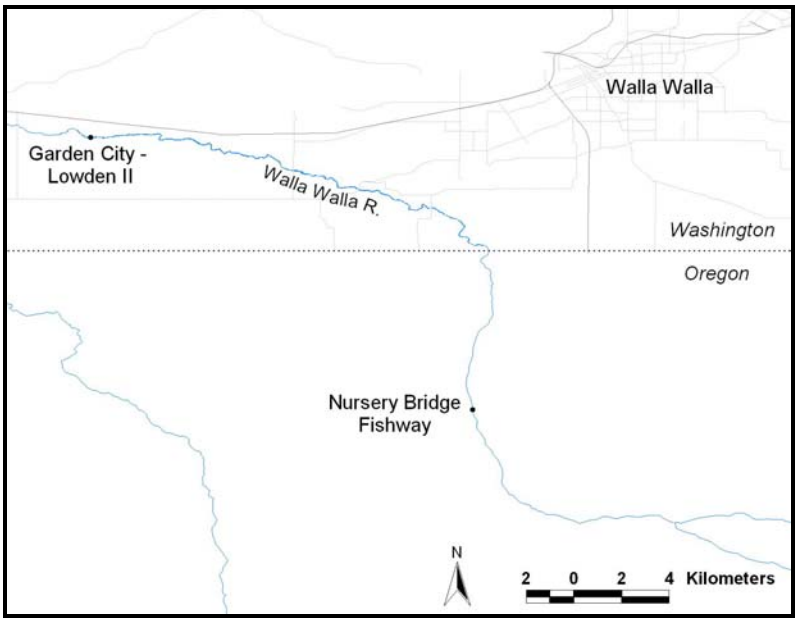

Figure 1.1. Map of Study Area in the Walla Walla River Basin

The methods currently used for evaluating screening facilities were developed while conducting similar studies at fish-screen facilities in the Yakima River Basin (Blanton et al. 1998, 1999; Chamness et al. 2001; Carter et al. 2002). These evaluations addressed three main questions:

1. Are screens designed, operated, and maintained to meet NMFS criteria standards over a wide range of conditions?

2. Do velocities/flows meet NMFS criteria?

3. Are screens effective at protecting fish from injury and from unnecessary migration delay?

These evaluations focused on questions 2 and 3 as the authors attempted to determine the louver settings that would produce the best flow regimes and place the screens in compliance with the NOAA Fisheries criteria.

Figure 1.2. Nursery Bridge Fish Ladder Attraction Flow Screens. The red arrows show the direction of water flow.

Figure 1.3. Garden City/Lowden II Fish Screens. The red arrows show the direction of water flow.

2.0 Methods

The Nursery Bridge site was evaluated December 18, 2002, January 7, 2003, and March 27, 2003. Adjustments to the louvers were made on March 27, 2003. Rock weirs downstream of the dam were evaluated on September 3, 2003. The Garden City/Lowden II site was evaluated June 4, 2003. Evaluators collected water-velocity measurements and general operational data (e.g., screen submergence, bypass conditions, and fish presence) as described in the following sections.

2.1 Water-Velocity Measurements

2.1.1 Equipment

Water velocities at both sites were measured using a SonTek Acoustic Doppler Velocimeter®(a) (ADV). The ADV emits sound at 10 kHz. The frequency of the returning sound waves increases or decreases depending on whether the water is flowing toward or away from the ADV receiver. The difference between the emitted frequency and the received frequency is used to calculate the velocity of the water. The probe uses three receivers extending out at an angle from the transmitter to calculate the three-dimensional water velocity at a point 10 cm (3.9 in.) below the probe. Velocities were typically recorded at each sampling point along the screen for 30 to 40 seconds at a rate of 2 Hz (2 recordings per second) and stored in a computer file.

Water velocities in the rock weirs downstream of the Nursery Bridge Fishway were measured using the Marsh McBirney Flo-Mate Model 2000®(b) electromagnetic water current meter (MMB 2000). The MMB 2000 uses a uni-directional probe that measures velocity in a single direction. The unit was set to display the average of velocity readings taken over a period of 10 seconds. Output was read visually from a digital display and recorded in a field notebook.

2.1.2 Probe Positioning

2.1.2.1 Screen Bays

Measurements of water velocity were taken at several (2 to 4) evenly spaced points along the front of each screen. The vertical pole was placed close to the front of the screen, but not allowed to come in contact with the screen surface. Velocity measurements were recorded with the ADV probe 7.6 to 15.2 cm (3 to 6 in.) in front of the screen face. The probe was oriented in a down-looking orientation, with sweep (X) and approach (Y) velocities on the horizontal plane and vertical movement (Z) on the vertical plane. All measurements were taken with the axes of the probe oriented to measure water flowing parallel (sweep) and perpendicular (approach) to the screen face, regardless of the orientation of the screen in the canal. At the Garden City/Lowden II site, the pole on which the probe was mounted was held parallel to the screen surface, which is oriented at an angle 45° from vertical. The height that the

(a) SonTek Acoustic Doppler Velocimeter is a registered trademark of SonTek/YSI, Inc., San Diego, California.
(b) Marsh McBirney Flo-Mate Model 2000 is a registered trademark of Marsh-McBirney, Inc., Frederick, Maryland.

probe was set from the bottom depended on the depth of water in the forebay. In cases where the forebay depth was less than 1.2 m (48 in.), one set of measurements was taken at 0.6 of depth from the surface. In cases where the forebay depth was greater than or equal to 1.2 m (48 in.), measurements were taken at two depths, 0.2 and 0.8 of depth, from the surface.

2.1.2.2 Rock Weirs

Velocity was recorded just upstream and directly downstream of the constriction points where it was estimated that the majority of water was passing through each rock weir in the Walla Walla River immediately downstream of the Nursery Bridge Fishway. Five velocity measurements were recorded (a total of 50 seconds) near the bottom, middle, and surface at each location.

2.1.3 Data Collection and Analyses

Multiple velocity measurements were taken in front of every screen or panel. Cleaning systems (brushes and air bursts) were turned off during velocity measurements. Average sweep and approach velocities were calculated for each position at each site. At rock weirs, an average velocity was calculated for each depth at each measuring point.

2.2 General Data

Additional data collected during each evaluation included the following:

- General site descriptions and photographs
- Screen and seal conditions
- Screen submergence levels
- Cleaning-system operation and the incidence of headloss across the screen face
- Fish presence
- Observations of debris in the forebay
- Presence or absence of operator control aids, such as water gauges and drum submergence marks on screen frames.

At the rock weirs, water depth was measured and recorded in intervals of 1 m (3.3 ft) starting at the entrance to the fishway, approximately 10 m (33 ft) upstream of the first constriction and ending 50 m (164 ft) downstream of the downstream-most constriction. The depth measurements were taken in the main channel.

2.3 Data Analyses

The NOAA Fisheries criteria define several conditions concerning velocity (NMFS 1995):

- Maintaining a uniform flow distribution over the screen surface to minimize approach velocity
- Keeping approach velocities ≤ 12.2 cm/s (≤0.4 ft/s)
- Achieving sweep velocities greater than approach velocities

- Affecting a bypass flow greater than or equal to the maximum flow-velocity vector resultant upstream of the screens.

In addition, there should be a gradual and efficient acceleration of flow into the bypass entrance to minimize delay by emigrating salmonids. Screen operators should try to achieve these criteria at all sites throughout the year. The authors compared their field measurements of water velocity and general data-collection results for each screen site to the NMFS criteria. The following section contains the results of these comparisons for each site.

3.0 Results and Discussion

3.1 Nursery Bridge Fishway Screens

3.1.1 Initial Velocity Measurements

The Nursery Bridge site was evaluated December 18, 2002, January 7, 2003, and March 27, 2003. Figures 3.1 through 3.4 show the results of the velocity measurements from December and January. For the west screen on December 18, 29% of the measured approach velocities exceeded the NOAA Fisheries criteria of 12.2 cm/s (0.4 ft/s), while on the east screen, none of the measured approach velocities exceeded 12.2 cm/s on the same day. On January 7, 8% of the approach velocities measured on the west screen exceeded the NOAA Fisheries criteria, while only 4% of the measured approach velocities on the east screen exceeded the criteria on the same day. The flow in the Walla Walla River was 7.99 cubic meters per second (m^3/s) (282 cubic feet per second [cfs]) on December 18, 2002, and 17.50 m^3/s (618 cfs) on January 7, 2003, as recorded by the U.S. Geological Survey gage near Touchet (approximately 30 km [19 mi] downstream from the Nursery Bridge fishway) (Figure 3.5). For the purpose of PNNL's evaluations, a site is considered to be in compliance with the NOAA Fisheries criteria if less than 10 percent of the measured approach velocities exceed 12.2 cm/s (0.4 ft/s). Thus, the conditions at the site on December 18, 2002, would be considered to exceed the criteria and require action to reduce the approach velocities, while the conditions at the site on January 7, 2003, would be considered to meet criteria and require no action.

On March 27, 2003, PNNL researchers set out to evaluate the velocity conditions at the Nursery Bridge Fishway screens and, if needed, adjust the metal louvers that help to control flow from the back side of the screen. An entire set of velocity measurements at 0.2 and 0.8 of depth, in front of both sets of screens (east and west) was taken before the louvers were moved. A cursory examination of the March 7 data showed approach velocities exceeding the NOAA Fisheries criteria of 12.2 cm/s (0.4 ft/s) on the west screen at every measured location with the exception of points 3 and 4 on screen 1 (Figures 3.6 and 3.7).

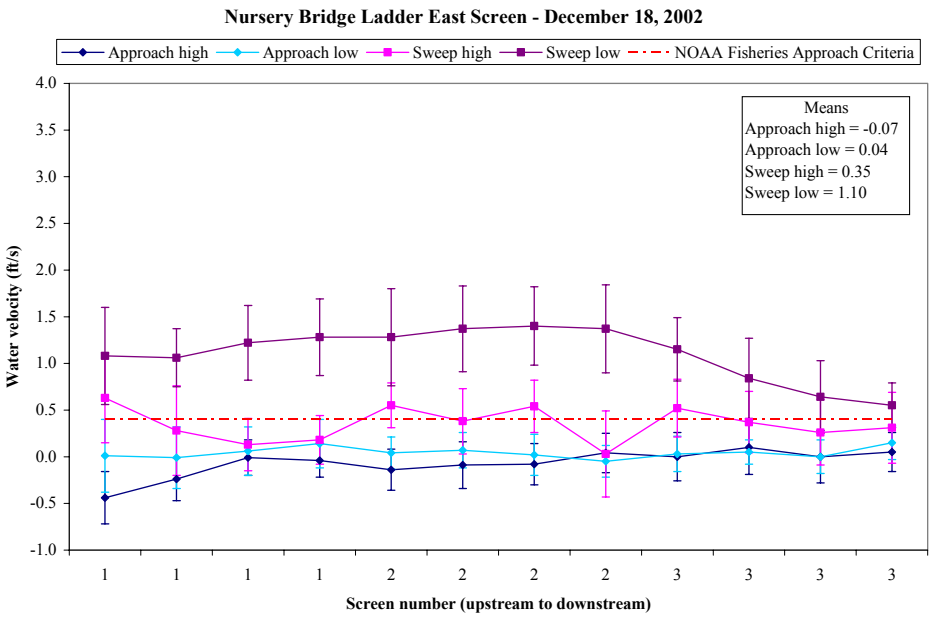

Figure 3.1. Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder East Screen on December 18, 2002. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

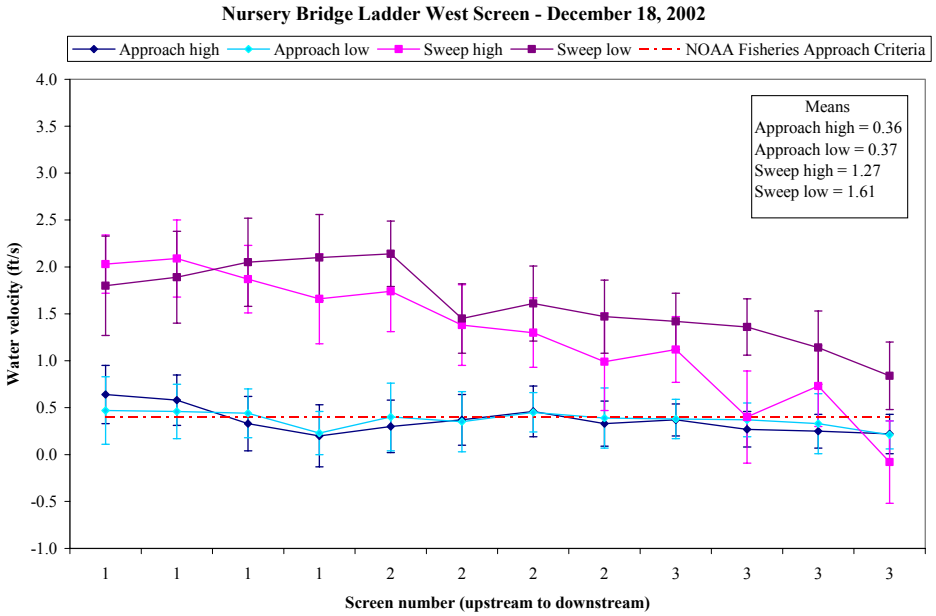

Figure 3.2. Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder West Screen on December 18, 2002. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

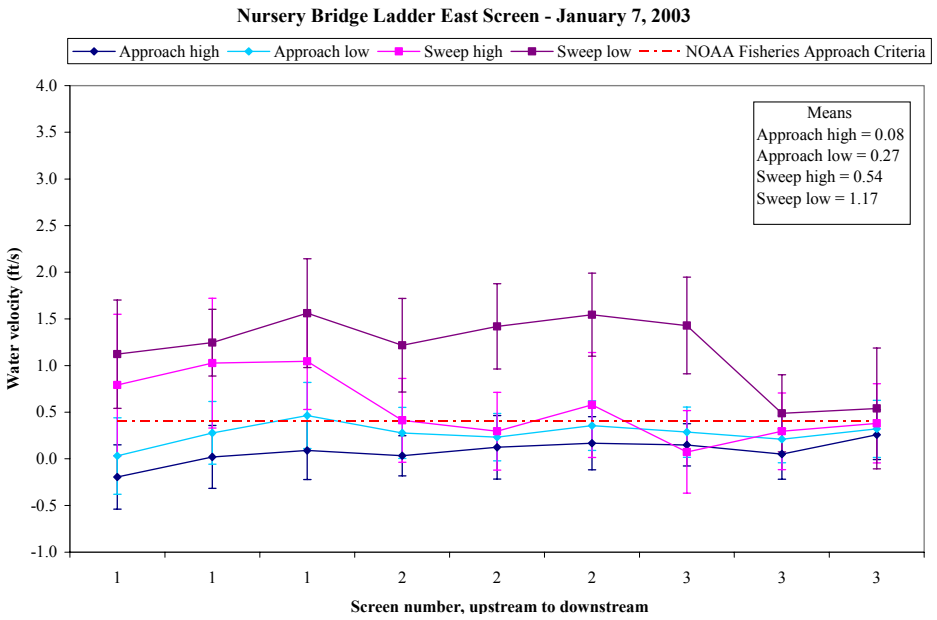

Figure 3.3. Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder East Screen on January 7, 2003. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

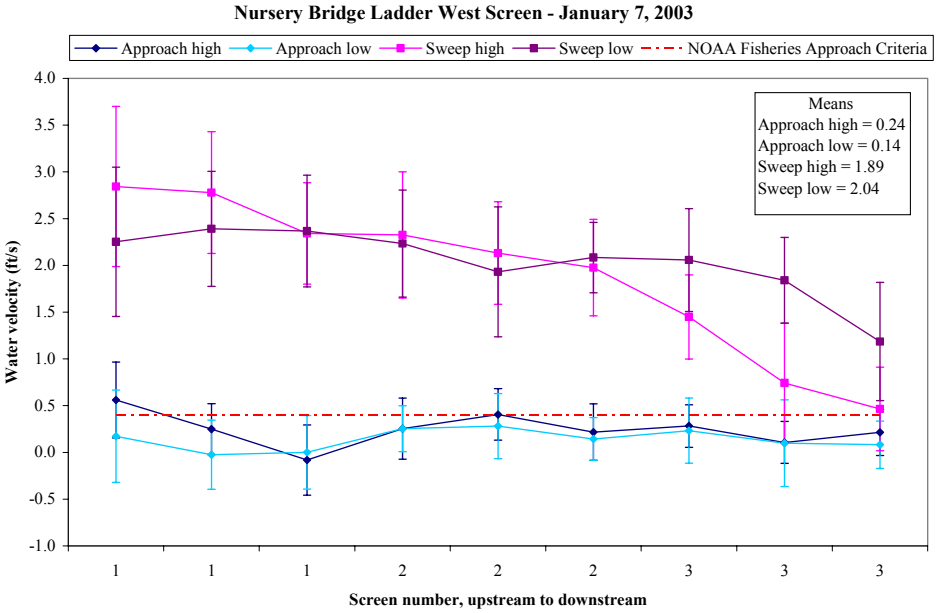

Figure 3.4. Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder West Screen on January 7, 2003. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

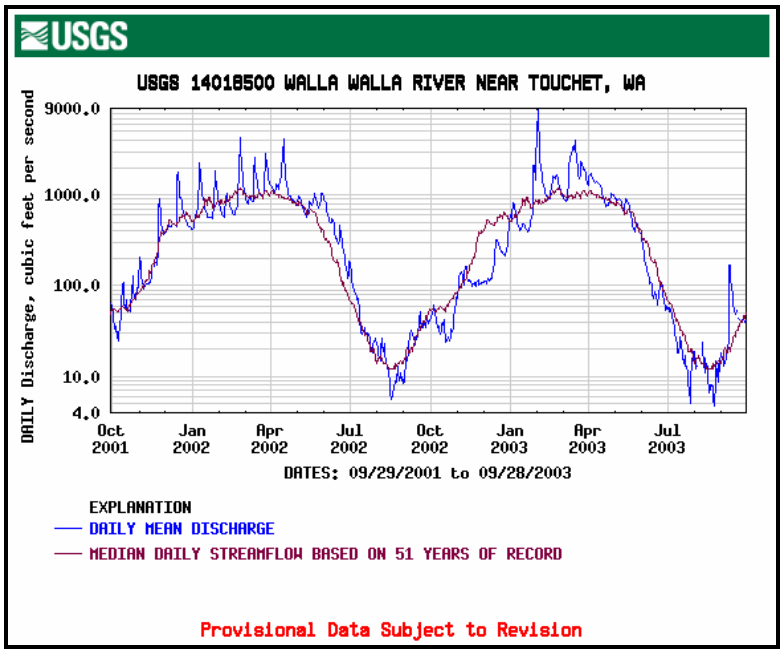

Figure 3.5. Daily Mean Discharge from the Walla Walla River, Measured at the USGS Station Near Touchet, Washington

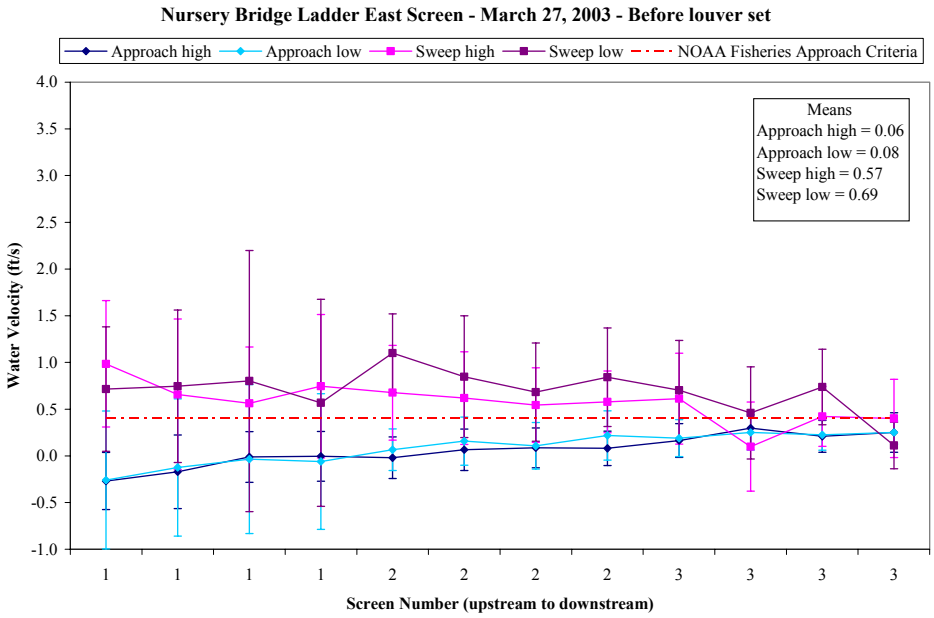

Figure 3.6. Initial Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder East Screen on March 27, 2003. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

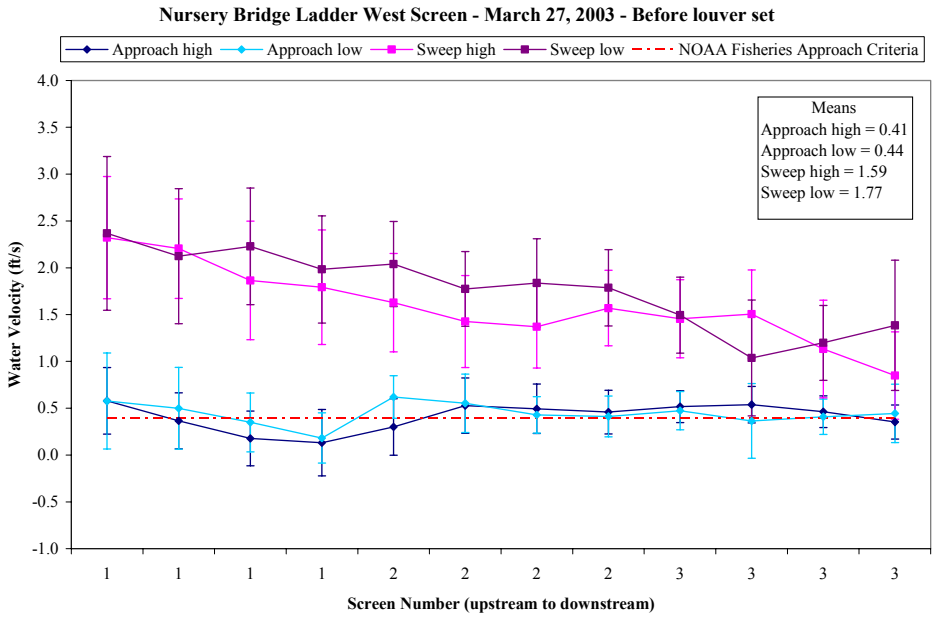

Figure 3.7. Initial Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder West Screen. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

3.1.2 Flow Measurements after Changing the Louver Settings

Based on a review of the data, researchers decided to completely close down the louvers on the two most upstream screens on the west-side screen. They also opened up the louvers to approximately 45 degrees on the most downstream screen on the east side in an attempt to draw more water further downstream into the site and towards the east-side screen.

A second set of measurements was taken after the louvers were moved. The results showed that two spots (in the middle of screen three) on the east side exceeded 12.2 cm/s (0.4 ft/s). On the west side, the number of points that exceeded criteria dropped slightly from 66% to 54% (Table 3.1). There was a greater decrease in the velocity at the higher measuring point than at the lower point, especially across screen two (Figure 3.8 and Figure 3.9, and Table 3.1).

Changing the louver settings behind the screens did not change the flow patterns as much as researchers had expected, nor was it sufficient to put the site in compliance with NOAA Fisheries criteria for approach velocity, especially in front of the west screen. Two factors contribute to these problems. The first is the site design. The water enters the site at an angle toward the west screen, in essence hitting the west screen with much more force (and higher velocities) than it would if the majority of the flow were parallel to the screen face. The second problem is the louver design. Generally, louvers are designed so that when completely closed, almost no water passes through them. The edge of one meets or overlaps the edge of the next. The louvers at the Nursery Bridge Fishway do not overlap; they do not even meet. There is a gap approximately 2.2 cm (0.875 in.) wide (Figure 3.10) between the louvers when they are

completely in the "closed" position. This gap allows water to flow through the screens even when the louvers are completely closed. Therefore, the approach velocity problems at this site cannot be fixed merely by closing the louvers.

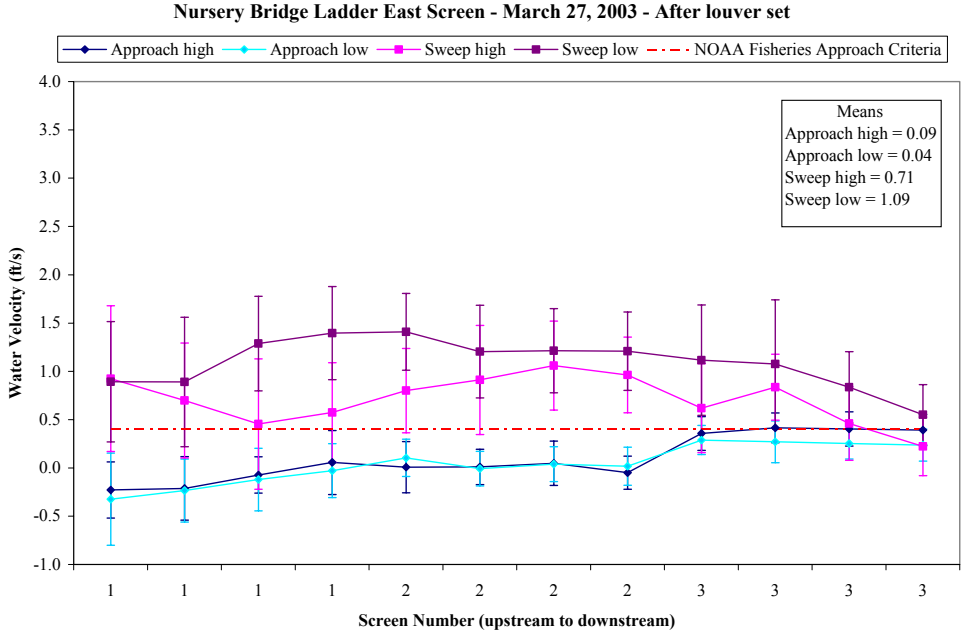

Figure 3.8. Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder East Screen After Setting the Louvers. The dashed line at 12.2 cm/s (0.4 ft/s) represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

3.2 Nursery Bridge Rock-Weir-Velocity Evaluations

The rock weirs in the river downstream of the entrance to the Nursery Bridge Fishway were evaluated on September 3, 2003, to determine whether they might present a barrier to upstream movement of juvenile salmonids. The daily average flow for September 3 was 0.37 m^3/s (13.0 cfs), which is approximately equal to the minimum daily average based on 51 years of data (Figure 3.5). Over the past 2 years, there has been a total of 38 days, mainly in July and August, with stream flows less than 0.37 m^3/s (13.0 cfs). The minimum daily average streamflow was 0.13 m^3/s (4.7 cfs). The authors will assume their data are representative of the conditions a fish would experience during the low-flow season.

Figure 3.11 through Figure 3.13 depict the results of the rock-weir evaluations. Figure 3.11 lists all of the velocity measurements in and around the rock weirs. As can be seen in Figure 3.11, velocity was generally measured where the greatest amount of water flowed through the weirs. Figure 3.12 shows water depths and velocity measurements in the fish apron and at the lower entrance to the fishway. There are only two routes upstream from Figure 3.12. One is through the small channel in the fishway apron

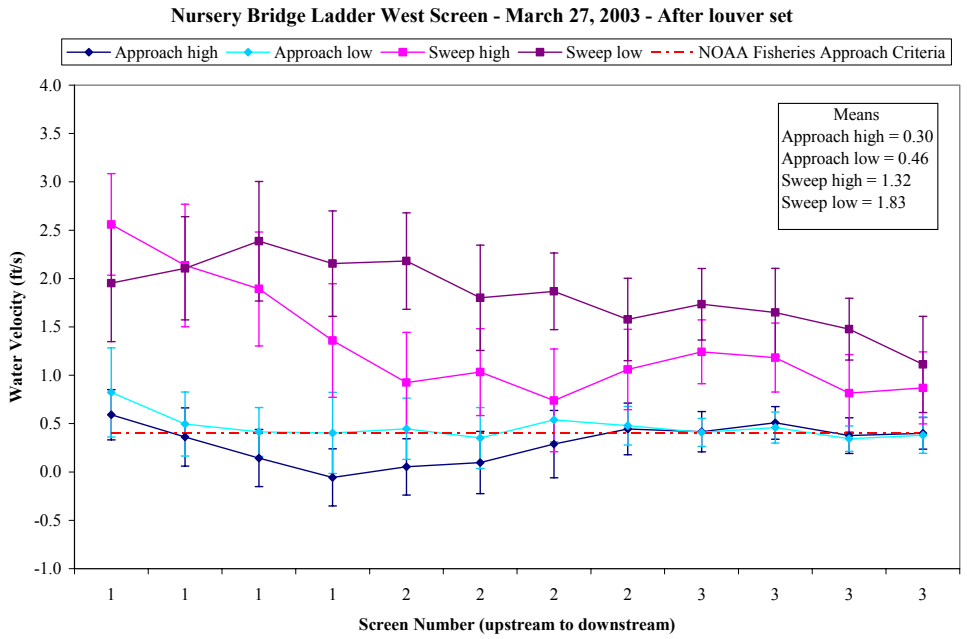

Figure 3.9. Approach and Sweep-Velocity Measurements at the Nursery Bridge Ladder West Screen After Setting the Louvers. The dashed line at 12.2 cm/s (0.4 ft/s) represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

Table 3.1. Summary of Fish-Screen Water-Velocity Data for East and West Screens at the Nursery Bridge Ladder Site, March 27, 2003

Nursery Bridge Fishway Screens		Mean Sweep	Mean Approach	% of Approach Values > 0.4 ft/s	Turbulence	
					Sweep	Approach
Before louver set	East	0.63	0.07	0.00	0.59	0.31
	West	1.68	0.43	66.67	0.53	0.28
After louver set	East	0.90	0.07	8.33	0.49	0.23
	West	1.58	0.38	54.17	0.48	0.26

Figure 3.10. The Louvers at Nursery Bridge Fishway Attraction Water-System Screens Had a Gap the Size of a Nickle (Approximately 2.2 cm [0.875 in.]) Between Them when Fully Closed. This is a view from the top looking down at the water surface, with a quarter placed next to the gap in the louvers.

above the fishway entrance; the other is through the fishway, the entrance of which is located just inside the wall on the left side of the picture. Figure 3.13 shows the river depths measured every meter in what was determined to be the main channel of water movement. This was established by stretching out a meter tape and allowing the current to carry it downstream.

To evaluate the rock weirs, the authors first determined that there were five constriction levels (Figure 3.11), or five rock weirs that held back the water, each creating a pool with a loss of elevation between it and the pool or river downstream. The first of these was approximately 10 m (32.8 ft) downstream of the entrance to the fishway. It was composed mostly of small rocks and large wood branches. (This is the first weir downstream of the fishway, at the bottom of Figure 3.12. The picture looks downstream from there.) There was approximately 40 cm (16 in.) in elevation difference between the level of water at the entrance to the fishway and the second pool. The weir that contained the second pool was composed of small rocks and a few large boulders. The next drop was approximately 30 cm (12 in.), to the third pool, which was contained by mostly large submerged boulders. There was virtually no drop from pool three to pool four, though if the flows decreased that could change.

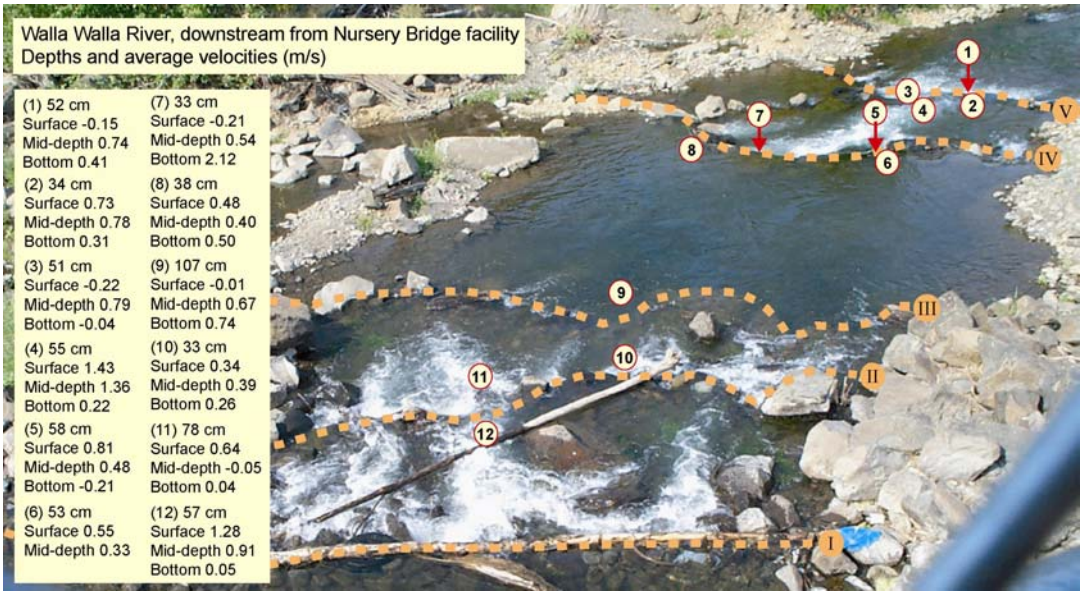

Figure 3.11. Water Velocities in Constriction Points in the Walla Walla River Downstream of the Nursery Bridge Fishway on September 3, 2003. The numbered lines represent the five rock wiers.

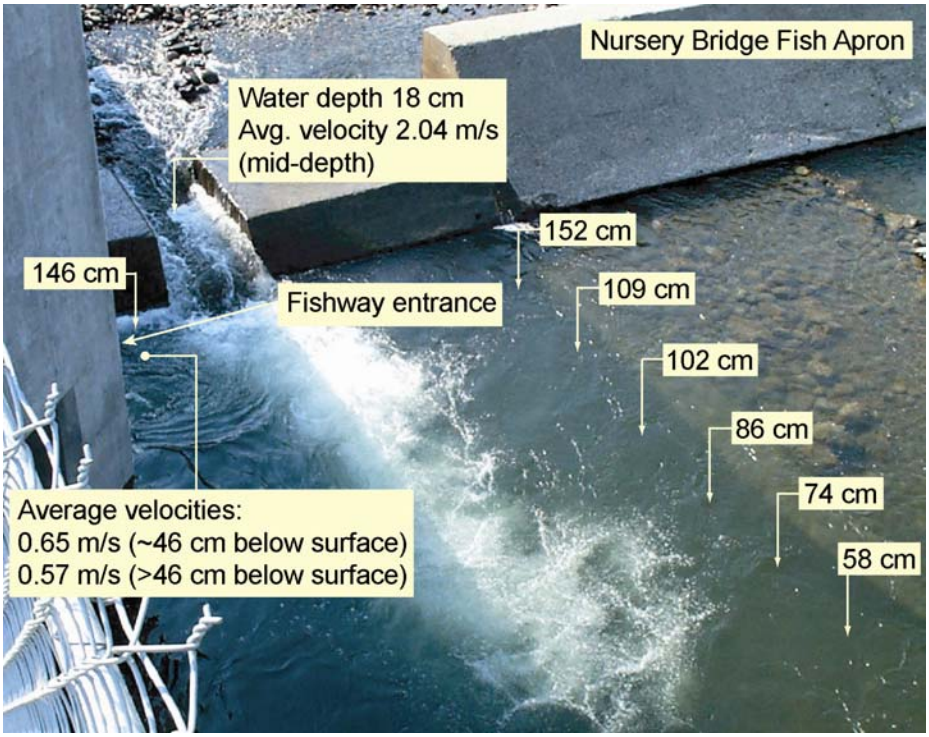

Figure 3.12. Water Depths and Velocities Along the Nursery Bridge Fishway Apron and in the Entrance to the Fishway on September 3, 2003. The fishway entrance is just inside the wall on the left side of the picture.

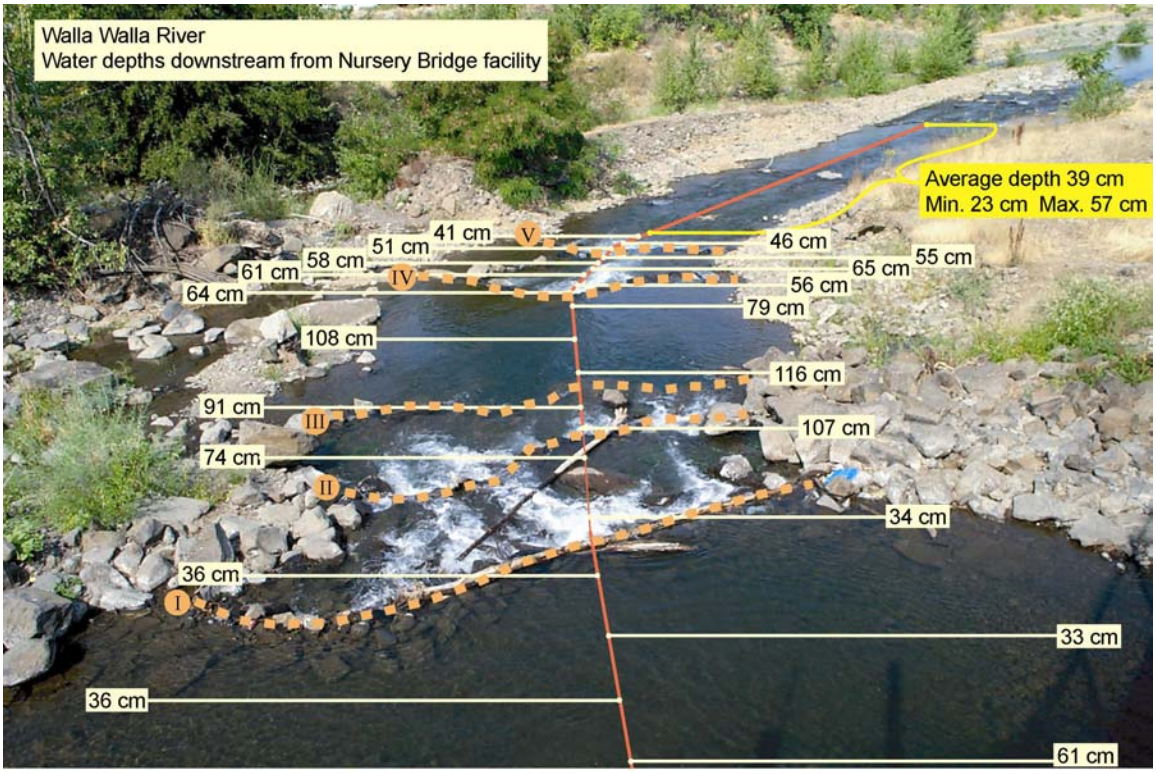

Figure 3.13. Water Depths in the Walla Walla River Downstream of the Nursery Bridge Fishway on September 3, 2003. The numbered lines represent the five rock wiers.

Pool four was a deep pool approximately 5 m (16.4 ft) long that was contained mostly by boulders. There was an approximate 30 cm (12 in.) drop from the level of pool four to the last pool, which was approximately 4 m (13.1 ft) long. The downstream-most constriction was composed mostly of smaller rock and some boulders. The final drop to the river level below this constriction was not measured, but was estimated to be less than 30 cm (12 in.).

Velocity measurements ranged from -0.22 to 2.11 m/s (-0.73 to 6.92 ft/s). There was no consistent relationship between depth and velocity. Relatively high velocities were sometimes observed at the surface, as was expected, although very low and sometimes negative velocities were also observed at the surface, probably as a result of eddies caused by waterfalls. Relatively low velocities were expected near the bottom, which was observed at times, although occasionally relatively high velocities were observed at the bottom (Figure 3.12). All of these data suggest very turbulent conditions in and around the constriction points.

Burst swimming in salmonids is described as a speed that can be maintained for only a few seconds. Juvenile salmonids typically have a burst speed of about 9 body lengths/second (Puckett and Dill 1984). A 100-mm-long (3.9-in.) Chinook salmon would have to swim at 21.3 body lengths/second to move upstream through the fastest current measured. The fastest water expected to be navigable by a 100-mm-long salmonid is approximately 0.91 m/s (3 ft/s). So, while a juvenile salmonid could not swim

up water flowing at nearly 2.1 m/s (7 ft/s), that constriction point was not expected to impede upstream movement because there were other routes available with lower velocities (Figure 3.12).

3.3 Garden City/Lowden II Fish Screens

The Garden City/Lowden II fish screens were evaluated on June 4, 2003. It is an inclined plate screen with eight 1.8 m (6 ft) high by 1.2 m (4 ft) wide screen panels. The site was running at approximately 39% of its capacity, at 0.54 m^3/s (19 cfs). The screens each have baffles and are equipped with an air-burst cleaning system. The purpose of this evaluation was to get an initial velocity characterization of the site and to determine whether the baffles needed to be adjusted.

Approach velocities were well within the NOAA Fisheries approach criteria. Sweep velocities were generally lower than approach velocities (Figure 3.14). The water velocity did not increase from upstream to downstream within the site, and velocities tended to be somewhat variable from point to point. The ratio of sweep to approach was 0.77. Further testing is needed to determine whether the site would meet the NOAA Fisheries criteria when it is running closer to its capacity limit.

Based on the low approach velocities, it was determined that the louver settings did not need to be adjusted.

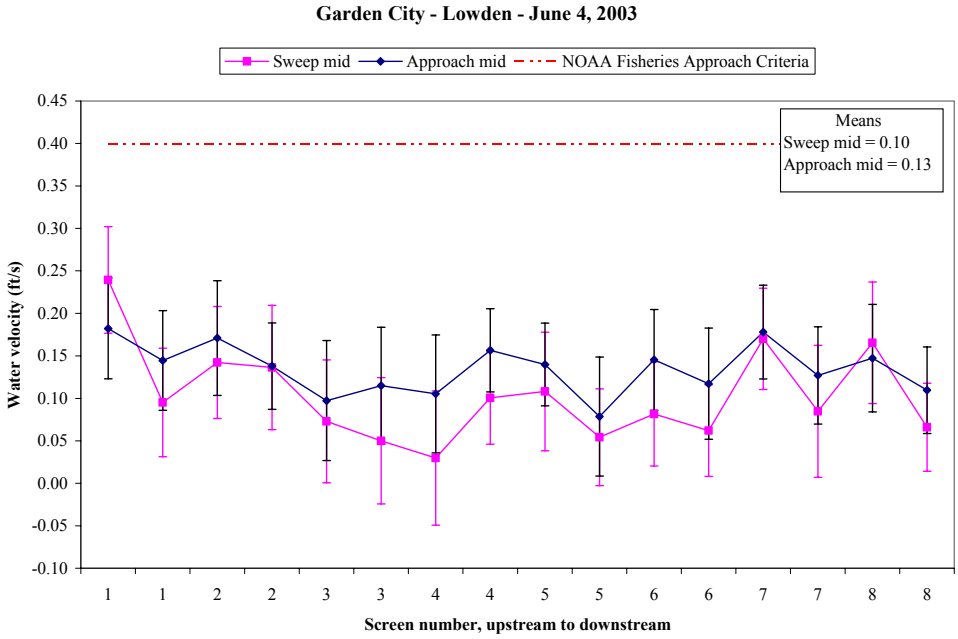

Figure 3.14. Approach and Sweep Velocities at Garden City/Lowden II Fish Screens June 4, 2003. The dashed line at 0.4 ft/s represents the NOAA Fisheries criteria for approach velocities. The error bars (± the standard deviation) represent turbulence at each point. The text box shows the mean across all screens for the measured parameter.

4.0 References

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