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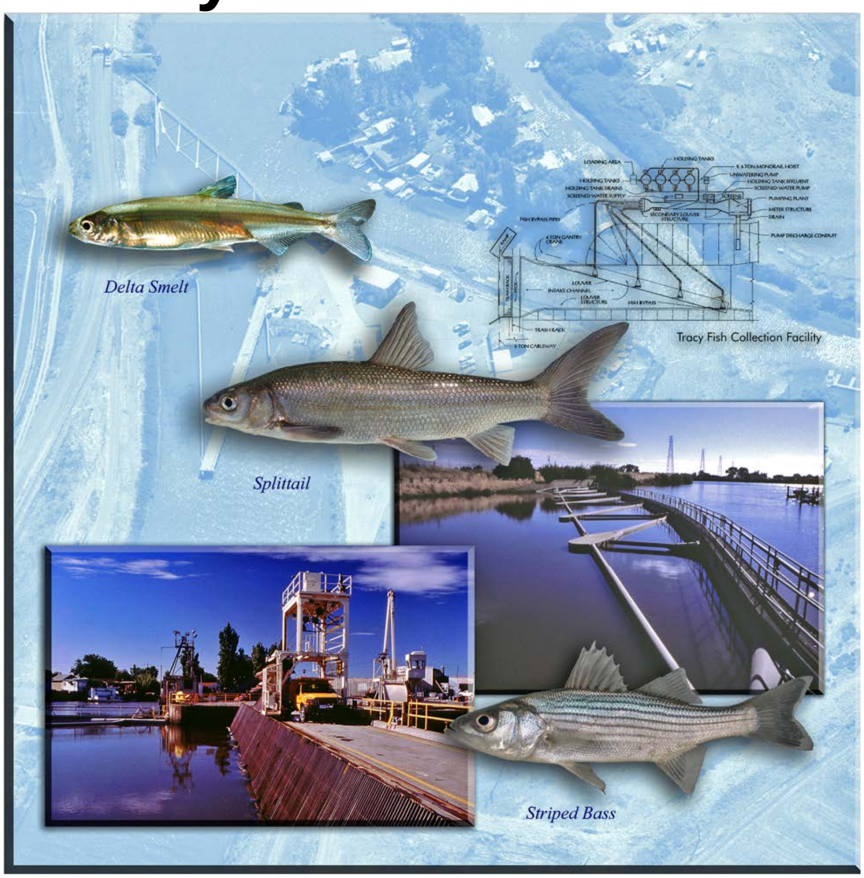
Tracy Technical Bulletin 2015-5

Hydraulic Evaluation of Hydrolox Traveling Screen in the Secondary Channel of the Tracy Fish Collection Facility



U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region and
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June 2016

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14. ABSTRACT
A hydraulic field evaluation of Hydrolox screens installed in the secondary channel of the Tracy Fish Collection Facility was conducted on August 11 and 12, 2015. Three-dimensional velocities were collected 3 in from the screen face using a SonTek/YSI acoustic Doppler velocimeter mounted inside a lead sounding weight during high tide. Average approach velocity across all four screens was 0.37 ±0.14 and 0.34 ±0.11 ft/s for secondary channel velocities of 2.52 and 1.82 ft/s, respectively. Approach velocities increased along the four Hydrolox screens in the downstream direction. As the secondary channel velocity increased, the uniformity of approach velocities decreased in both the longitudinal and vertical directions. Sweeping velocities along the screens increased in the downstream direction and reached a maximum at the entrance to the holding tanks. Screen performance may be improved by incorporating baffles to restrict flow through screens with higher approach velocities, thereby producing more uniform approach velocities across the entire screen structure. Observations of the debris collection system before and after each hydraulic test revealed good performance of all components for a relatively light debris load of primarily Egeria (*Egeria densa*). Headloss across the Hydrolox screens was not recorded because the water level sensor downstream from the screen was not operational.

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Tracy Fish Facility Studies
California

Hydraulic Evaluation of Hydrolox Traveling Screen in the Secondary Channel of the Tracy Fish Collection Facility

Tracy Technical Bulletin 2015-5

by

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EXECUTIVE SUMMARY

The Tracy Fish Collection Facility (TFCF) is located at the head of the Delta Mendota Canal just west 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. In 2014, two rows of secondary louvers were replaced with a single line of Hydrolox^{TM} engineered polymer traveling screens to reduce fish loss associated with the cleaning and maintenance of the secondary louver system. The self-cleaning Hydrolox screens provide fish protection by guiding fish into the holding tanks while catching aquatic debris on pegs and transporting debris to a conveyor collection system at the work surface.

This report provides findings from a field evaluation of hydraulic conditions at the Hydrolox traveling screens. Approach, sweeping, and vertical velocities were collected at nine locations across each of the four Hydrolox screens for two different secondary channel velocities, referred to as "tests" in the remainder of the document. Velocities were collected using a SonTek/YSI acoustic Doppler velocimeter mounted inside a lead sounding weight which maintained the velocity probe's orientation with respect to the screen and kept the probe stationary during data collection.

Average approach velocity across all four screens was 0.37 ±0.14 and 0.34 ±0.11 ft/s for secondary channel velocities of 2.52 (Test No. 1) and 1.82 ft/s (Test No. 2), respectively. Approach velocities increased from 0.21-0.40 ft/s and 0.22-0.43 ft/s along the screens in the downstream direction for tests No. 1 and No. 2, respectively. As the secondary channel velocity increased, uniformity of approach velocities decreased in both longitudinal and vertical directions. Sweeping velocities along the screens increased in the downstream direction and reached a maximum at the entrance to the holding tanks. Uniformity of approach velocities may be improved by incorporating baffles to restrict flow through screens with higher approach velocities, thereby producing more uniform approach velocities across the entire screen.

Test No. 1 was conducted Aug 11, 2015 without the clean water bypass operating and Test No. 2 was conducted Aug 12, 2015 with the clean water bypass operating. Hydraulic performance of the screen was better for Test No. 2, although it is not clear if screened water flow was responsible for the improved hydraulics or if the lower secondary channel velocity was responsible. Additional testing with the clean water bypass on and off would be needed to isolate the effects of the clean water bypass on screen performance.

Observations of the debris collection system before and after each hydraulic test revealed good performance of all components for a relatively light debris load of primarily Egeria (*Egeria densa*). Debris for each test was consistent and should not have impacted the testing. The head loss across the Hydrolox screens was not recorded because the water level sensor downstream of the screen was not operational. When the sensor is operational, water levels should be recorded by facility operators for a wide range of operations to document head loss characteristics for the screens.

INTRODUCTION

The Bureau of Reclamation's (Reclamation) Tracy Fish Collection Facility (TFCF), located in the southern Sacramento-San Joaquin Delta (Delta) was designed to divert juvenile Chinook salmon (*Oncorhynchus tshawytscha*), striped bass (*Morone saxatilis*) and other species from Delta Mendota Canal flows, thereby preventing entrainment loss to the downstream Jones Pumping Plant (JPP, Bates *et al*. 1960). The TFCF uses a louver-bypass system to intercept and guide fish from entrainment in the Delta Mendota Canal into holding tanks, where they are held until they are truck-transported back to the Delta and away from the immediate influence of the JPP (Figure 1).

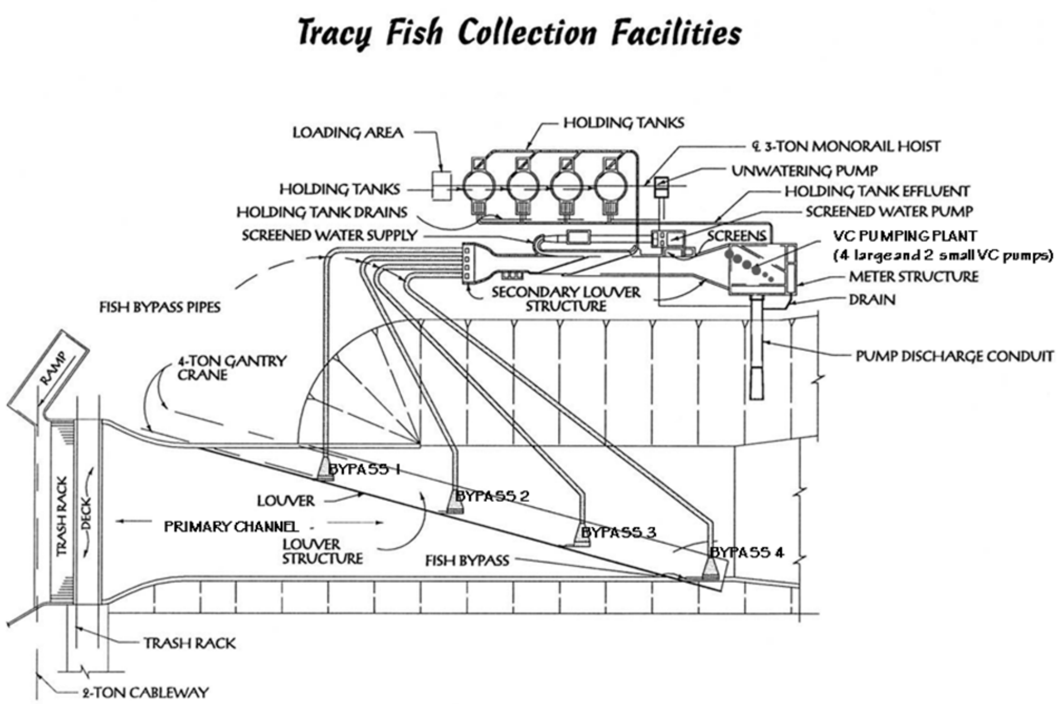

Figure 1. Schematic of major features of the Tracy Fish Collection Facility.

The original louvers in the primary and secondary channel consisted of a series of vertical slats placed at 1-in (2.5-cm) spacing with slats oriented normal to the flow direction. The louvers are designed to generate disturbances in the flow field that fish avoid. Fish maintain a distance off of the louver face, while sweeping flow is intended to guide fish along the louver line and into the bypasses (Figure 2).

Figure 2. Original louver system in secondary channel.

Historically, the secondary channel was dewatered daily to clean the louvers with a high pressure water jet. While the secondary is dewatered for up to 1 hour, no fish can be salvaged. According to the Reasonable and Prudent Alternatives in the 2009 Biological Opinion, Reclamation was directed to determine "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" (National Marine Fisheries Service, 2009).

In 2014, two rows of secondary louvers were replaced with a single line of Hydrolox™ engineered polymer traveling screens (Hydrolox, Harahan, Louisiana). The self-cleaning Hydrolox screens provide fish protection by guiding fish into the holding tanks while catching aquatic debris on pegs and transporting debris to a conveyor collection system at the work surface. Each of the four vertical screen panels is 12.9 ft wide by 14.5 ft high with a screen slot width of 0.07 inches (1.75 mm) and 32 % porosity.

Prior to Hydrolox installation, a partial full-scale physical model of the traveling screen system was tested in Reclamation's hydraulics laboratory in Denver, Colorado (Heiner and Mefford 2011). In the laboratory, specialized debris pegs were mounted to the screen to determine the optimal design, spacing, and traveling screen speed for catching and removing pond weed and other stringy debris passing in front of the screens prior to the flow entering the fish holding tanks. Egeria, a common pond weed, is the primary debris load encountered at the TFCF (Boutwell and Sisneros 2007). Water hyacinth, a free-floating aquatic plant, and woody debris are also entrained at the TFCF. The design of the Hydrolox screens includes the recommended debris pegs which are intended to remove channel debris (pegs were specifically designed for Egeria removal) without needing to dewater the screens (Figure 3).

Figure 3. Debris pegs on the Hydrolox traveling screen loaded with the pond weed, Egeria.

In August 2015, hydraulic evaluation tests of the Hydrolox traveling screens were conducted to confirm the screens are operating as designed. Specific goals included:

1. Document approach and sweeping velocity distributions along the traveling screen in the TFCF secondary channel.

2. Document head loss across the traveling screen.

This study included an evaluation of hydraulic conditions only. Head loss information could not be collected because the downstream water level sensor was not functioning properly during tests. Studies of fish collection efficiencies or debris collection efficiencies are beyond the scope of this study.

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METHODOLOGY

Velocity Measurements

The major component of the hydraulic evaluation was making velocity measurements over the majority of the four traveling screen panels. Three-dimensional velocity measurements were taken 3 inches from the screen face using a SonTek/YSI acoustic Doppler velocimeter (ADV) as shown in Figure 4. The 16 MHz Micro ADV has an accuracy of ± 1% of the measured velocity with a velocity range from ±0.003 to 8.2 ft/s. Data were acquired at sampling rates of 25 Hz, allowing for the measurement of turbulence characteristics of the flow.

Figure 4. SonTek/YSI Field ADV probe and splash-proof signal processing module.

Approach velocities (perpendicular to the screen face), sweeping velocities (parallel to the screen face), and vertical velocities were measured with the ADV. The ADV was mounted inside a modified 50-lb sounding weight which was used to maintain the velocity probe's orientation with respect to the screen and to hold the probe stationary during data collection (Figure 5). The modified sounding weight has been used many times by the authors, and does not interfere with the sweeping or approach velocity measurements. The ADV was maintained at a distance of 3 inches from the screen face by metal fins that were retrofit to the sounding weight's body (Figure 5). The ADV probe head was positioned just above the bottom of the sounding weight and fixed in a position so the x-axis of the probe was parallel to the screen face (Figure 6).

Velocity measurements were collected at nine locations on each screen. Measurements were made at longitudinal stations located 3.5, 6.5, and 9.5 ft from the leading edge of each screen. A custom made trolley system was used to transport the sounding weight from station to station on each screen in an upstream to downstream direction (Figure 7). Velocity measurements were made at three vertical elevations positioned at 20, 50 and 80 % of the secondary flow depth starting at the surface and working downward. Velocities were measured at three longitudinal positions across the screen before lowering the weight to the next water depth. At the mid-level (50 %) and near-bottom (80 %) depths, the sounding weight had to be pulled upstream using a tagline to compensate for the drag on the ADV probe.

Figure 5. SonTek/YSI Micro ADV deployment setup used for the Hydrolox screen evaluation. The ADV probe is mounted inside a 2-in diameter aluminum tube. The sounding weight maintains the ADV position into the flow and offset 3 in from the screen face.

Figure 6 Close-up view of the SonTek Micro ADV probe's orientation inside the sounding weight. The arm with the red tape indicates the x-axis for this probe.

Figure 7. Photograph of Hydrolox screen panel No. 1 with yellow debris pegs. The velocity probe winch and trolley system is shown in the foreground. The conveyor debris collection system is shown in the background.

Care was taken to ensure the probe was seated against the screen face prior to velocity data collection. Likewise, vertical velocities were observed to confirm the probe was not tilted from being caught on a debris peg. However, it is possible that minor deviations in alignment could have unknowingly occurred since visual verification of probe position was not possible. Once the probe was oriented at the proper location and depth, a 20 second velocity measurement was collected at 25 Hz for a total of 500 samples. Each data set was reviewed in real-time to check for problems with debris, probe orientation, or excessive vibration before moving to the next location. If any erroneous velocity data were observed, the ADV measurement was repeated.

Velocity Data Analyses

Velocity data were analyzed using WinADV which is a Windows-based viewing and post-processing utility for ADV files that was developed by Reclamation (Wahl, 2000). This program provides an integrated environment for viewing, reviewing, and processing data collected using ADVs. Time series velocity data were processed to determine the average velocity components (x, y, z) and summary statistics for each measurement location. Data were filtered to remove measurements with signal-to-noise ratios (SNR) less than 5 and correlation (COR) values less than 70. Filtered data were carefully analyzed to remove debris-affected velocity measurements and then compiled to assess the hydraulic performance of each screen panel.

Hydraulic Conditions

Tidal fluctuation at the facility causes water depths in the secondary channel to vary (typically about 3 feet) which affects the hydraulics along the traveling screens. Tidal stage data for the TFCF is available at the Old River near the Delta Mendota Canal gage which is managed by California Department of Water Resources (CDEC station OBD).

Two sets of velocity data were collected. Target secondary channel velocities were 3.0-3.5 ft/s to correspond to operating criteria when salmon are present, and less than 2.5 ft/s to correspond to operating criteria for striped bass, catfish, shad, and other fish (State Water Resources Control Board 1978). To maximize submergence on the screen, data were collected during high tides. High tides occurred from 19:00 to 20:30 on August 11, 2015 and from 06:00 to 08:00 on August 12, 2015. Figure 8 shows stage data from a gaging station on Old River near the Delta Mendota Canal and the two testing periods.

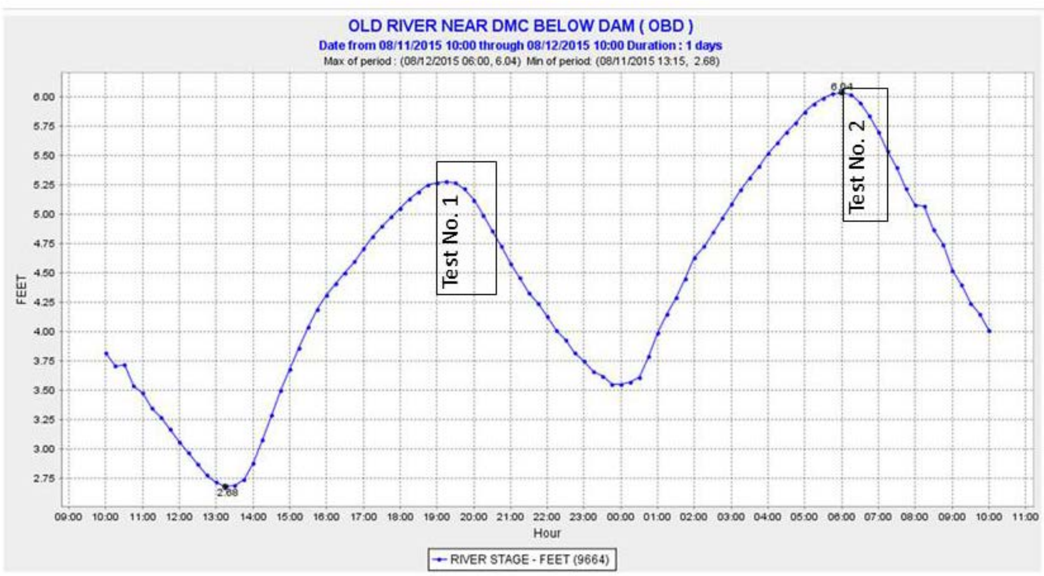

Figure 8. Tide conditions near the Tracy Fish Collection Facility during hydraulic evaluation data collection. The two test periods are indicated.

Each Hydrolox screen was cleaned to remove debris prior to taking velocity measurements. After the screen cleaning was complete, the screen was stopped and the spray system was turned off for the duration of each test. For these tests, there was very little debris on the screens before or after the test period. Egeria was the primary aquatic material observed during screen cleaning operations.

Secondary channel depths were recorded from the water level sensor upstream from the screen. The water level sensor downstream of the screen was not operational, so screen headloss characteristics could not be evaluated. Water depth in the secondary channel did not vary by more than 0.5 ft during the velocity measurements. Secondary channel discharge was calculated as the sum of the discharge recorded by the four bypass flow meters. Secondary velocity was calculated as the secondary channel discharge divided by the secondary channel flow area (flow depth multiplied by a channel width of 8.0 ft). Velocity control (VC) pumps at the downstream end of the secondary channel were used to set the secondary channel velocity to 2.52 and 1.82 ft/s for Test No. 1 and Test No. 2, respectively. Channel velocities between 3.0-3.5 ft/s were not obtainable during high tide.

The clean water bypass system recirculates water from left side of the secondary channel downstream of the Hydrolox screen to the left side of the secondary channel a few feet upstream from the bypass entrance. Screened water should be released on the south side of the channel at or slightly above the secondary channel velocity to ensure maximum removal of aquatic plant debris by the Hydrolox screen (Heiner and Mefford 2011). During Test No. 1, the clean water bypass was not used since there was no pumping at the JPP. During the Test No. 2, the JPP had one pump running, so the clean water bypass was operated at a pumping rate of 14.9 cfs. Table 1contains a summary of TFCF operations data for the two test periods.

Table 1. Operations summary table for hydraulic evaluation

Parameter	Test No. 1	Test No. 2
Test Period	**August 11, 19:00–20:35**	**August 12, 06:00–08:00**
Secondary Channel Depth (ft)	**7.42**	**8.67**
Secondary Channel Flow (cfs)	**149.0**	**126.0**
Secondary Channel Velocity (ft/s)	**2.52**	**1.82**
JPP Export (# of Pumps On)	**0**	**1**
Large VC Pumps On (Pump #)	**4 (# 1, 2, 3, 4)**	**3 (# 1, 2, 3)**
Small VC Pumps On (Pump #)	**0**	**1 (# 2)**
Clean water bypass	**Off**	**On**
Clean water bypass Flow (cfs)	**0**	**14.9**
Holding Tank Flow (cfs)	**N/A**	**12.1**
Water Temperature (deg F)	**75.0**	**74.6**

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RESULTS

Test No. 1 Results – Secondary Channel Velocity 2.52 ft/s

Data collection for Test No. 1 was initiated at 19:00 near the peak of the high tide cycle and was completed by 20:30. At the start of the testing, the secondary channel velocity was computed to be 2.52 ft/s. Contours of the measured approach velocities (V_y) are displayed in Figure 9. The x-axis shows the longitudinal position of the measurement along the screen with black vertical lines indicating the structural support piers between the 4 screens. The average velocities for all points on screen 1, 2, 3, and 4 were 0.21, 0.40, 0.47, and 0.40 ft/s, respectively. The overall average approach velocity was 0.37 ft/s with an average turbulent fluctuation[1] of ±0.14 ft/s. Variations in approach velocity occurred more strongly in the longitudinal direction than the vertical direction.

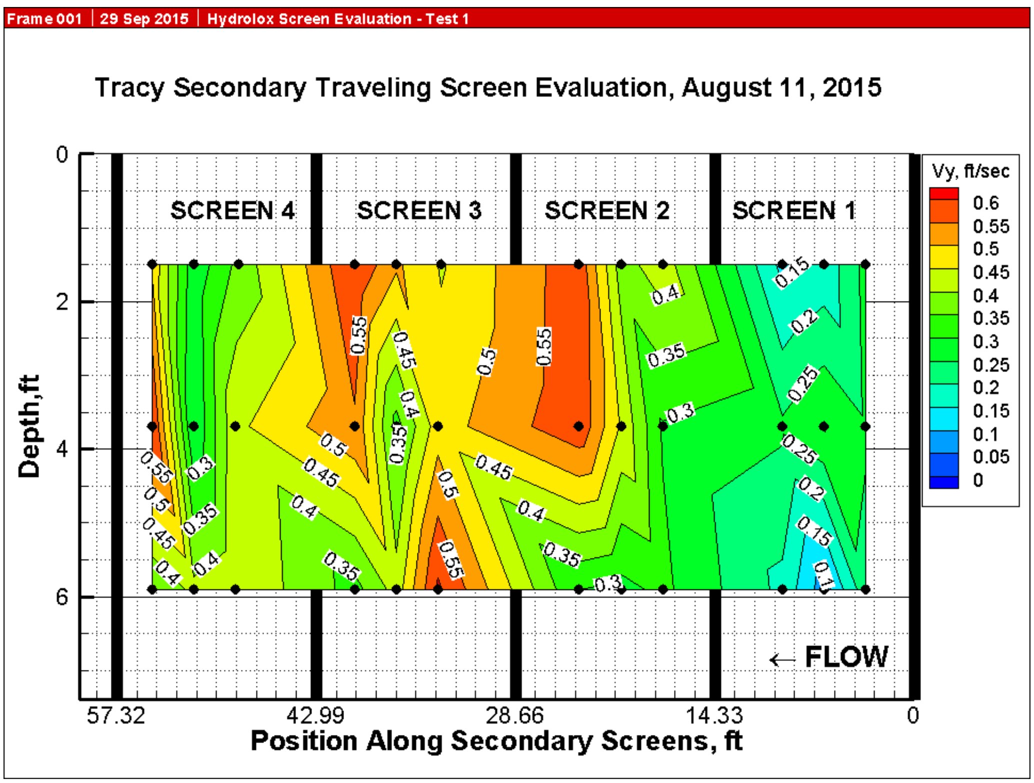

Figure 9. Test No. 1 approach velocity contours for a secondary channel velocity of 2.52 ft/s. The black dots represent velocity measurement locations.

Contours of the measured sweeping velocities (V_x) are displayed in Figure 10. Sweeping velocities increased from Screen 1 to Screen 4 as flow constricts down

[1] Turbulent fluctuation was computed in WinADV as the root mean square (RMS) of the velocity fluctuation for each velocity component (Vx', Vy', and Vz')

to the bypass entrance. The overall average sweeping velocity was 4.59 ft/s with an average turbulent fluctuation of ±0.20 ft/s. The overall average vertical velocity (V_z) was 0.03 ft/s with an average turbulent fluctuation of ±0.11 ft/s. Tabular velocity data for Test No. 1 can be found in Appendix B.

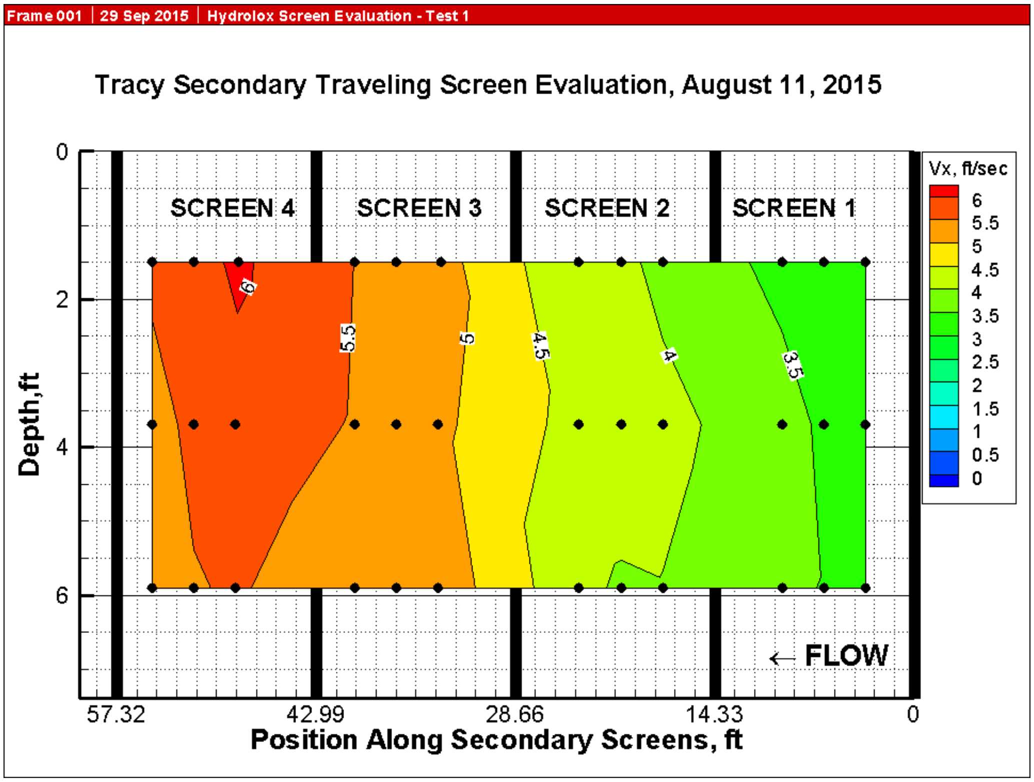

Figure 10. Test No. 1 sweeping velocity contours for a secondary channel velocity of 2.52 ft/s. The black dots represent velocity measurement locations.

A verification of the approach velocity can be obtained using a mass balance approach. For example, taking the incoming flowrate and subtracting out any flow going to the holding tank and adding any flow provided by the clean water bypass then dividing by the total wetted screen area gives an estimate of the average approach velocity. For Test No. 1 [(149-10+0)/(12.9*7.42*4)] the calculation gives 0.36 ft/sec. Note: the flow into the holding tank was not available during this test, but was estimated at 10 cfs based on the incoming water depth. The estimated calculation of 0.36 ft/sec compares very well with the measured 0.37 ft/sec determined during Test No. 1.

Test No. 2 Results – Approach Channel Velocity 1.82 ft/s

Data collection for Test No. 2 was initiated at 06:00 during the peak of high tide cycle and was completed by 08:00. At the start of the testing the secondary channel velocity was computed to be 1.82 ft/s. Contours of the measured approach velocities (V_y) are displayed in Figure 11. The average velocity for all points on Screen 1, 2, 3, and 4 was 0.22, 0.33, 0.37, and 0.43 ft/s, respectively. The overall average approach velocity was 0.34 ft/s with an average turbulent fluctuation of ±0.11 ft/s. Longitudinal gradient in approach velocity was not as prominent for Test No. 2.

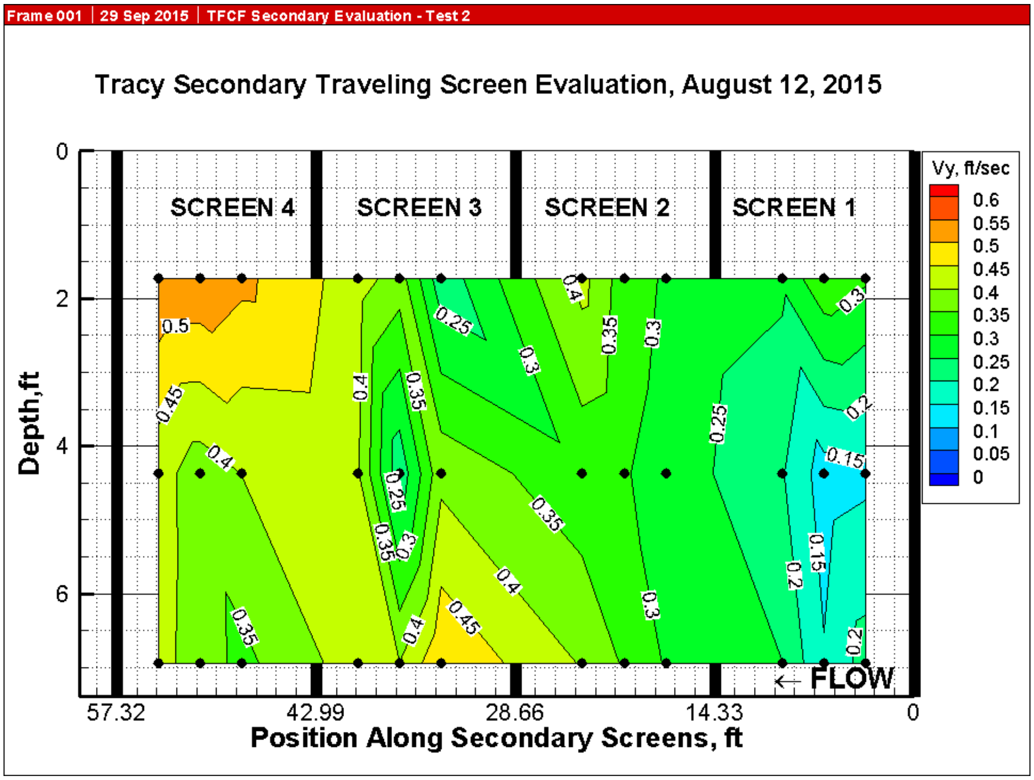

Figure 11. Test No. 2 approach velocity contours with secondary channel velocity of 1.82 ft/s. The black dots represent velocity measurement locations.

Contours of the measured sweeping velocities (V_x) are displayed in Figure 12. Sweeping velocities increased from Screen 1 to Screen 4 as flow constricts down to the bypass entrance. The overall average sweeping velocity was 3.31 ft/s with an average turbulent fluctuation of ±0.15 ft/s. The overall average vertical velocity (V_z) was -0.01 ft/s with an average turbulent fluctuation of ±0.09 ft/s. Tabular velocity data for Test No. 2 can be found in Appendix B.

A verification of the approach velocity can be obtained using a mass balance approach. For example, taking the incoming flowrate and subtracting out any flow going to the holding tank and adding any flow provided by the clean water bypass then dividing by the total wetted screen area gives an estimate of the average approach velocity. For Test No. 2 [(126-12.1+14.9)/(12.9*8.67*4)] the calculation gives 0.29 ft/sec. The estimated calculation of 0.29 ft/sec is within 15% of the measured 0.34 ft/sec determined during Test No. 2 which is considered an acceptable deviation given the average turbulent fluctuation of ±0.11 ft/s and the complexity of obtaining the velocity measurements.

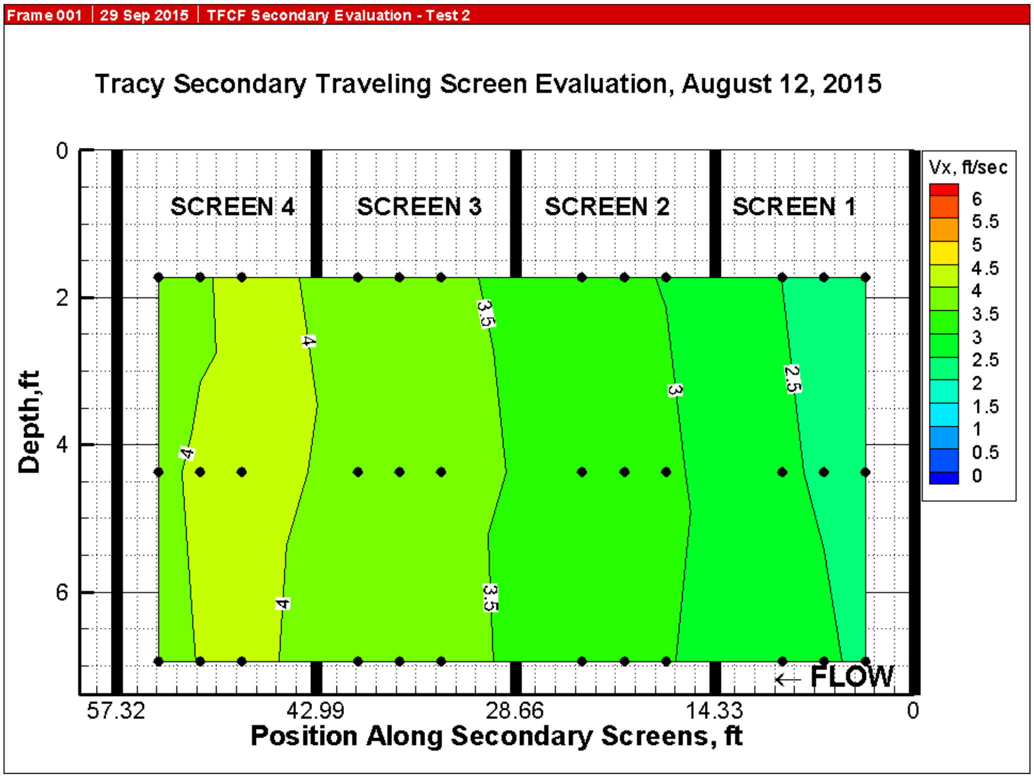

Figure 12. Test No. 2 sweeping velocity contours with secondary channel velocity of 1.82 ft/s. The black dots represent velocity measurement locations.

CONCLUSIONS AND RECOMMENDATIONS

Hydraulic evaluation of the Hydrolox traveling screens in the secondary channel showed that the average approach velocity across all four screens was 0.37 ±0.14 and 0.34 ±0.11 ft/s for secondary channel velocities of 2.52 and 1.82 ft/s, respectively. Approach velocities increased along the screens in the downstream direction. As the secondary channel velocity increased the uniformity of approach velocities decreased in both the longitudinal and vertical directions.

Screen performance may be improved by incorporating baffles to restrict flow through screens with higher approach velocities, thereby producing more uniform approach velocities across the entire screen.

Sweeping velocities along the screens increased in the downstream direction and reached a maximum at the entrance to the holding tanks. These results are consistent with the observed increased drawdown in water level from the most upstream screen to the most downstream screen. Increased approach and sweeping velocities at the downstream screens could also be a result of tidal influence during testing. Tests started at the peak of the tidal cycle and were

completed when the tide was dropping. Thus, the water depth in the secondary channel was falling during the tests. With constant flow through the system, a decreased depth would result in higher sweep and approach velocities.

Test No. 1 was conducted with no clean water bypass flow, and Test No. 2 was conducted with clean water bypass flow. Hydraulic performance of the screen was better for Test No. 2 having more uniform approach velocities and smaller turbulent fluctuations. However, it is not known if the clean water bypass flow or the lower secondary channel velocity was responsible. Additional testing with the clean water bypass turned on and off would be required to isolate the effects of the clean water bypass on screen performance. Laboratory testing recommended that the system only be operated with the clean water bypass on.

To maximize submergence on the screen, data were collected during two consecutive high tide cycles. A secondary channel velocity in a 3.0-3.5 ft/s range was not obtainable during testing. A follow up hydraulic evaluation while the facility is being operated for salmon may be desired to understand screen performance during this time.

Observations of the debris collection system before and after each hydraulic test revealed good performance of all components for a relatively light debris load of primarily Egeria.

The head loss across the Hydrolox screens was not determined because the water level sensor downstream from the screen was not operational. Once the sensor is operational, water levels should be recorded for a wide range of operations to determine the head loss characteristics for the screens.

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APPENDIX 1 - ACOUSTIC DOPPLER VELOCIMETER THEORY OF OPERATION

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A high-resolution acoustic Doppler velocimeter (ADV) measures 3-dimensional velocity vectors in a remotely sampled volume. The ADV is a bi-static Doppler current meter which means the ADV uses separate acoustic transducers for transmitter and receivers (Figure A1-1). The transducers are mounted such that their respective beams intersect over a volume of water located some distance away, called the sampling volume. ADVs normally report velocity data in a Cartesian (X,Y,Z) coordinate system relative to the probe's orientation. Depending on the ADV model, the sampling volume can be located either 5 or 10 cm from the tip of the acoustic sensor. The 5 cm sensor is usually used in laboratories and in shallow water, and the 10 cm sensor is a more robust field probe that has less potential for flow interference in turbulent flow.

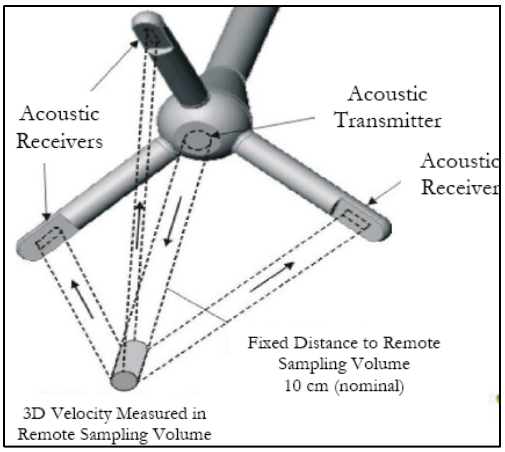

Figure A1-1. Schematic of ADV probe head orientation and sampling volume. (Image provided by Sontek/YSI Inc.).

The SonTek Micro ADV used for this project has serial number A311F and the probe configuration used throughout testing is shown in Table A1-1.

Table A1-1. Sontek ADV instrument specifications and configuration

Parameter	Value
Instrument Model	Micro ADV
Instrument Serial Number	A311F
Operating Acoustic Frequency	16 Megahertz (MHz)
Sampling Volume	0.09 cm^3 (0.005 in^3)
Distance to Sampling Volume (from acoustic transmitter)	5 cm (1.96 in)
Resolution	0.01 cm/s (0.0003 ft/s)
Accuracy	±1% of measured velocity, 0.25 cm/s
Instrument Configuration	**Instrument Configuration**
Sampling rate	25 Hz
Max Velocity Range Setting	250 cm/s (8.2 ft/s)
Data Collection Period (Burst)	20 seconds
Salinity	1 ppt (part per thousand)
Water temperature	25 °C

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APPENDIX 2 - TABULAR SCREEN VELOCITY DATA

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Table A2-1. Test No. 1 screen velocity data with a secondary channel velocity of 2.52 ft/s. Average sweeping velocity (Vx), approach velocity (Vy), vertical velocity (Vz), and velocity magnitude (Vmag) are tabulated along with the root mean square (RMS) values of the velocity fluctuations (Vx', Vy', and Vz').

Screen	Position (ft)	Depth (ft)	Average Vx	Average Vy	Average Vz	Average Vmag	RMS[Vx']	RMS[Vy']	RMS[Vz']
1	3.5	1.5	3.07	0.27	-0.28	3.09	3.10	0.19	0.15
1	6.5	1.5	3.30	0.16	-0.27	3.32	3.33	0.22	0.18
1	9.5	1.5	3.36	0.14	-0.33	3.38	3.39	0.22	0.15
1	3.5	3.7	3.25	0.26	-0.04	3.26	3.26	0.26	0.16
1	6.5	3.7	3.43	0.30	-0.03	3.44	3.45	0.25	0.15
1	9.5	3.7	3.68	0.26	-0.02	3.69	3.69	0.20	0.14
1	3.5	5.9	3.34	0.23	0.24	3.36	3.36	0.25	0.17
1	6.5	5.9	3.49	0.07	0.03	3.49	3.49	0.13	0.11
1	9.5	5.9	3.55	0.19	0.06	3.56	3.56	0.21	0.12
2	17.9	1.5	3.86	0.43	-0.25	3.89	3.89	0.16	0.13
2	20.9	1.5	4.13	0.38	-0.24	4.15	4.16	0.19	0.13
2	23.9	1.5	4.06	0.58	-0.25	4.11	4.11	0.23	0.13
2	17.9	3.7	4.16	0.30	0.10	4.17	4.17	0.17	0.12
2	20.9	3.7	4.28	0.44	0.13	4.31	4.31	0.17	0.11
2	23.9	3.7	4.32	0.59	0.11	4.36	4.36	0.15	0.12
2	17.9	5.9	3.98	0.31	0.22	4.00	4.00	0.14	0.12
2	20.9	5.9	3.94	0.29	0.38	3.97	3.97	0.19	0.11
2	23.9	5.9	4.11	0.30	0.07	4.12	4.12	0.16	0.12
3	34.0	1.5	5.18	0.45	-0.20	5.20	5.20	0.15	0.13
3	37.0	1.5	5.21	0.51	-0.10	5.23	5.24	0.14	0.14
3	40.0	1.5	5.49	0.60	-0.20	5.53	5.53	0.14	0.12
3	34.0	3.7	5.11	0.48	0.14	5.13	5.13	0.11	0.10
3	37.0	3.7	5.30	0.33	0.08	5.32	5.32	0.12	0.12
3	40.0	3.7	5.46	0.54	0.13	5.49	5.49	0.14	0.10
3	34.0	5.9	5.32	0.61	0.24	5.36	5.36	0.16	0.12
3	37.0	5.9	5.15	0.42	0.30	5.18	5.18	0.18	0.12
3	40.0	5.9	5.14	0.33	0.30	5.15	5.16	0.20	0.14
4	48.4	1.5	6.08	0.36	-0.24	6.09	6.09	0.15	0.11
4	51.4	1.5	5.84	0.26	-0.11	5.85	5.85	0.23	0.15
4	54.4	1.5	5.62	0.49	-0.04	5.64	5.65	0.37	0.22
4	48.4	3.7	5.83	0.44	0.06	5.85	5.85	0.16	0.10
4	51.4	3.7	5.63	0.25	0.27	5.65	5.65	0.24	0.14
4	54.4	3.7	5.28	0.61	-0.02	5.32	5.33	0.45	0.27
4	48.4	5.9	5.56	0.45	0.21	5.58	5.58	0.21	0.14
4	51.4	5.9	5.46	0.41	0.39	5.49	5.49	0.21	0.16
4	54.4	5.9	5.12	0.35	0.29	5.14	5.14	0.29	0.17

Table A2-2. Test No. 2 screen velocity data with a secondary channel velocity of 1.82 ft/s. Average sweeping velocity (Vx), approach velocity (Vy), vertical velocity (Vz), and velocity magnitude (Vmag) are tabulated along with the root mean square (RMS) values of the velocity fluctuations (Vx', Vy', and Vz').

Screen	Position (ft)	Depth (ft)	Average Vx	Average Vy	Average Vz	Average Vmag	RMS[Vx']	RMS[Vy']	RMS[Vz']
1	3.5	1.7	2.15	0.31	-0.08	2.18	0.15	0.14	0.13
1	6.5	1.7	2.23	0.34	-0.04	2.26	0.18	0.14	0.11
1	9.5	1.7	2.50	0.26	-0.02	2.52	0.18	0.16	0.12
1	3.5	4.4	2.34	0.14	-0.05	2.35	0.20	0.13	0.12
1	6.5	4.4	2.41	0.13	-0.01	2.42	0.20	0.12	0.10
1	9.5	4.4	2.60	0.20	0.00	2.61	0.19	0.11	0.10
1	3.5	6.9	2.33	0.22	-0.02	2.35	0.17	0.12	0.10
1	6.5	6.9	2.63	0.15	-0.03	2.64	0.14	0.10	0.08
1	9.5	6.9	2.71	0.25	-0.06	2.72	0.15	0.10	0.08
2	17.9	1.7	2.99	0.29	-0.01	3.00	0.16	0.11	0.10
2	20.9	1.7	3.04	0.32	-0.03	3.06	0.15	0.10	0.10
2	23.9	1.7	3.11	0.42	-0.07	3.14	0.15	0.11	0.09
2	17.9	4.4	3.08	0.28	-0.01	3.09	0.14	0.11	0.09
2	20.9	4.4	3.09	0.30	0.01	3.11	0.13	0.10	0.08
2	23.9	4.4	3.26	0.32	-0.02	3.28	0.12	0.10	0.07
2	17.9	6.9	3.03	0.29	0.01	3.04	0.13	0.11	0.07
2	20.9	6.9	3.04	0.34	0.04	3.06	0.14	0.09	0.07
2	23.9	6.9	3.09	0.40	0.02	3.12	0.12	0.10	0.07
3	34.0	1.7	3.64	0.22	-0.01	3.65	0.09	0.10	0.08
3	37.0	1.7	3.72	0.38	0.00	3.75	0.13	0.09	0.07
3	40.0	1.7	3.78	0.42	-0.12	3.81	0.13	0.09	0.08
3	34.0	4.4	3.71	0.39	0.00	3.73	0.11	0.10	0.08
3	37.0	4.4	3.76	0.21	0.03	3.77	0.10	0.09	0.07
3	40.0	4.4	3.89	0.41	-0.04	3.91	0.12	0.08	0.07
3	34.0	6.9	3.74	0.49	-0.08	3.77	0.16	0.10	0.07
3	37.0	6.9	3.66	0.40	0.16	3.68	0.11	0.10	0.07
3	40.0	6.9	3.76	0.43	0.08	3.79	0.11	0.10	0.07
4	48.4	1.7	4.21	0.51	-0.16	4.25	0.14	0.07	0.07
4	51.4	1.7	3.90	0.54	-0.12	3.95	0.21	0.14	0.13
4	54.4	1.7	3.66	0.54	-0.07	3.71	0.16	0.13	0.11
4	48.4	4.4	4.15	0.40	0.06	4.17	0.13	0.08	0.07
4	51.4	4.4	4.08	0.37	-0.02	4.10	0.21	0.11	0.11
4	54.4	4.4	3.89	0.42	-0.01	3.91	0.18	0.11	0.11
4	48.4	6.9	4.11	0.34	0.00	4.13	0.14	0.09	0.08
4	51.4	6.9	4.02	0.38	0.12	4.04	0.19	0.10	0.09
4	54.4	6.9	3.80	0.42	0.11	3.82	0.15	0.11	0.10