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Hydraulic Laboratory Technical Memorandum PAP-1081

ISI Cone Screen Riverine Performance with an External Baffle

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October 2013

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ISI Cone Screen Performance with an External Baffle

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Background

Fish screens are commonly used to prevent entrainment of fish and other aquatic species at water diversion intakes. Resource agencies developed design standards (criteria) to protect target species from entrainment, impingement and other means of harm at fish screens. Design criteria include values for approach velocities (water velocities perpendicular to the screen face), uniformity of approach velocity distribution over all screen area, sweeping velocity (water velocity parallel to the screen face), screen opening size, and screen orientation with respect to stream flow. Cone screens are conical shaped screen units designed for small water diversions in shallow, tidal areas where ambient water velocities are slow if at all present. Cone screens proved to be highly effective in tidal areas and were soon used in back water areas along rivers and streams where little ambient water velocity existed.

In 2009 cone screens were installed at a temporary, seasonal water diversion on the Sacramento River where ambient river velocities were approximately 5 feet per second, but the location was too shallow to use other traditional screening methods such as cylindrical units. Resource agency personnel measured near-screen velocities on those cone screens and found that approach velocities were not uniformly distributed over all areas of the screen. In addition, in some places approach velocities were an order of magnitude greater than allowed per fish screen design criteria.

Cone screens are typically equipped with baffle systems that distribute diverted flow over the entire screen area when installed in slack water locations; but the baffling system used in the riverine environment above was inadequate for approach velocities to meet fish screen design criteria. To use cone screens in a riverine environment a new baffle system was needed.

In order to accomplish this objective an improved understanding of cone screen hydraulics was needed. As a result, in 2010 the Hydraulics Investigations and Laboratory Services Group at the U.S. Bureau of Reclamation (Reclamation) in Denver conducted testing to develop an effective internal baffle design for providing an effective positive barrier for fish exclusion in a shallow river environment. The baffle design that was developed as a result of this initial study was effective in improving the performance of the ISI screen significantly [1]. However, because of the large draw down in flow depth that occurs on the downstream face of the screen at high velocities, improvement in performance using an internal baffle was limited. Therefore there was interest in improving performance further in a riverine environment using some sort of external baffle design. To accomplish this, three external baffle configurations were tested and are referenced here as bullnose concepts 1, 2, and 3.

The study presented herein compares the results of these tests to baseline data (without any type of baffle installed) as well as previous results conducted with the final internal baffle design.

Baseline data was gathered on the performance of an ISI (Intake Screens Inc.) cone screen tested with a screen intake flow set to 5.4 ft^3/s and a flume velocity of 2 ft/s. Testing for the initial bullnose concept was conducted with a screen intake flow set to 5.4 ft^3/s and a flume velocity of 2.5 ft/s. Based on these data, several modified bullnose design configurations were tested to determine if screen performance could be improved. In addition the bull nose configuration that provided the best performance was taken a step further and was also tested with a flume velocity of 4 ft/s. In this study a 5.5 ft diameter cone screen with 1.75 mm wedgewire and 50% open area was loaned to Reclamation by ISI for testing and performance evaluation (figure 1). This screen had no baffle or structure internal to the wedgewire surface, other than structural ribbing for support, and was designed to be placed over a flat surface with a 16 inch minimum diameter opening extending from the suction side of a diversion.

Figure 1. ISI Cone screen inside test flume. Note the 3 screen brushes have been removed.

Model Set-Up

The cone screen was installed in a 10 ft wide by 4 ft deep flume. Screen performance was evaluated based on uniformity of approach velocities distributed around the screen's surface. A test apparatus was designed to hold and rotate a SonTek acoustic doppler velocimeter (ADV probe) so that approach velocities could be measured at eight locations around the circumference of the screen at a set distance of 3 inches from screen's surface as required to meet resource agency screen velocity criteria. The test apparatus also allowed the probe to move parallel to the screen surface so that for each of the eight locations around the circumference of the screen, approach velocities could be measured at 2 inch increments parallel to the screen surface from top to bottom (figure 2).

The screen was installed 15 ft downstream from the entrance to the flume and was centered over a 16 inch opening in the flume floor to provide outflow from the flume through the cone screen. The screen discharge pipe, below the flume floor, transitioned from the 16 inch opening into a 12 inch pipe that extended about 28 ft downstream from the screen before depositing flow back into the laboratory sump. Flow through the cone screen was regulated with a gate valve and was set

Figure 2. Sontek ADV probe test apparatus

and measured, with a Controlotron transit time acoustic flow meter. The flow rate through the screen was set to the design flow for the screen , 5.4 ft^3/s for all test cases. The three brushes that normally rotate around the circumference of the screen were removed for the purpose of these tests. This was done to simplify the baffle design process since at any given time the location of the brushes may change. The effect on flow hydraulics with the brushes reinstalled may have a significant effect on the performance of the screen baffle design and will be discussed in the conclusions section of this report.

In each test case, approach velocity is defined as the component perpendicular to the screen surface with positive approach velocities indicating flow is going into the screen. It is worth noting that because it is impossible to measure velocities over the entire screen control surface, the velocities measured at the eight locations around the screen circumference at a 3.0 in. distance from the screen face, cannot necessarily be extrapolated to represent total through-screen flow to satisfy flow continuity.

In addition, due to limited funding, tests with debris were minimal and were only added to facilitate observations of performance. Debris was made up of whatever was available at the time of testing and was not measured for consistency for each test case. Tests were conducted without the brush attachments so that observations could be made regarding how well each configuration that kept the screen from collecting debris.

Baseline Condition

Initial testing was conducted without a baffle installed in the screen so that baseline data could be established to be compared to future test data. A flume velocity was established at 2.0 ft/s with a screen intake flow of 5.4 ft^3/s. Approach velocities were measured at each of the eight locations, labeled L1 through L8, shown as dashed lines, in the sketch in figure 3. Figure 4 shows screen approach velocities measured, beginning near the top of the wedgewire surface, (indicated by y = 0.0) and extending down the screen surface at 2 inch increments parallel to the screen face for a distance of 28 inches (corresponding to y = -28, with the y axis oriented parallel to the screen surface). All measurements were taken at a 3 inch distance perpendicular to the screen surface and positive values indicate flow is going into the screen. The top position where measurements actually began, varied for each location depending on flow depth and drawdown on the downstream face of the screen. Figure 4 shows the approach velocity profiles measured without a baffle at locations L1 through L8.

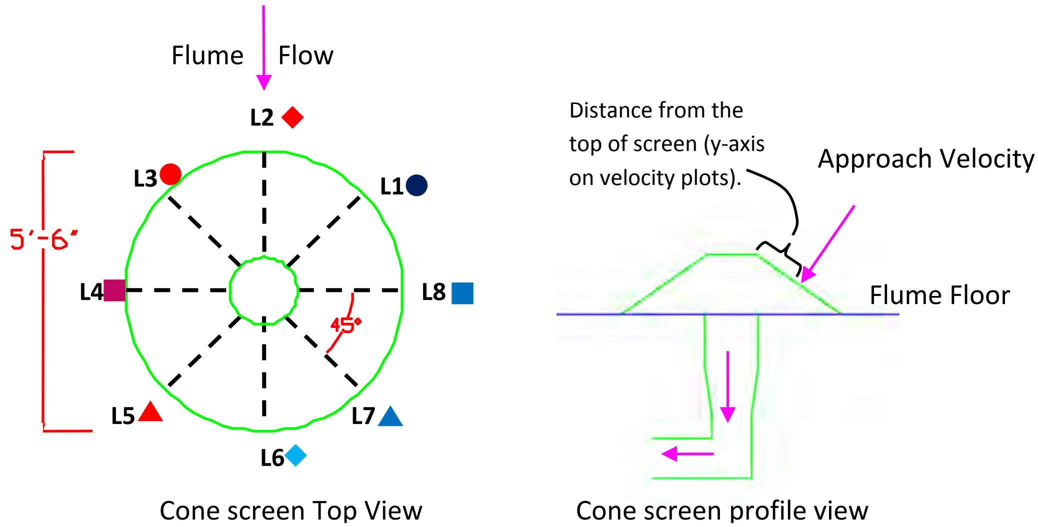

Figure 3. Velocity measurement locations for baseline condition and profile view of the screen setup.

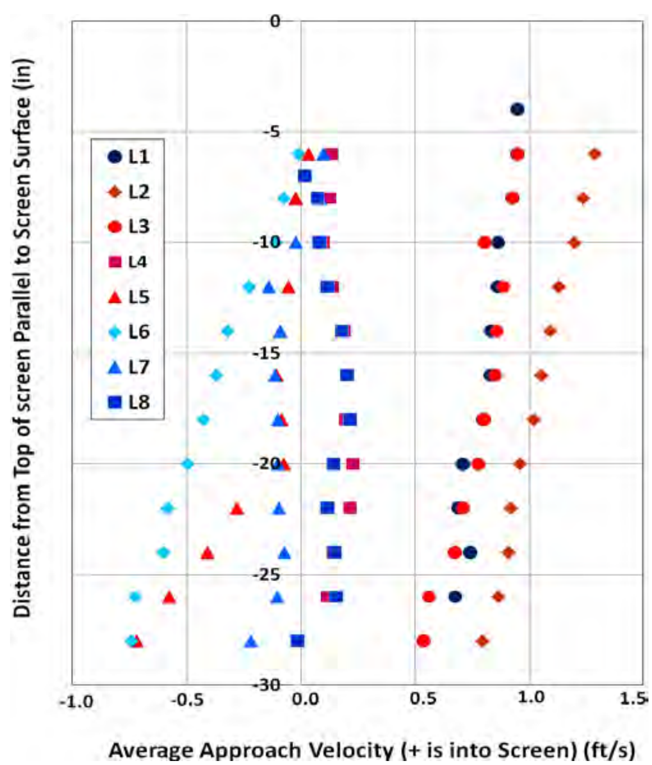

Figure 4. Baseline condition tested in 2010 [1] with no Baffle --- Cone Screen approach velocity profiles measured at locations L1 through L8.

As would be expected, Figure 4 shows that velocities are highest going into the screen at locations L1, L2 and L3 where the flume flow is directly impinging on the upstream face of the screen. Velocities are also slightly higher at those locations near the top of the screen, where screen surface area around the screen is least and is closest to the centered outflow circumference. Figure 4 shows that on the downstream side of the screen, velocities are going outward as flow goes through the upstream side and out the downstream face of the screen. These baseline velocities were used to compare with each bull nose design to determine if performance was improved in providing a more even distribution of approach velocities around the screen surface.

Bullnose Concepts

Bullnose Concept 1

The initial concept for an external bullnose design consisted of a circular section of aluminum panel following the leading edge of the screen circumference, a tail section to prevent drawdown on the backside of the screen, and two side openings to allow fish, and possibly debris, a means of escape. There was no internal baffle system installed during any of the bullnose concept testing. Concept 1 is illustrated in figure 5 with the bullnose panels shown as solid blue lines and the cone screen outline shown in green. Once this arrangement was installed, flow was set to provide a 2.5 ft/s average flume velocity adjacent to the screen centerline, parallel to the flume side walls (figure 6). A flow depth of 28 inches was used so that velocity measurements could be taken within 2 inches of the top of the screen surface. Velocity profiles were measured at locations A1 through A8 as shown in figure 7. The reason these locations do not line up with the baseline measurements is that the screen was rotated 12.5 degrees to facilitate 2010 testing with an internal baffle system, and these locations were kept the same for later comparisons of the baffled designs. Once this set-up was complete, approach velocity measurements were taken around the circumference of the screen. The velocity profiles measured for locations A1 through A8 are shown in Figure 8.

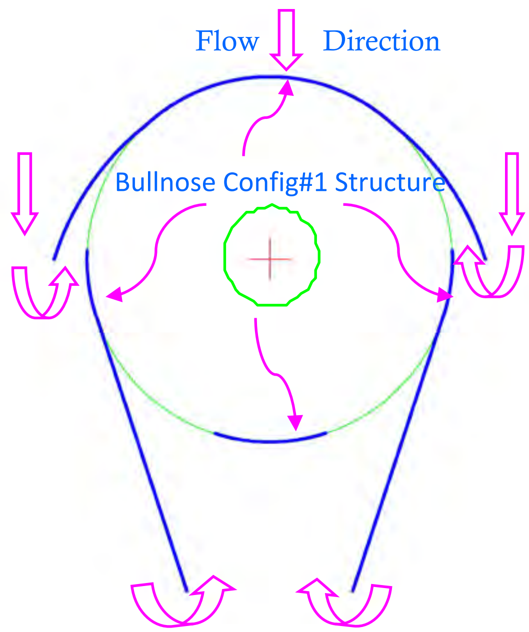

Figure 5. Illustration of Bullnose Concept 1. Blue lines indicate bullnose structure.

Figure 6. Photo of cone screen operating with Bullnose Concept 1.

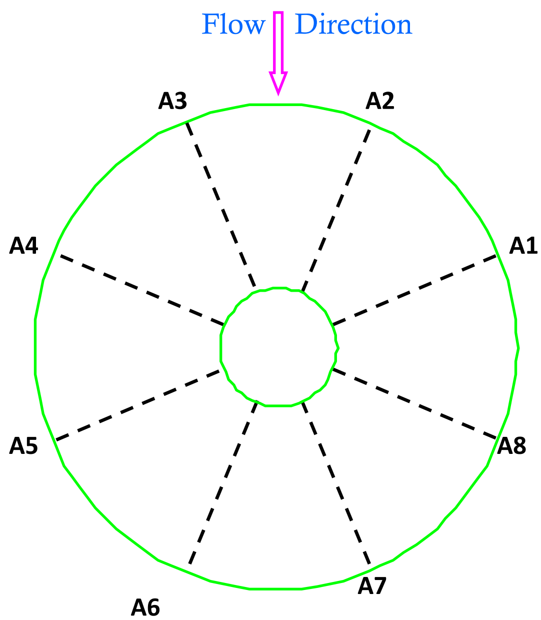

Figure 7. Velocity measurement locations for baffled (external and internal) cone screen.

The velocity profiles measured with the initial bullnose concept installed are significantly improved over the baseline condition. Approach velocities measured have been reduced from over 1.0 ft/s at some locations, to less than 0.6 ft/s. Velocities at all locations were reduced as demonstrated in figure 8. Velocities coming out of the screen on the downstream side have also been significantly reduced.

Miscellaneous debris in the form of hay and weeds were injected into the flow about 4 ft upstream from the screen. A fair amount of this debris was carried into the area inside the bullnose where it was recirculated and trapped. Some of this debris was pulled onto the screen surface where it stayed for long periods of time, although occasionally it was swept off and then reattached to the screen surface.

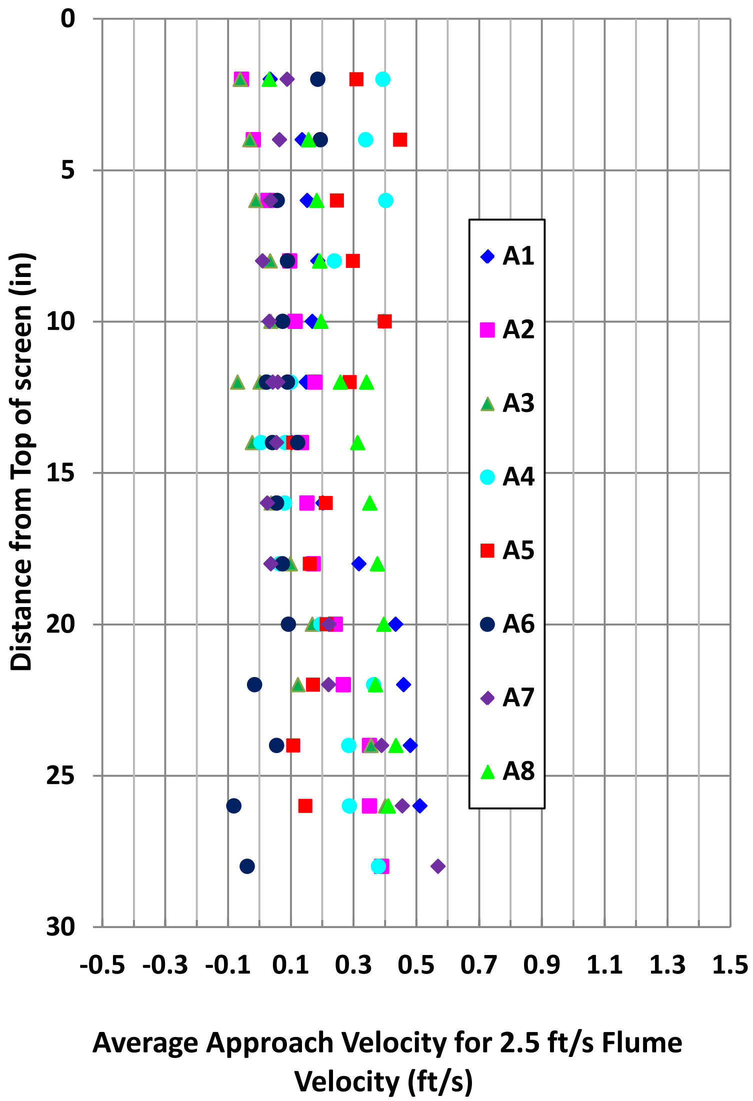

Figure 8. Bullnose Concept 1 - Cone screen approach velocity profiles measured at locations A1 through A8.

Bullnose Concept 2

The next step was to see if approach velocities around the surface of the screen could be further improved in uniformity, while providing better flow conditions within the structure. To accomplish this, two additional open slots were added to the bullnose structure as shown in figure 9. Once this arrangement was installed, flow was again set to provide a 2.5 ft/s average flume channel velocity adjacent to the screen centerline and parallel to the flume sidewalls. The flow depth remained set to 28 inches (figure 10).

Approach velocity profiles measured at locations A1 through A8 are shown in figure 11 for the Concept 2 configuration. Velocity profiles are improved over Concept 1 with a tighter grouping and thus lower values for approach velocities. The approach velocities measured for bullnose concept 2 are never greater than 0.5 ft/s and most values are below 0.4 ft/s.

Some debris injected into the flow 4 ft upstream from the screen was captured within the bullnose structure. However, when debris was recirculated within the structure, sweeping flow around the circumference of the screen kept debris predominantly away from the screen surface. Occasionally when debris was pulled onto the screen surface it was swept off again within a few seconds.

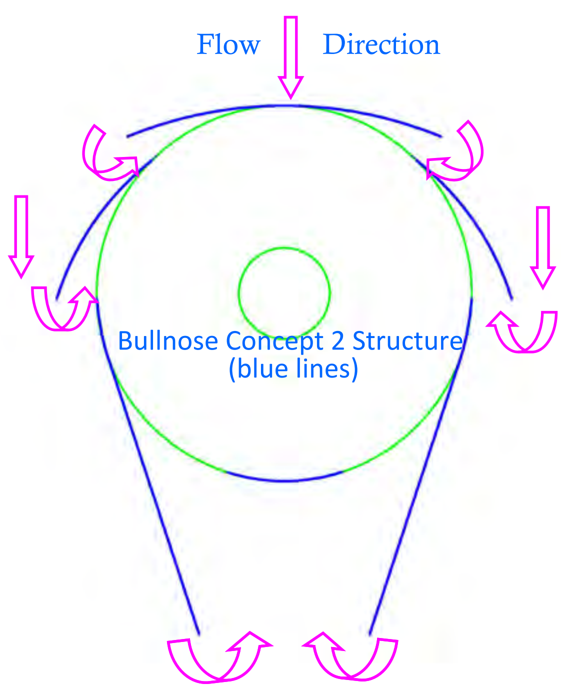

Figure 9. Illustration of Bullnose Concept 2. Blue lines indicate bullnose structure.

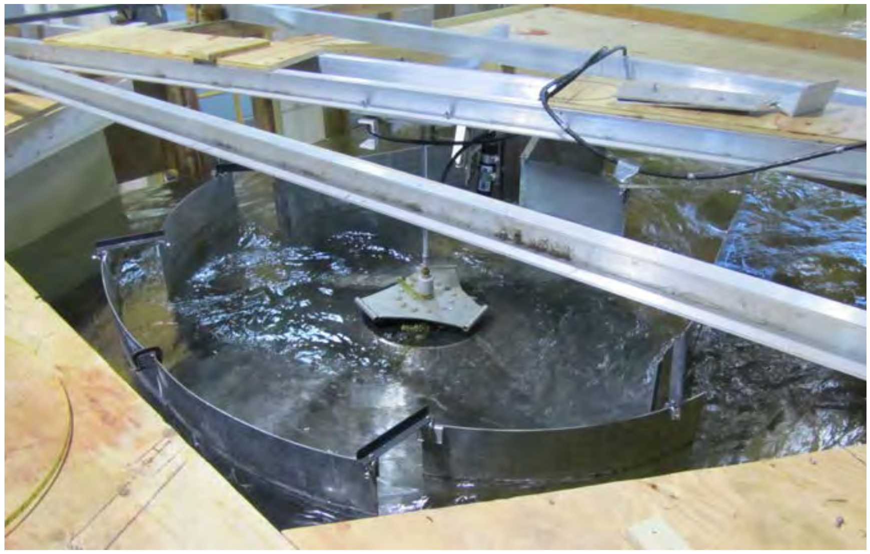

Figure 10. Photo of cone screen operating with Bullnose Concept 2.

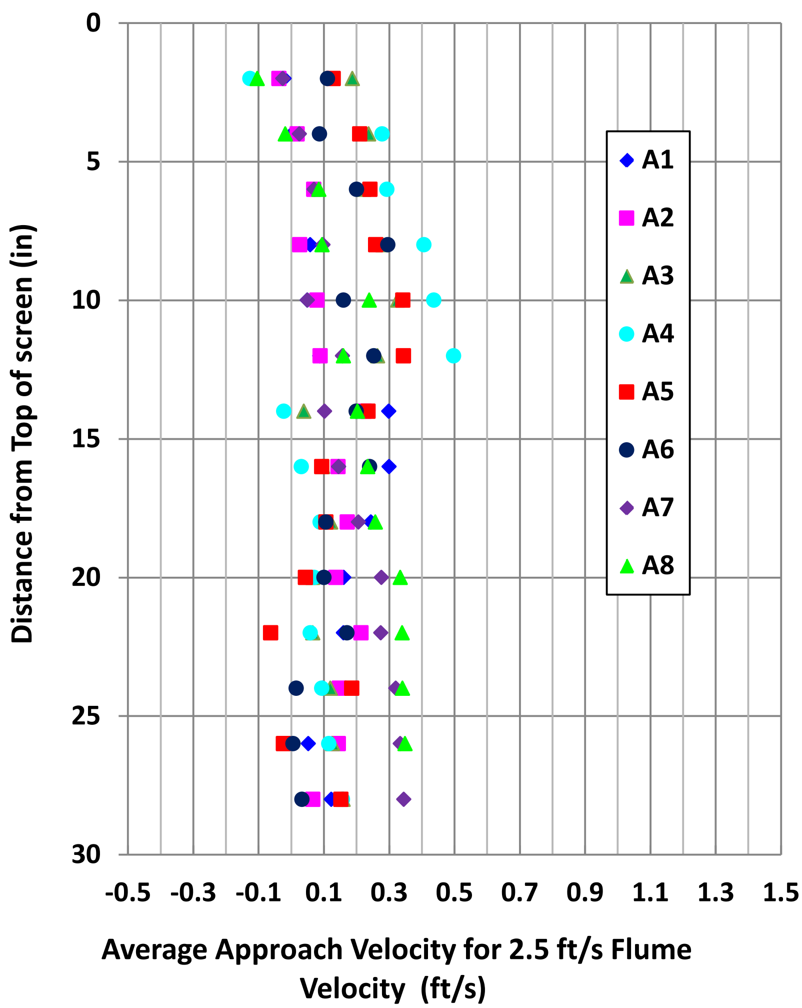

Figure 11. Bullnose Concept 2 - Cone Screen approach velocity profiles measured at locations A1 through A8.

Bullnose Concept 3

A third concept was tested to see if the sweeping flow across the screen surface could be increased to further improve uniformity of approach velocities. This time the slots in the bullnose configuration were designed to create a bias that would produce a stronger sweeping flow in one direction around the circumference of the screen surface. The configuration for bullnose concept 3 is shown in figure 12. Once again flow conditions were set up as they had been previously for testing concepts 1 and 2. The approach velocities measured for bullnose Concept 3 are shown in figure 13. Approach velocities for this concept are much more scattered than with the previous concepts due to the additional swirling action produced when inflow from the added slots intersects one another within the boundary of the bullnose structure. Therefore screen performance was worse with respect to uniformity of approach velocities.

Debris injected into the flow 4 ft upstream from the screen was captured within the bullnose structure. Some debris would cling to the screen and then be swept off periodically. However, all debris remained within the bull nose structure and remained there for longer than 30 minutes after screen operation was closed off.

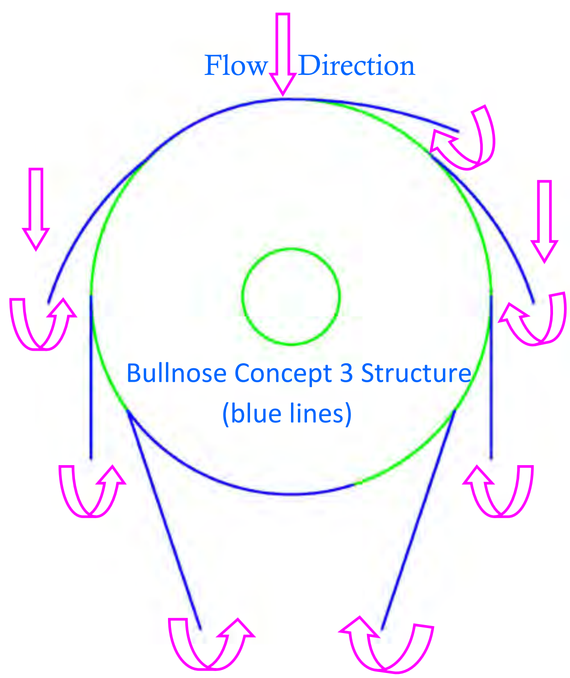

Figure 12. Illustration of Bullnose Concept 3. Blue lines indicate bullnose structure.

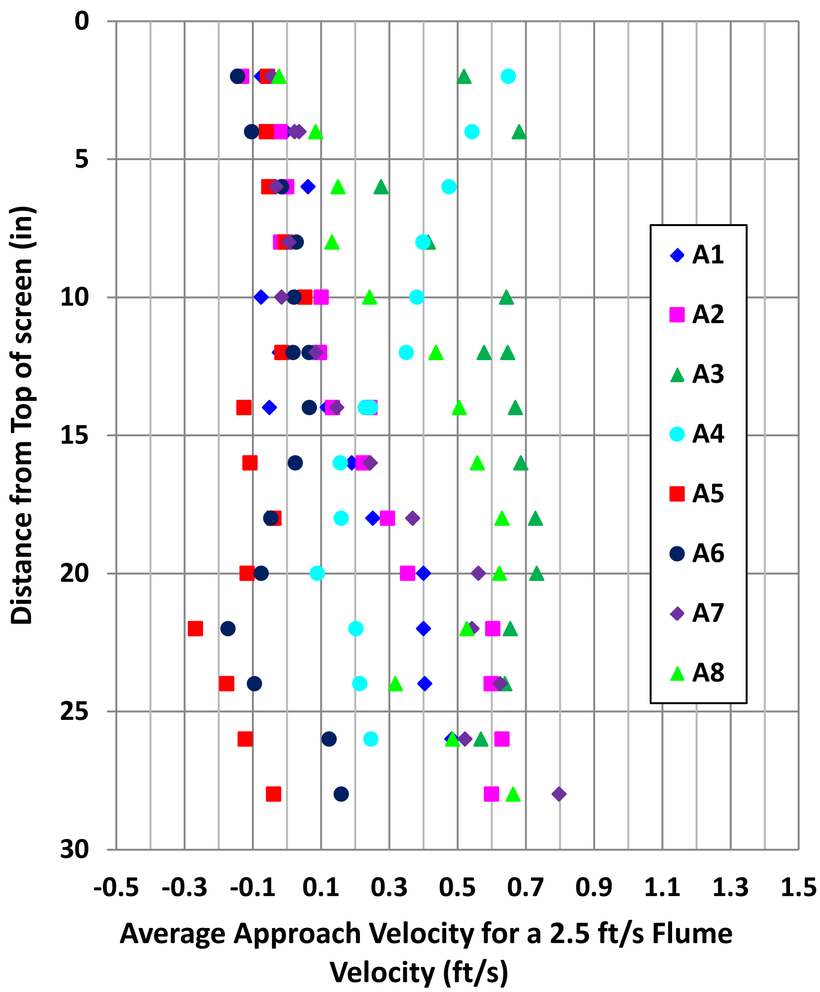

Figure 13. Bullnose Concept 3 - Cone Screen approach velocity profiles measured at locations A1 through A8.

High velocity and Flushing - Bullnose Concept 2

Since concept 2 had produced the best performance, the bullnose structure was reconfigured back into concept 2 and tested with the flume flow velocity increased to 4 ft/s, while keeping the flow depth set to 28 inches, to see if screen performance would still be acceptable. Figure 14 shows screen approach velocities measured with a flume velocity of 4 ft/s. The figure shows that performance is still good with most approach velocities falling below 0.5 ft/s. Debris was injected into the flow and once again sweeping flow produced around the circumference of the screen kept the screen predominantly free from debris.

Finally in an effort to remove debris from within the bullnose structure and move it downstream into the main channel without having to physically remove it, flow through the screen was shut down temporarily. This test demonstrated that debris works its way out of the bullnose structure and into the main channel flow within about 5 to 10 minutes of the screen flow being shut down, with an average flume velocity of 4 ft/s. Therefore if debris should accumulate within the bull nose structure it may be possible to flush it out, from within the structure, by periodically shutting down screen flow. This test was repeated for concept 2 with the flume channel flow set to 2.5 ft/s. Again debris was flushed from within the structure into the main flow, this time within about 20 minutes. These conditions could change when the screen brushes are installed and operational.

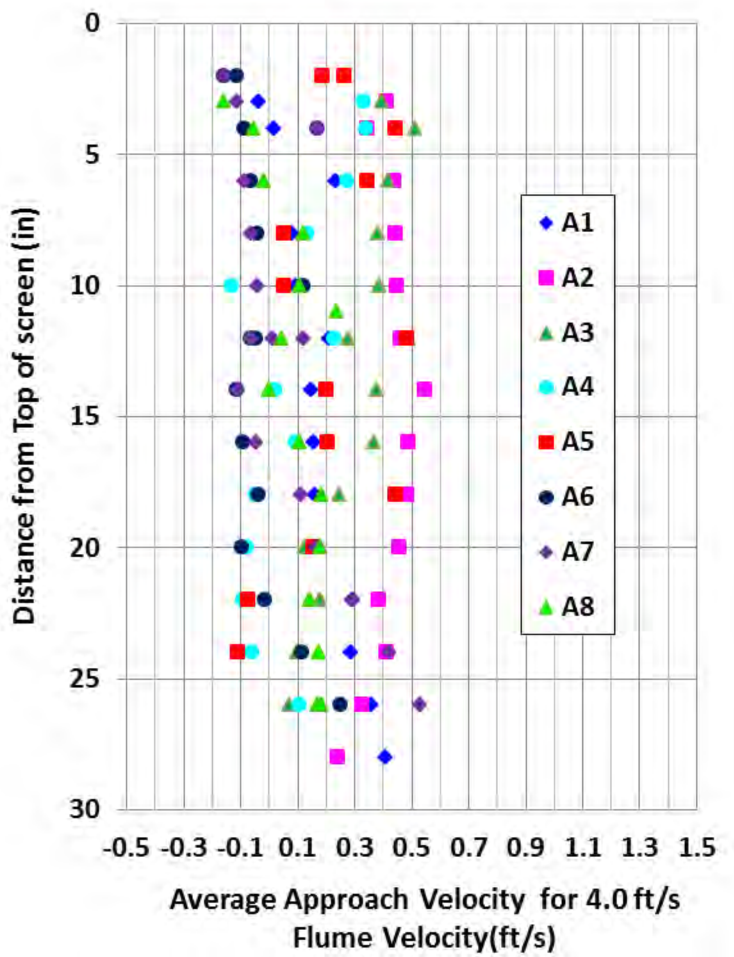

Figure 14. Bullnose Concept 2 and 4 ft/s flume velocity - Cone Screen approach velocity profiles measured at locations A1 through A8.

Conclusions

All three bullnose concepts provided a significant improvement in the performance of the ISI cone screen with comparison to the baseline condition without a baffle. Bullnose Concept 2 provided the best performance and continued to provide good performance when flume velocity was increased to 4 ft/s. In addition performance for this design at a flume velocity of 2.5 ft/s was improved over the best internal baffle design tested during previous investigations with a flume velocity of 2.0 ft/s [1] (figure 15). Screen approach velocity for Bullnose Concept 2 for both flume flow conditions remained less than 0.6 ft/s with most values falling below 0.5 ft/s even for the high velocity flume condition. Details for the final design of Bullnose concept 2 are provided in figure 16.

Although some debris was captured within the bullnose structure it is important to note that some of the debris that is captured within the structure may be due to the fact that the flume walls are in close proximity to the structure (about 2 ft between flume walls and screen circumference), so this may over accentuate the exposure of the structure to debris that might otherwise be carried away from the structure in a natural riverine environment. When the screen inflow was shut down, debris within the bullnose structure works its way out into the main channel flume flow and is eventually carried downstream.

The screen was tested without the brush attachments, so it is also important to note that the effect of reinstalling the brush arms will reduce the effective area of the screen and may also reduce the effectiveness of screen sweeping flows in keeping the screen surface free from debris . Since the brush arms are not stationary and rotate around the circumference of the screen, designing the baffle to compensate for this effect was not practical. However with bullnose concept 2 installed, there is a strong sweeping component, compared with approach velocities around the circumference of the screen, so minimal debris is expected to accumulate on the screen surface. With this in mind, it may be reasonable to consider either eliminating the brushes altogether, or use just one or two brushes and reduce the number or frequency of rotation cycles for cleaning.

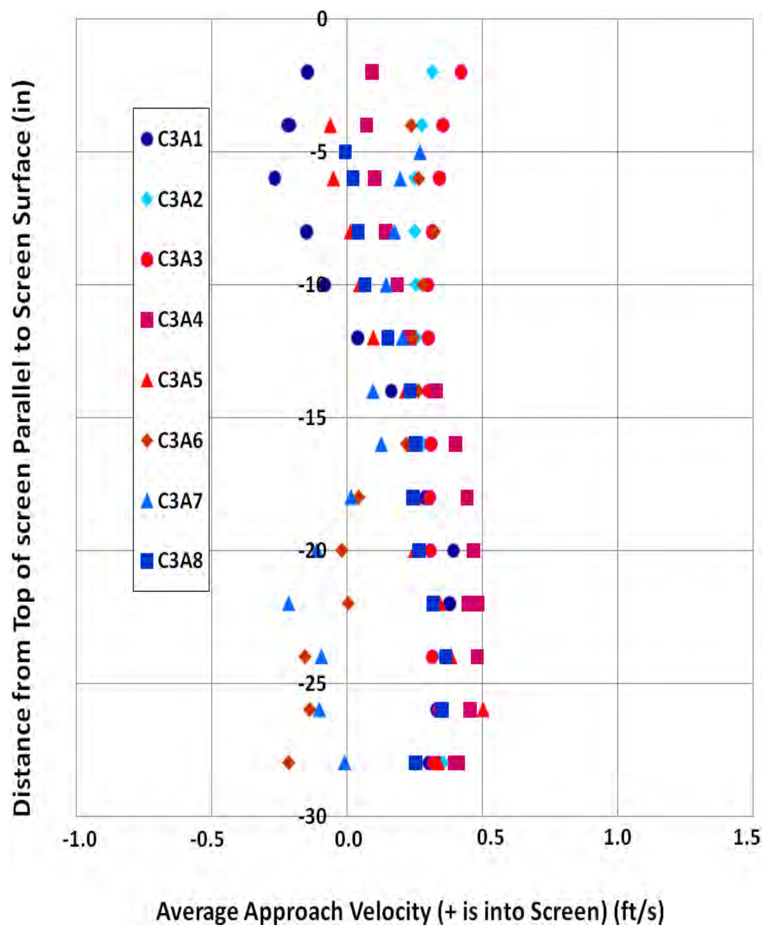

Figure 15 Internal Baffle Concept 3 with 2 ft/s flume velocity - Cone screen approach velocity profiles measured at locations A1 through A8.

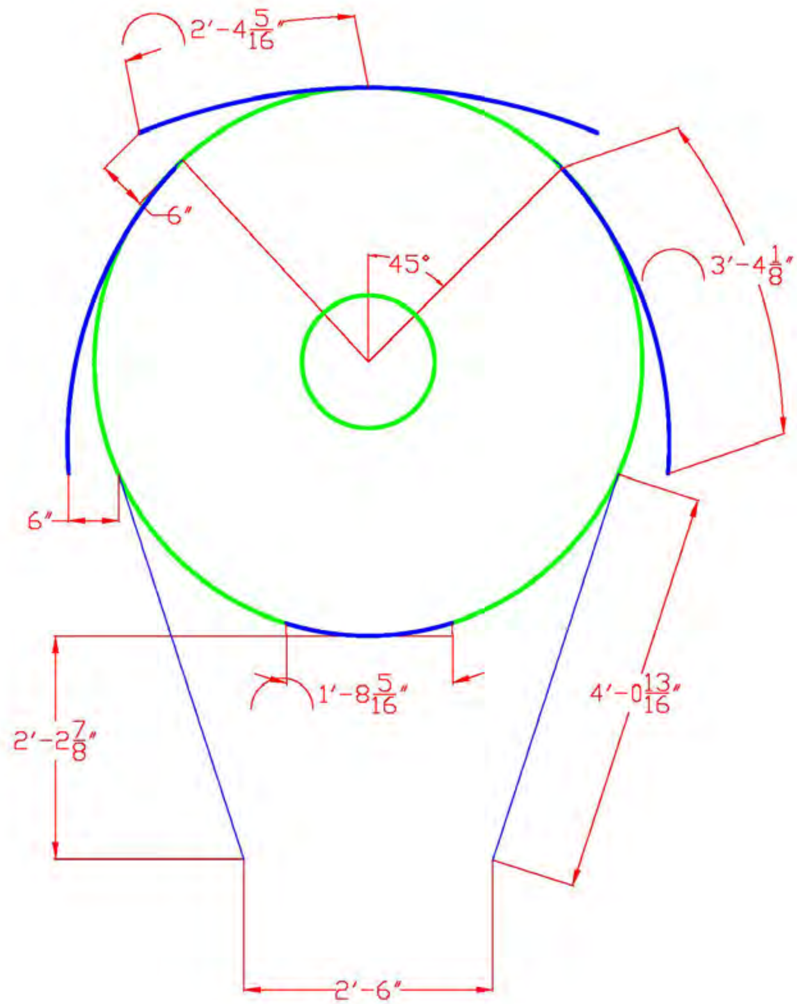

Figure 16. Details for final external bullnose Concept 2.

References

1. Hanna, Leslie "ISI Cone Screen Performance in a Riverine Environment", Hydraulic Laboratory Report PAP-1037, Bureau of Reclamation, Denver ,Colorado, October 2010.