Quarterly Progress Report

Jan. 1, 2012 to Mar. 31, 2012

In the previous quarters, Particle Image Velocimetry (PIV) and Acoustic Doppler Velocimetry (ADV) were used in all three phases in accordance with the test matrix. Meanwhile, additional validations were made to the instruments whenever minor issues were spotted to refine the data. While most improvement can be implemented by proper processing of the data, it was found that significant enhancement in resolution could be offered to some tests in the first phase if they can be repeated. In the original setting, the water prisms manufactured to reduce radial distortions were limiting the field of view. The carriage on which cameras and water prisms were sitting was blocking near wall view. As a result, the velocimetry results were not covering the whole area of the interest. To address the issue, new water prisms were redesigned and fabricated. The carriage was extended allowing user to capture a larger field of view as well as increasing the sharpness of the particles in the images. This reduced the errors originated from out of focus particles. Consequently, most vector errors (outliers) diminished.

This series of tests used a quarter of the pipe without sediment bed. The test matrix with this pipe included 3 different flow depths and 2 different velocities. PIV and ADV measurements were obtained and plotted in the following sections. The data were also interpolated to produce a uniformly gridded data format to be compared with CFD results.

1st CMP Section Velocimetry Results (quarter-pipe without sediment bed):

Below are the test results for the 1st CMP section. Note that, the test was conducted with both ADV and PIV.

1st Case Scenario Low Velocity (4.5” flow depth and 0.71’/s velocity):

The hydraulic properties of the 1st case study low velocity are presented in Table 1.

Table 1 1st case study low velocity

Bed El. [in]	Water Level [in]	Average Velocity [ft/sec]	Wetted Area [in^2]	Discharge [in^3/sec]
0	4.5	0.71	36.99	315.18

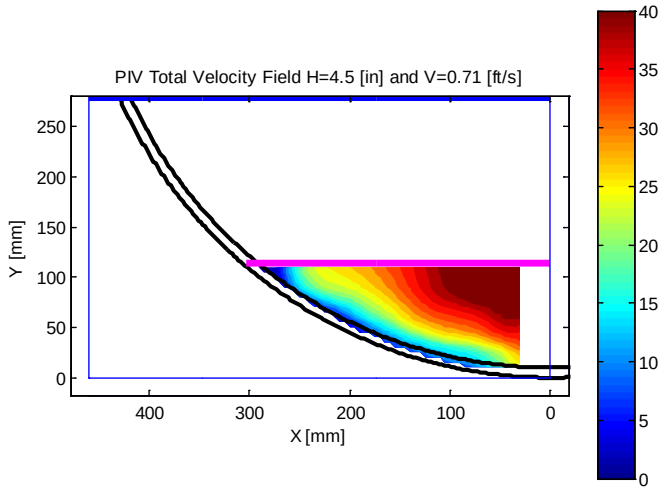

Figure 1 PIV results for the 1st CMP section with water height=4.5 [in] and average velocity= 0.71 [ft/s]

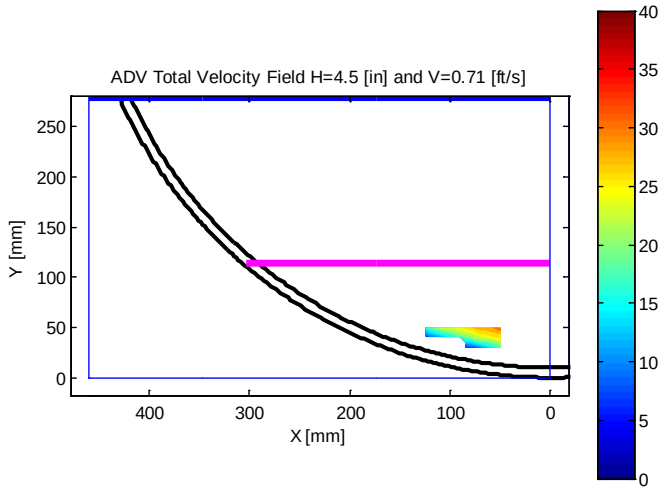

Figure 2 ADV results for the 1st CMP section with water height=4.5 [in] and average velocity= 0.71 [ft/s]

1st Case Scenario High Velocity (4.5" flow depth and 1.1'/s velocity):

The hydraulic properties of the 1st case study high velocity are presented in Table 2.

Table 2 1st case study high velocity

Bed El. [in]	Water Level [in]	Average Velocity [ft/sec]	Wetted Area [in^2]	Discharge [in^3/sec]
0	**4.5**	**1.10**	**36.99**	**488.31**

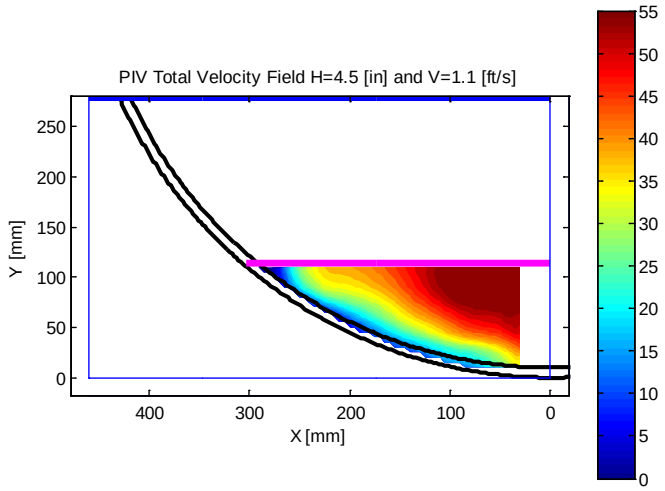

Figure 3 PIV results for the 1st CMP section with water height=4.5 [in] and average velocity= 1.10 [ft/s]

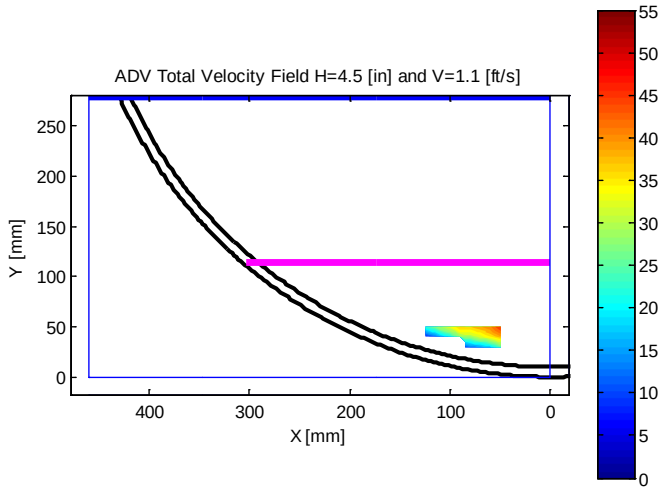

Figure 4 ADV results for the 1st CMP section with water height=4.5 [in] and average velocity= 1.10 [ft/s]

2nd Case Scenario Low Velocity (6" flow depth and 0.71'/s velocity):

The hydraulic properties of the 2nd case study low velocity are presented in Table 3.

Table 3 2nd case study low velocity

Bed El. [in]	Water Level [in]	Average Velocity [ft/sec]	Wetted Area [in^2]	Discharge [in^3/sec]
0	6	0.71	56.18	478.69

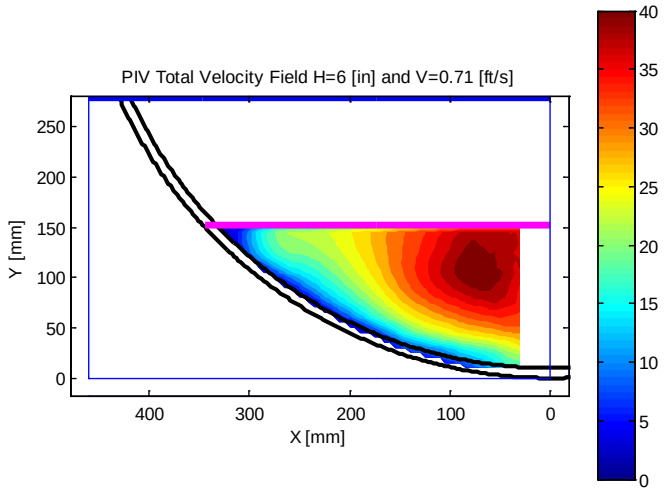

Figure 5 PIV results for the 1st CMP section with water height=6 [in] and average velocity= 0.71 [ft/s]

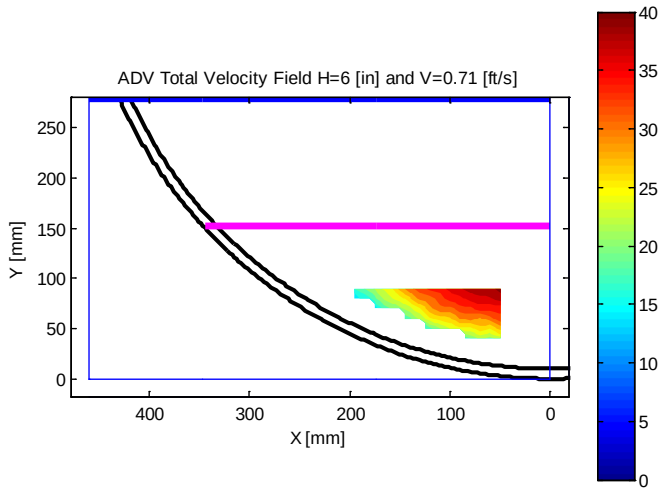

Figure 6 ADV results for the 1st CMP section with water height=6 [in] and average velocity= 0.71 [ft/s]

2nd Case Scenario High Velocity (6" flow depth and 1.1'/s velocity):

The hydraulic properties of the 2nd case study low velocity are presented in Table 4.

Table 4 2nd case study high velocity

Bed El. [in]	Water Level [in]	Average Velocity [ft/sec]	Wetted Area [in^2]	Discharge [in^3/sec]
0	6	1.10	56.18	741.63

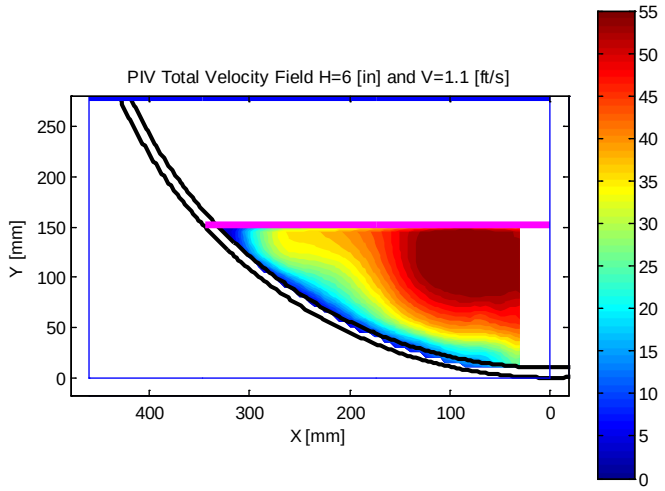

Figure 7 PIV results for the 1st CMP section with water height=6 [in] and average velocity= 1.10 [ft/s]

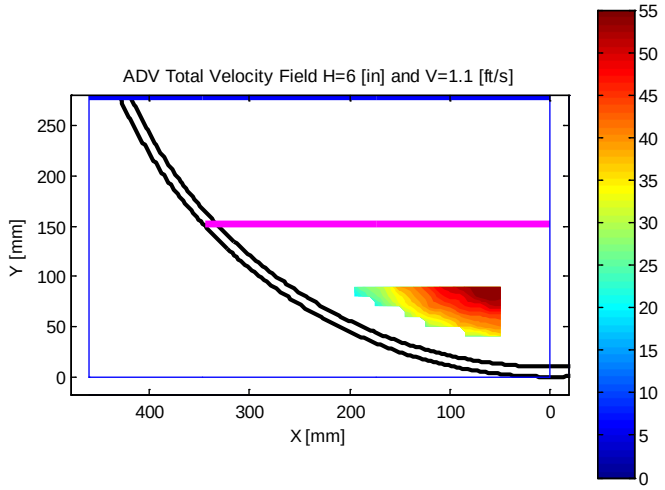

Figure 8 ADV results for the 1st CMP section with water height=6 [in] and average velocity= 1.10 [ft/s]

3rd Case Scenario Low Velocity (9" flow depth and 0.71'/s velocity):

The hydraulic properties of the 3rd case study low velocity are presented in Table 5.

Table 5 3rd case study low velocity

Bed El. [in]	Water Level [in]	Average Velocity [ft/sec]	Wetted Area [in^2]	Discharge [in^3/sec]
0	9	0.71	100.31	854.64

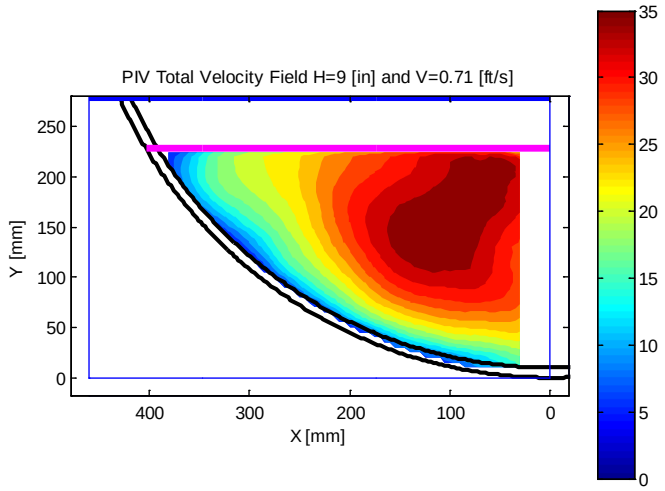

Figure 9 PIV results for the 1st CMP section with water height=9 [in] and average velocity= 0.71 [ft/s]

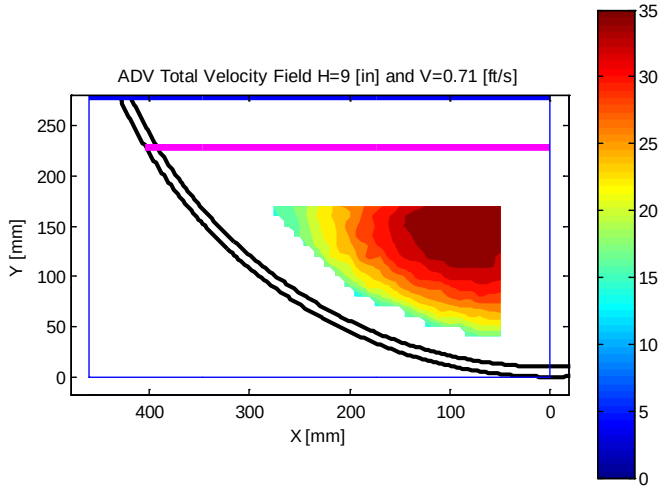

Figure 10 ADV results for the 1st CMP section with water height=9 [in] and average velocity= 1.10 [ft/s]

3rd Case Scenario High Velocity (9" flow depth and 1.1'/s velocity):

The hydraulic properties of the 3rd case study high velocity are presented in Table 6.

Table 6 3rd case study high velocity

Bed El. [in]	Water Level [in]	Average Velocity [ft/sec]	Wetted Area [in^2]	Discharge [in^3/sec]
0	9	1.10	100.31	1324.09

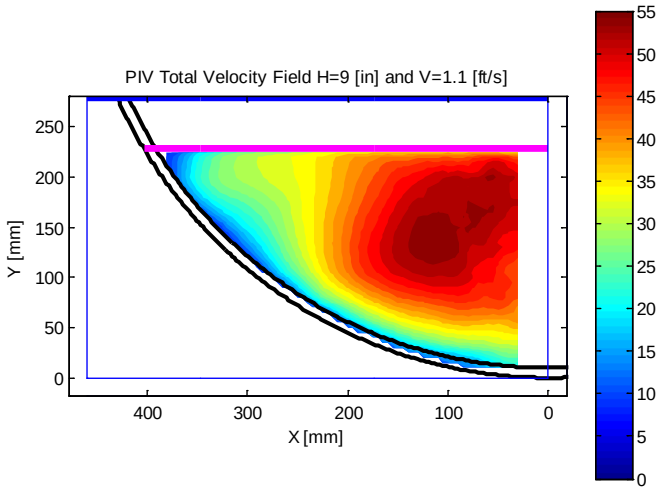

Figure 11 PIV results for the 1st CMP section with water height=9 [in] and average velocity= 1.10 [ft/s]

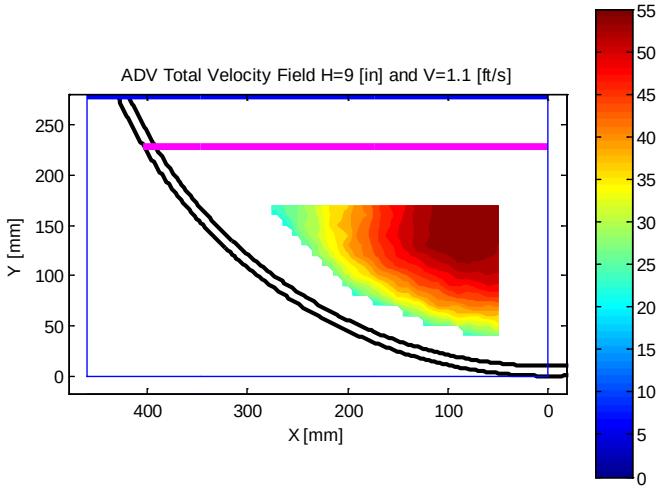

Figure 12 ADV results for the 1st CMP section with water height=9 [in] and average velocity= 1.10 [ft/s]

Discussion:

In this part, the results from the physical tests are compared with the results from CFD simulation. Since the ADV probe cannot measure reliably within a relatively large area near the walls, , the comparison is primarily made between PIV and CFD results. However, ADV data in the area where the probe provides good reading is an important cross-reference for PIV data.

Two statistical concepts so called root mean square error and the standard error are introduced.

Root Mean Square Error (RMSE):

RMSE is a statistical concept mostly used in measuring differences between data and an estimator. In this study, the physical test (PIV and ADV) can be used as data and the CFD data can be used as an estimator.

$$RMSE = \sqrt{\frac{(V_{PIV} - V_{CFD})^2}{n}} \qquad (1)$$

Normalized Root Mean Square Error (NRMSE) or Standard Error:

RMSE is an index of how well the model prediction fits the real world phenomenon. The drawback for RMSE is being dependent on the dimension because it has a length scale. In order to have RMSE in a dimensionless form it is normalized with the largest range of difference. This can be considered a standard error.

$$NRMSE = \frac{RMSE}{V_{max} - V_{min}} \qquad (2)$$

The comparison was made in two modes. The first mode is the comparison between the vertical profiles of PIV and CFD values. The average velocity and normalized RMSE values are given on the plotting. (see Figures 13-18). The NRMSE values range from 12% to 17%.

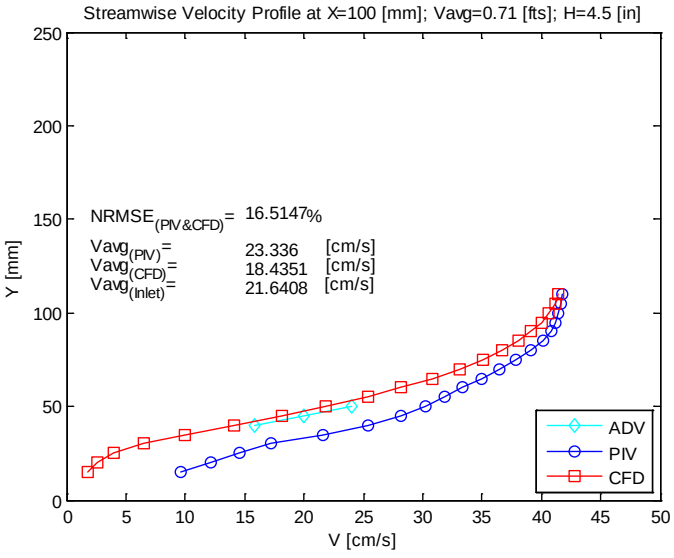

Figure 13 CFD, PIV and ADV comparison for the 1st CMP section water height=4.5 [in] and average velocity= 0.71 [ft/s]

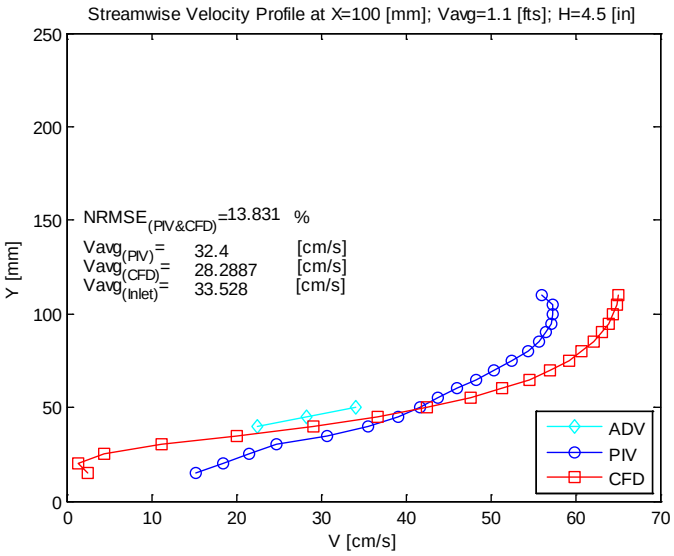

Figure 14 CFD, PIV and ADV comparison for the 1st CMP section water height=4.5 [in] and average velocity= 1.10 [ft/s]

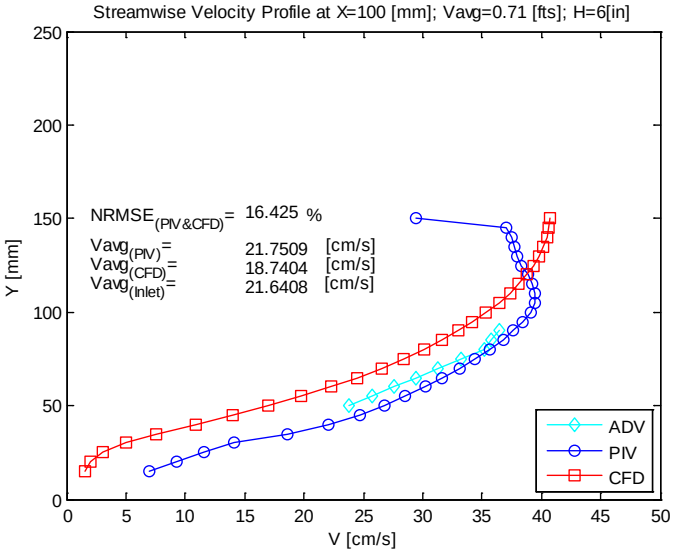

Figure 15 CFD, PIV and ADV comparison for the 1st CMP section water height=6 [in] and average velocity= 0.71 [ft/s]

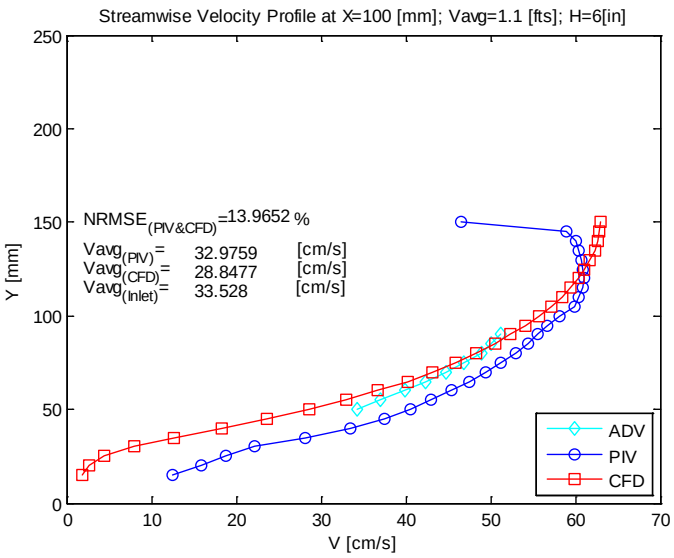

Figure 16 CFD, PIV and ADV comparison for the 1st CMP section water height=6 [in] and average velocity= 1.10 [ft/s]

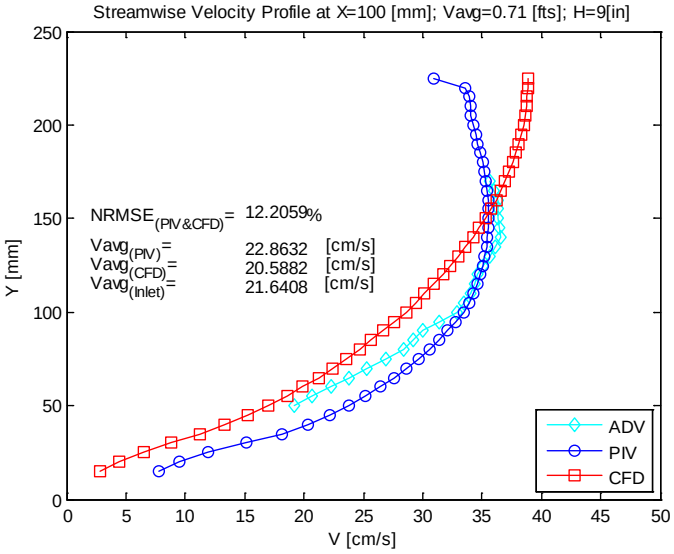

Figure 17 CFD, PIV and ADV comparison for the 1st CMP section water height=9 [in] and average velocity= 0.71 [ft/s]

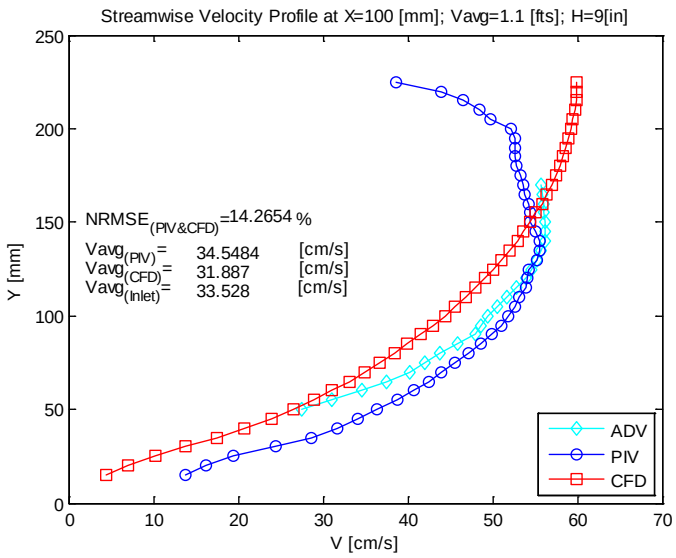

Figure 18 CFD, PIV and ADV comparison for the 1st CMP section water height=9 [in] and average velocity= 1.10 [ft/s]

The NRMSE was assessed for a measuring station at Y=100 [mm] (see Figure 19). The maximum error is less than 15%.

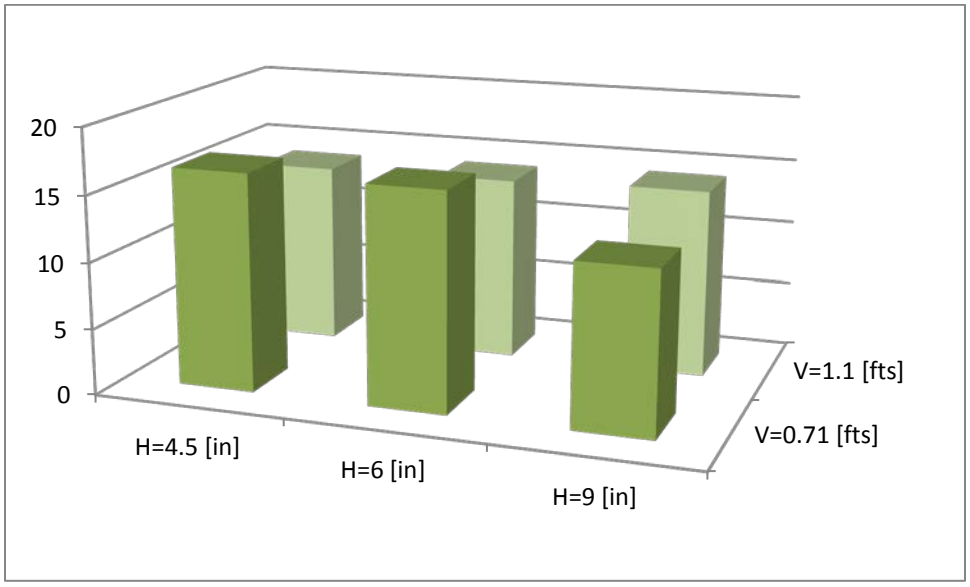

Figure 19 RMSE between PIV and CFD for the 1st CMP section in spanwise mode

The second mode is the comparison between horizontal profiles of PIV and CFD values. in streamwise velocity distribution (see Figures 20-25). The average velocity and normalized RMSE values are given on the plotting. (see Figures 13-18). The NRMSE values range from 6% to 18%.

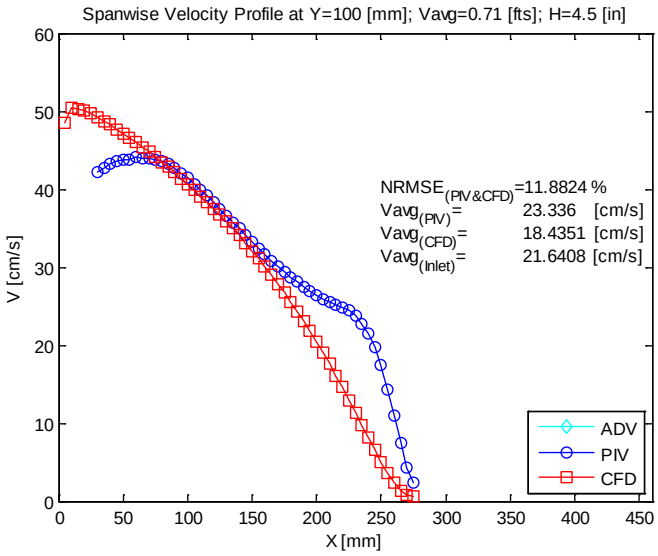

Figure 20 CFD, PIV and ADV comparison for the 1st CMP section water height=4.5 [in] and average velocity= 0.71 [ft/s]

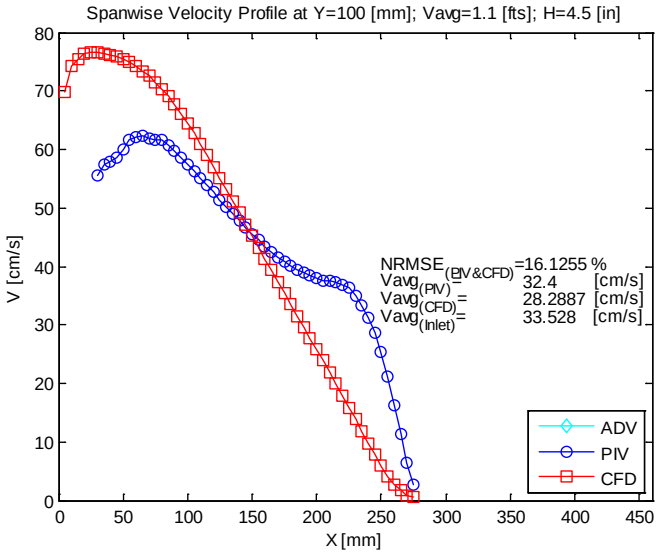

Figure 21 CFD, PIV and ADV comparison for the 1st CMP section water height=4.5 [in] and average velocity= 1.10 [ft/s]

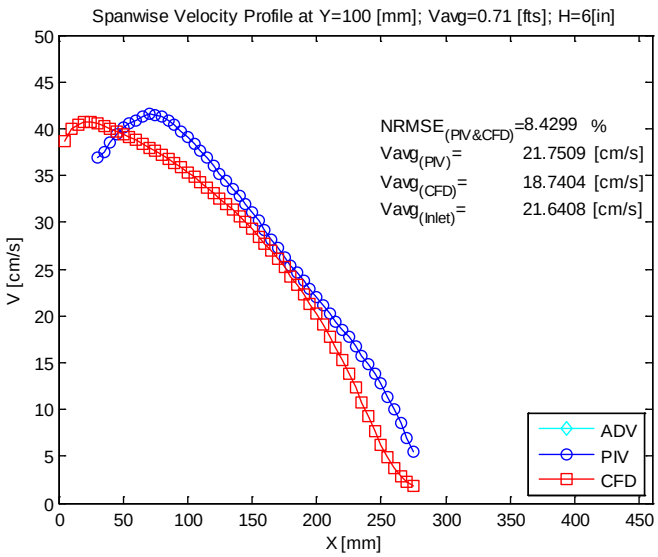

Figure 22 CFD, PIV and ADV comparison for the 1st CMP section water height=6 [in] and average velocity= 0.71 [ft/s]

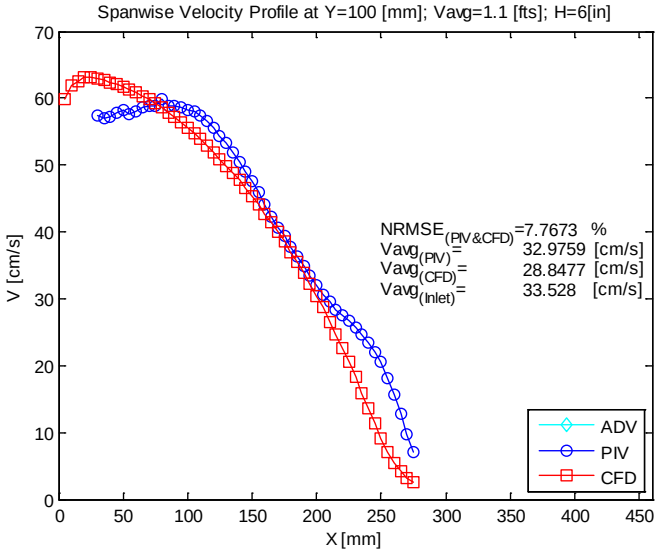

Figure 23 CFD, PIV and ADV comparison for the 1st CMP section water height=6 [in] and average velocity= 1.10 [ft/s]

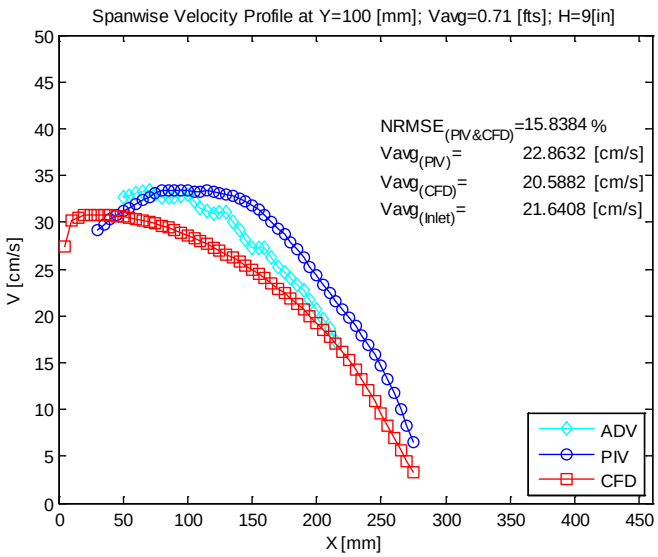

Figure 24 CFD, PIV and ADV comparison for the 1st CMP section water height=9 [in] and average velocity= 0.71 [ft/s]

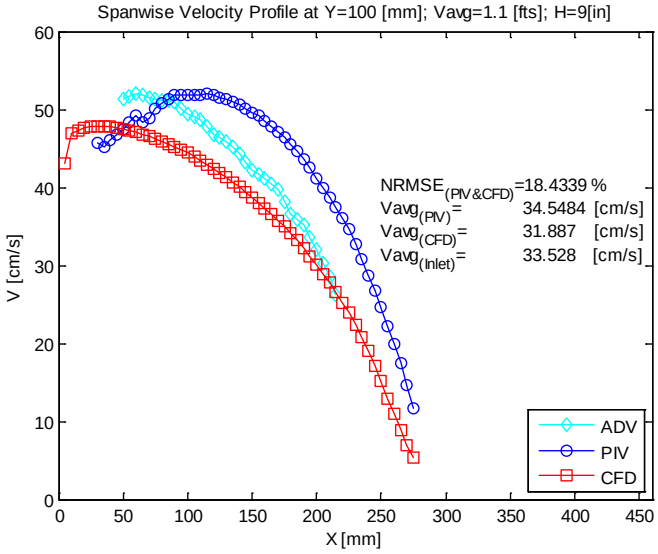

Figure 25 CFD, PIV and ADV comparison for the 1st CMP section water height=9 [in] and average velocity= 1.10 [ft/s]

The NRMSE was assessed for a measuring station at X=100 [mm] (see Figure 26). In this case, the maximum error is around 15%.

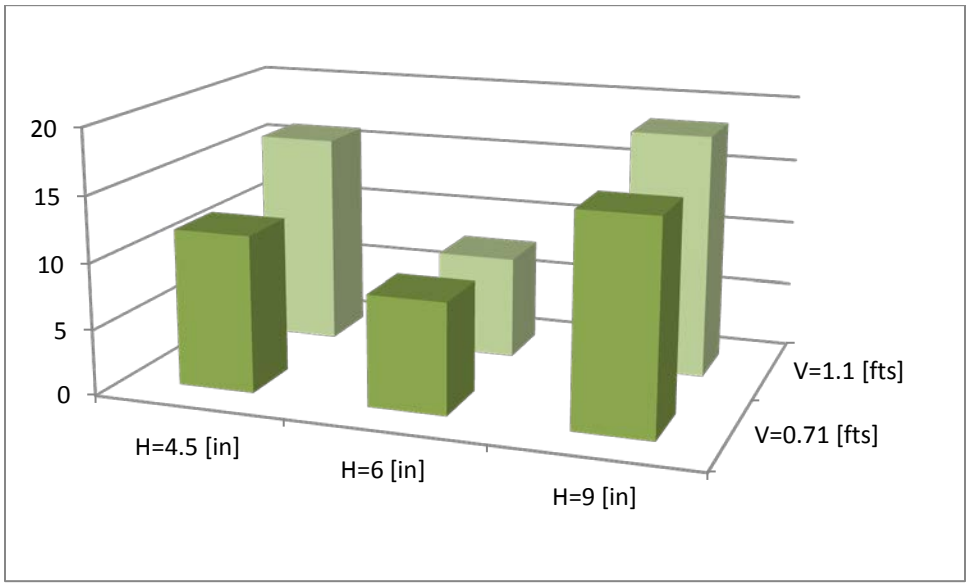

Figure 26 NRMSE between PIV and CFD for 1st CMP streamwise mode

Time Schedule Progress:

Table 7 shows the progress and the planned schedule of the project. In this quarter period, physical testing is complete. CFD modeling is extending the test results to prototype scale, which is in line with the original test proposal. The preliminary draft report is being composed.

Table 7 Time schedule and progress chart for the fish passage in large culverts with low flows

Task																		
Year	2010	2011											2012					
Month	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Construct Model Pipe	100%																	
Flume Tests according to Test Matrix		Progress												100%				
CFD Experiments according to Test Matrix		Progress														85%		
Data Analysis and Recommendations for Implementation		Progress														85%		
Preliminary Draft Report																		
Final Report																		