U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT

ANALYSIS OF OBSERVED WATER VELOCITIES BONNEVILLE DAM: UNIT 8 (FGE)

Final Report

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1 Introduction

This report summarizes the analysis of water velocity data gathered upstream of the First Powerhouse at the Bonneville Project. This data was gathered in support of concurrent biologic studies on migrating smolt behavior. The behavior of smolt in this region is an ongoing research topic, although it is plausible to assume that behavior may be strongly linked to the hydrodynamic flow field in this region.

Water velocity data analyzed in this report was gathered upstream of the Unit 8 intake. The instrument was placed on an automated moving traverse that crossed back-and-forth across the intake once each hour at a uniform speed.

Velocity data was gathered for several months during the spring and summer of 2000. From this large data set, a period of twenty days between June 8 (Julian Day 160) and June 28 (Julian Day 180) were selected for analysis. This period was selected because all instruments and the turbine unit were functioning consistently.

Section 2 discusses the methods used to gather this data, plus an overall analysis of flows through the intake unit during this period. Section 3 then presents a qualitative overview of the velocity data. Since the nature of the data is three-dimensional, a movie has been constructed that shows the velocity vectors from various perspective locations. Sections 4 though 6 discuss variations in velocity readings with depth, laterally, and with flow. These sections qualify the mean values, as well as providing a measure of the variability of the flow field. Finally, Section 7 presents conclusions and recommendations for future studies of velocity field near hydraulic structures. An appendix has also been included that displays the various components of the velocity field throughout the study period.

2 Methods

An acoustic Doppler current profiler (ADCP) was deployed in direct reading mode, with power being supplied from the surface and output data being recorded directly onto a personal computer. The unit operated at a frequency of 600kHz and the relative tilt of the transducer beams from vertical were 6-degrees. Typically transducer beams are tilted 20- or 30-degrees from the vertical, however by reducing the beam tilt this ADCP could be placed closer to hydraulic structures without the beams striking the trash rack and intake walls. The primary disadvantage of a reduced beam angle ADCP is that each single velocity reading (i.e., "ping") has a large theoretical standard deviation (61.6 cm/s with 0.5 m vertical bins). To reduce the standard deviation, numerous sequential readings are typically averaged together, and only these ensemble (i.e. time averaged) velocities are exported from the instrument. For the purposes of this study, a standard deviation of 3 cm/s was assumed acceptable, dictating 450 individual pings per ensemble velocity measurement. The ADCP was set to record the ensemble as quickly as possible, resulting in ensemble measurements being reported every 3-minutes. The speed of the horizontally moving traverse was set so that the ADCP would pass from the south to the north end of the intake and back in one hour; hence, the ADCP moved approximately 1.6 feet during the time to gather one reading. In addition, the approximate time between velocity readings at the center location was 30 minutes and once per hour at the north and south ends.

Five proximity sensors were placed along the traverse to record times and locations of the moving ADCP. Vertically, the ADCP was placed at elevation 58.2 ft, and the following horizontal conventions are followed in this report:

Table 1 Traverse location guide

Proximity sensor distance along the traverse	Reference location along intake face
0-inche	south end
44-inches	
90-inches	center
138-inches	
184-inches	north end

Data reported by the ADCP are in time series of three-dimensional velocity vectors over a range of water depths. Due to a programming error, the ADCP was set to measure only 15-meter meters from the unit, and as such readings are not available below this depth. The first measurement occurs at 0.88 m above the transducer head, and the last is just below the bottom-most tip of the ESBS.

The three-dimensional velocity vectors were decomposed into components and reported as follows: horizontal magnitude (H), horizontal direction (D), and vertical magnitude (W). A trigonometric sign convention was used throughout (see Figure 1 legend), and in the vertical, upwards was defined as positive. For each of the velocity components a standard deviation, σ, was calculated over the time period, resulting in six independent vector components. In addition to the velocity vectors, two additional degrees of freedom exist: turbine flow rate and traverse location. Note that the internal compass in the ADCP was disabled for these deployments because magnetic inference around the hydroelectric dam is unpredictable and may be transient depending upon turbine operation. In this mode, the ADCP uses the orientation of beam 3 as a directional reference. Unfortunately, the orientation of beam 3, relative to true north, was not recorded when the instrument was redeployed after an electrical failure. To orient velocity data relative to true north, it was assumed that on average flow into the intake would pass parallel to the intake centerline. Based upon this assumption and the velocity data records, beam 3 was placed 132-degrees west (ccw) of north, and all FGE data has been corrected to true north by this rotation in the horizontal plane. Figure 1 shows the orientation of the Powerhouse relative to true north (67-degrees) and the horizontal sign convention used in this report.

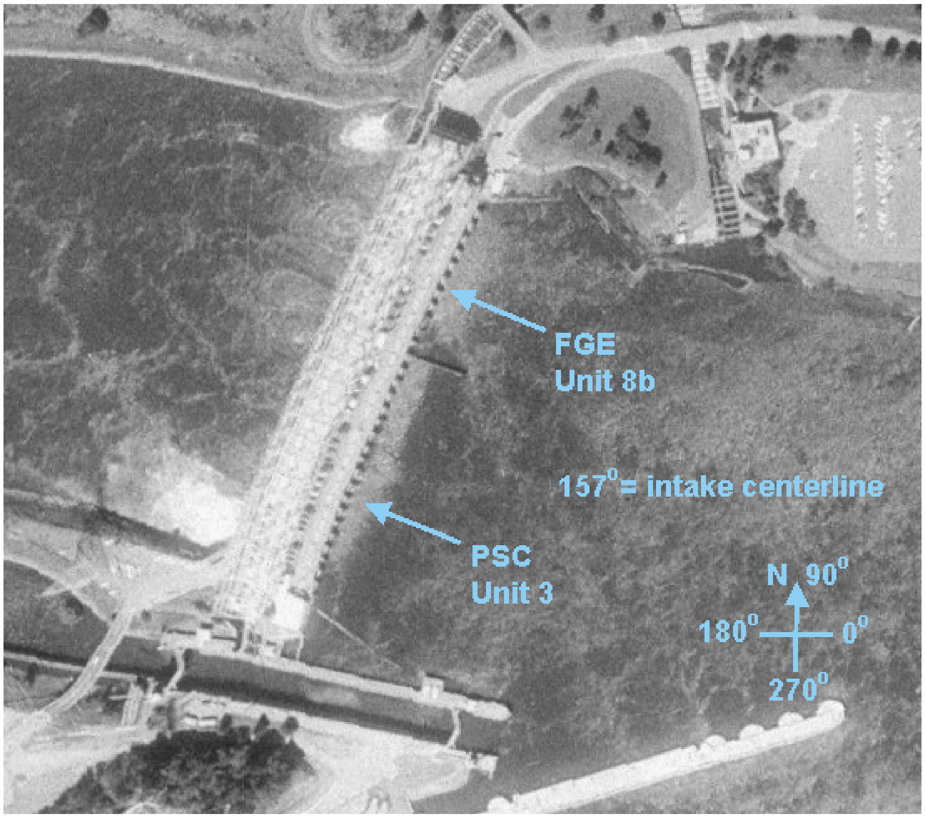


Figure 1 Bonneville 1st Powerhouse from space. Arrows show the orientation of the dam to true north. The centerline of the Unit 8b intake is at 157-degrees.

Figure 2 shows various views of the Unit 8, B-slot, turbine intake. The water surface (elevation 74.5 ft) has been shaded in blue and the details of the extended submersible bar screen (ESBS) have been approximated in this figure (color is for clarity only). The ADCP traverse super-structure was shaded white, and the ADCP beams, which emanate in a vertical swath of 15- to 27-degrees, have been colored in orange. The trash racks lie at an 11-degree pitch from the vertical, and the ADCP beams travel unobstructed to the bottom of the intake.

Unit 8 turbine operations were examined during the sampling period, and sorted by 1-kcfs bins (Figure 3). The operations dataset was further refined (Figure 4), and the predominant (non-zero) flows were found to range between 8.0 and 11.0 kcfs. Because of the size of the velocity data set, the flow range was grouped into six flow bins of 0.5 kcfs each, and Table 2 lists the number of ADCP velocity measurements per flow bin and proximity sensor.

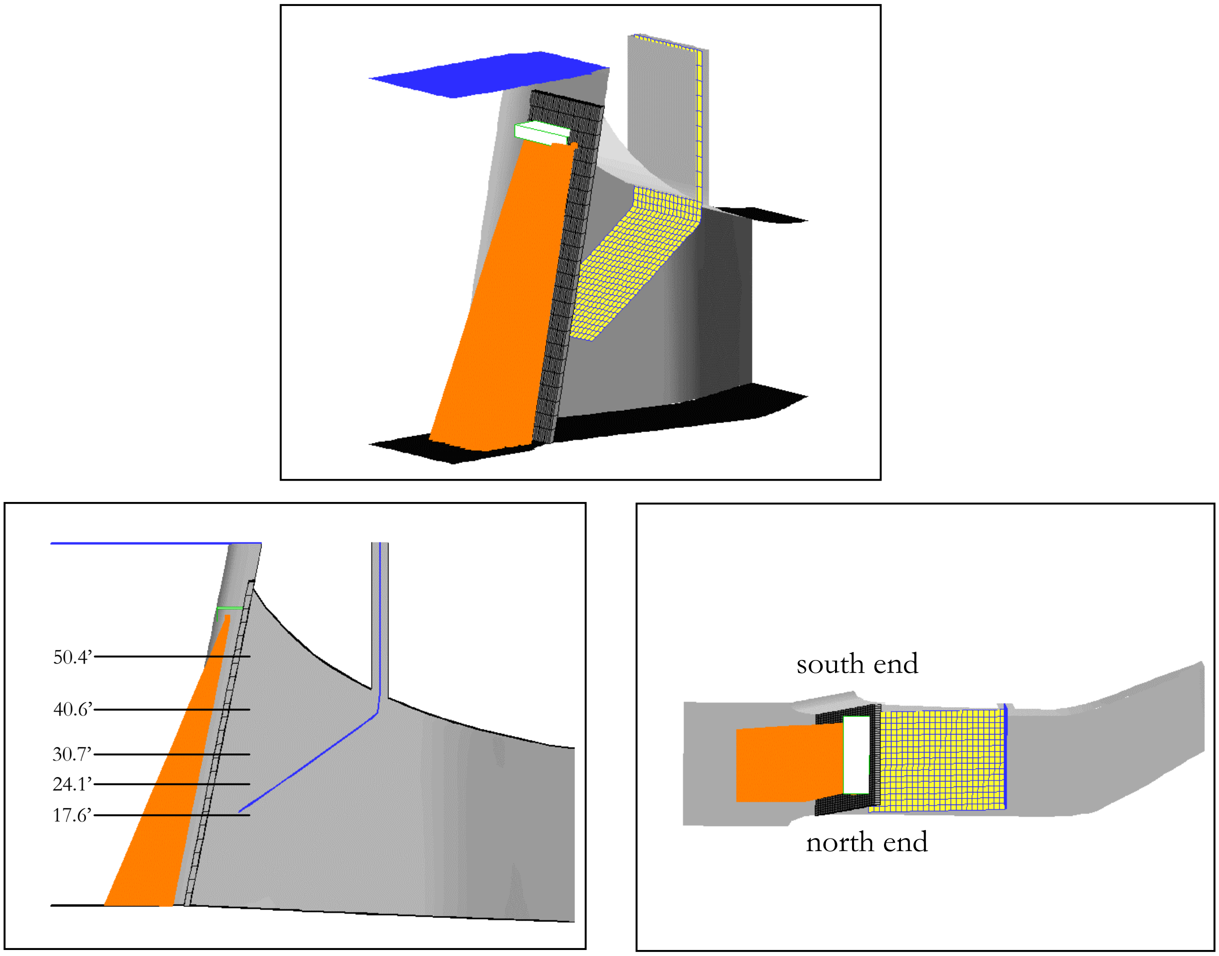


Figure 2 Three views of the FGE intake. ADCP beams were shaded orange. Traverse unit super-structure was shaded white, and the ESBS mesh shaded in yellow with a blue mesh. Water surface elevation was placed at 74.5 ft, and was shaded blue

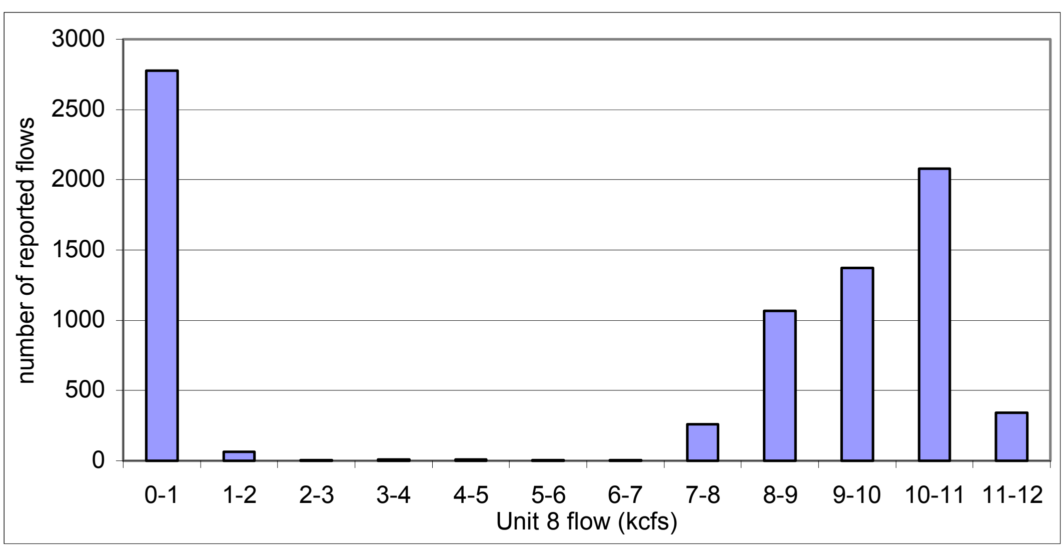


Figure 3 Reported Unit 8 flows between June 6 and July 16, 2000

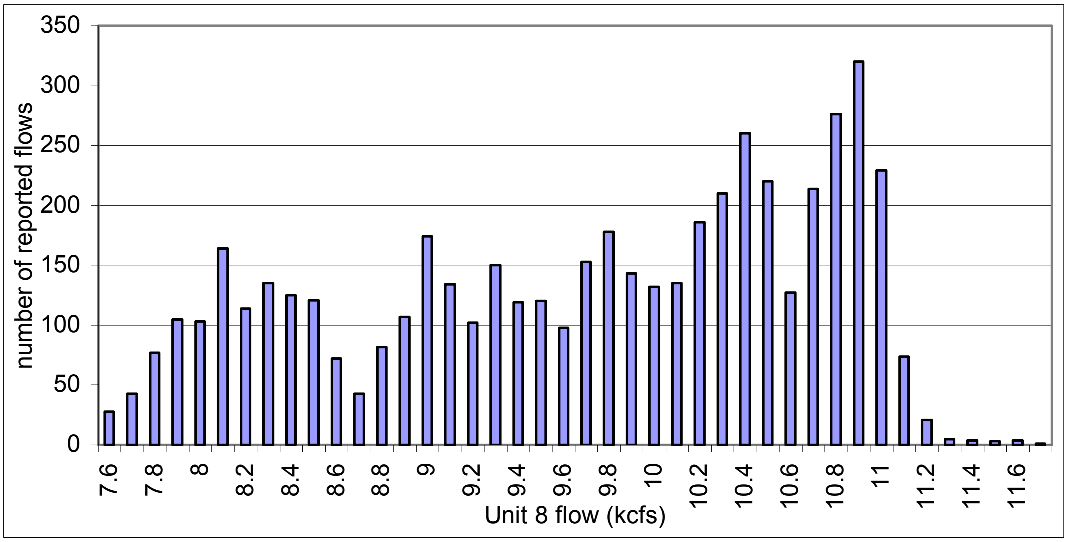


Figure 4 Reported Unit 8 flows between June 6 and July 16, 2000: Close up of 7.5 to 11.5 kcfs ranges

Table 2 Number of velocity measurements per proximity sensor and flow range.

	8 to 8.5 kcfs	8.5 to 9 kcfs	9 to 9.5 kcfs	9.5 to 10 kcfs	10 to 10.5 kcfs	10.5 to 11 kcfs
0-inches	51	29	40	46	75	80
44-inches	109	58	75	93	136	164
90-inches	113	57	71	88	130	176
138-inches	106	56	72	87	134	182
190-inches	53	27	33	45	61	93

3 Observed ADCP Results

Velocity vectors were observed at 24 vertical bins and, as discussed above, the predominant non-zero flow range of observations was aggregated into 6 groups of 0.5 kcfs. The data set was then sorted by proximity sensor, resulting in a total of 720 discrete velocity vectors (24 depths x 6 flows x 5 proximity sensors). In addition, each of these three-dimensional velocity vectors is comprised of 6 components (3 magnitudes with 3 related standard deviations). In efforts to distill this information into a meaningful assembly, this section provides qualitative figures and movies to describe the velocity vector variation along the inlet at the mean operational flow (9.5 to 10 kcfs).

The center profile of velocity vectors shown in Figure 5 (and the associated movie) was compiled by time averaging the raw data shown in Figure 6. This section of the dataset is typical, and although magnitudes change with flow rate, the general pattern observed in the figures remains fairly consistent. A more detailed discussion of variations across the intake, with depth, and with flow changes can be found in the proceeding sections.

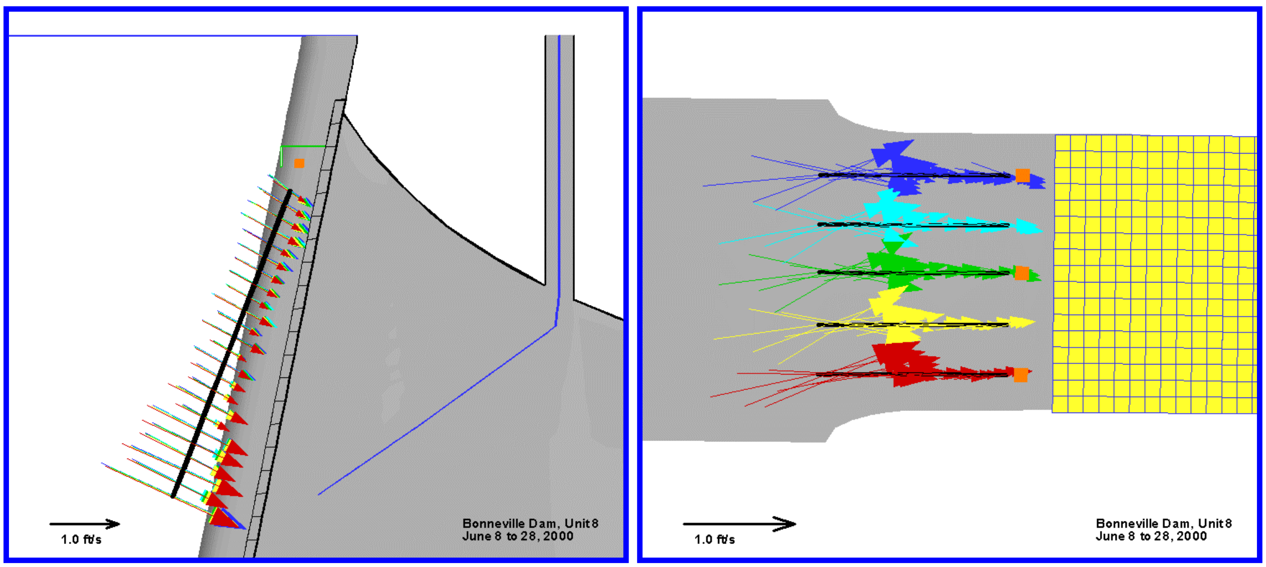


Figure 5 and Movie 1 Profiles of Velocity Vectors at the Mean Unit Flow (9.5 to 10 kcfs). Please click on the figure to view a hyperlinked movie of the velocity vectors (FGEmovie.avi).

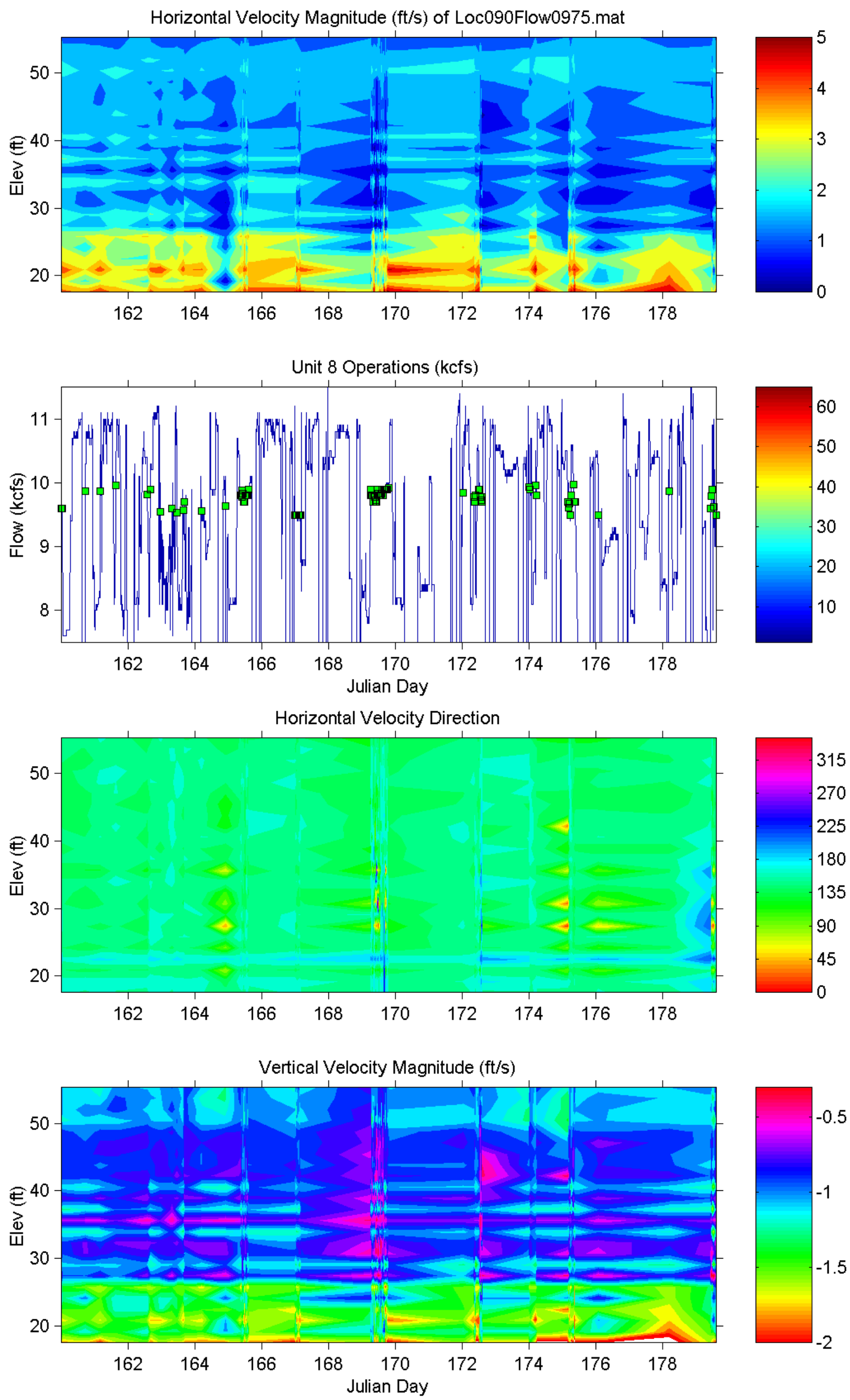


Figure 6 Velocity vector components from June 8 through June 28. All contour velocity components were observed at proximity sensor 90-inches and a turbine unit flow between 9.5 and 10 kcfs. Times of velocity measurements have been marked on the flow time series as green squares (Note: 88 observations exist for this combination of flow and location).

4 Variations with Depth

This section of the report discusses velocity variations along the centerline of the intake (i.e. at the 90-inche proximity sensor) and with flows between 9.5 and 10 kcfs. This flow range was selected because the average (non-zero) flow rate for the study was 9.65 kcfs. Variations of velocity with depth at other locations and flow rates can be observed in Appendix A.

The variation of the six vector components with depth has been displayed in both Table 3 and Figure 7. What is perhaps most noticeable is the rapid increase of both horizontal and vertical velocity magnitudes below elevation 26 ft (Note: for added clarity, all velocities below elevation 26 ft have been highlighted in red, and a vertical line has been added to the figures). Both components increase by 150% or more over this several foot zone. This increase is due to convergence of the flow as it approaches the ESBS, whose bottom most tip is at elevation 18 ft.

Above elevation 26 ft, a second zone of highly variable magnitude exits. This second zone extends upwards until approximately 43 ft. In this zone, magnitude standard deviations remain constant, while the magnitudes oscillate back and forth. Overall, however, the prevailing direction is towards the dam (as expected), and variations on the order of 30-degrees are not unusual. The oscillations in magnitude between 26 and 43 ft are larger than the standard deviations, and consistent oscillations in the flow pattern may exits. Perhaps numerical modeling can shed some light regarding these waves.

Above 43 ft all components smooth out considerably. Both magnitudes and direction remain consistent, while standard deviations decrease.

Table 3 Variations of Velocity Vector Components with Elevation. Note: water surface elevation of the tailrace was approximately 74.5 ft for the period and the lowest point of the ESBS is at approx. elev 18 ft.

Elev.(ft)	H (ft/s)	Std H	D (deg)	Std D	W (ft/s)	Std W
55.3	1.32	0.184	145.10	11.752	-0.97	0.111
53.7	1.56	0.137	154.37	8.559	-0.99	0.103
52.0	1.77	0.185	156.74	7.709	-0.98	0.104
50.4	1.91	0.199	160.26	6.989	-1.03	0.117
48.8	1.55	0.231	160.68	9.290	-0.86	0.111
47.1	1.52	0.238	154.75	10.025	-0.82	0.102
45.5	1.51	0.275	153.03	10.949	-0.80	0.105
43.8	1.56	0.301	157.12	10.540	-0.83	0.113
42.2	1.37	0.330	156.41	17.362	-0.76	0.118
40.6	1.83	0.345	162.75	11.429	-0.98	0.169
38.9	1.27	0.325	154.63	13.376	-0.71	0.116
37.3	1.90	0.398	161.65	10.715	-1.03	0.182
35.6	1.01	0.320	144.54	33.221	-0.58	0.110
34.0	1.82	0.478	166.60	13.645	-1.01	0.178
32.3	1.30	0.405	152.78	20.315	-0.74	0.132
30.7	1.27	0.477	145.95	39.224	-0.71	0.162
29.1	2.02	0.425	165.31	12.782	-1.08	0.148
27.4	1.34	0.555	142.09	44.284	-0.69	0.193
25.8	2.79	0.665	162.97	13.217	-1.43	0.206
24.1	2.38	0.696	150.25	16.436	-1.14	0.218
22.5	3.05	0.420	187.28	14.076	-1.41	0.177
20.9	3.40	0.832	145.74	18.065	-1.45	0.248
19.2	2.71	0.576	171.87	12.049	-1.28	0.196
17.6	3.87	0.782	164.36	10.760	-1.74	0.243

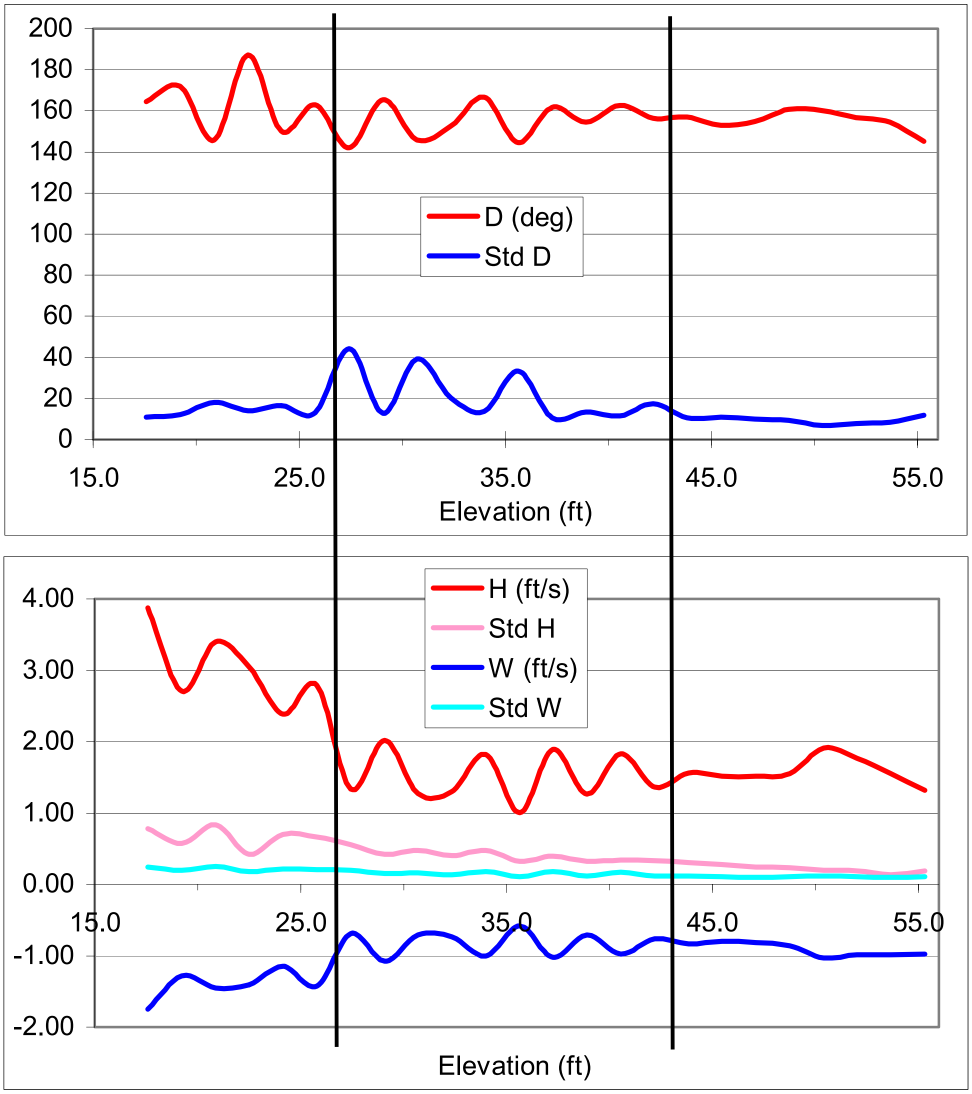


Figure 7 Variation of Velocity Components with Elevation. The centerline of the intake is at 157-degrees and negative vertical velocities imply a downward orientation.

5 Variations across the Intake

This section of the report discusses velocity variations across the centerline of the intake and with flows between 9.5 and 10 kcfs. This flow range was selected because the non-zero average flow rate for this 10-day period was 9.65 kcfs. The previous section on depth variations identified three zones (Figure 7) in the velocity field. Because the zone between 17 ft and 26 ft included a significant velocity variation, this range was split in two. In the tables below, the largest velocity component at each depth zone has been highlighted in red and the lowest highlighted in blue. "Mean" in the table below represents an arithmetic mean along the traverse, and "max(abs diff)" stands for the maximum absolute value difference between the mean and each traverse location per depth zone.

Variations of horizontal velocity magnitudes across the intake are less than the standard deviations. This is shown numerically in Table 4 and Table 5, and graphically in Figure 8. At all four depth zones, the standard deviation brackets the larger side-to-side variation. A slight increase of magnitude exists at the ends of the traverse (i.e. those most near the sides of the intake) below 26 ft. These increases are not strong enough to be a definite trend, however the difference is larger than the standard deviation. It is unusual however that this trend is not present higher in the water column, and that velocities decrease so rapidly between 0-inche and 44.0-inches in the below 26 ft zone.

Lateral variations of horizontal direction magnitude are smaller than the standard deviations for all four zones. Standard deviations are the largest in the 27 to 43 ft zone.

Vertical velocity components are smaller than their horizontal counterparts. Magnitudes are oriented downwards as the water converges under the sloping roof of the intake and the ESBS. As with the horizontal components, standard deviations are on the order of lateral variations, and a coherent lateral variation is not apparent. A slight trend may exist for magnitudes below 26 ft to be higher along the ends of the traverse than along the centerline.

Table 4 Horizontal Magnitudes

	Traverse Location						
Elevation	0.0	44.0	89.9	138.0	183.7	Mean	max(abs diff)
44 to 56	1.77	1.64	1.59	1.42	1.34	1.55	0.22
27 to 43	1.56	1.47	1.51	1.46	1.63	1.53	0.10
22 to 26	2.82	2.55	2.74	2.83	3.17	2.82	0.35
17 to 21	3.64	3.25	3.33	3.46	3.75	3.49	0.26

Table 5 Horizontal Magnitude Standard Deviations

	Traverse Location						
Elevation	0.0	44.0	89.9	138.0	183.7	Mean	max(abs diff)
44 to 56	0.18	0.21	0.21	0.20	0.18	0.19	0.01
27 to 43	0.40	0.43	0.41	0.42	0.37	0.40	0.04
22 to 26	0.65	0.68	0.59	0.68	0.44	0.61	0.17
17 to 21	0.79	0.86	0.73	0.78	0.64	0.76	0.12

Table 6 Horizontal Directions

	Traverse Location						
Elevation	0.0	44.0	89.9	138.0	183.7	Mean	max(abs diff)
44 to 56	149.20	151.90	154.99	161.79	162.44	156.06	6.86
27 to 43	151.11	153.46	155.27	157.99	158.38	155.24	4.13
22 to 26	163.62	165.20	166.83	167.25	167.71	166.12	2.50
17 to 21	161.40	162.27	160.66	163.16	168.08	163.11	4.97

Table 7 Horizontal Direction Standard Deviations

	Traverse Location						
Elevation	0.0	44.0	89.9	138.0	183.7	Mean	max(abs diff)
44 to 56	7.99	9.32	9.32	10.55	10.21	9.48	1.49
27 to 43	17.93	27.72	21.64	27.30	13.18	21.55	8.38
22 to 26	12.90	19.59	14.58	16.84	10.84	14.95	4.64
17 to 21	10.61	13.78	13.62	16.68	11.77	13.29	3.38

Table 8 Vertical Velocity Magnitudes (up is positive)

	Traverse Location						
Elevation	0.0	44.0	89.9	138.0	183.7	Mean	max(abs diff)
44 to 56	-0.96	-0.94	-0.92	-0.85	-0.80	-0.89	0.10
27 to 43	-0.86	-0.80	-0.83	-0.80	-0.89	-0.83	0.05
22 to 26	-1.39	-1.24	-1.33	-1.35	-1.51	-1.36	0.14
17 to 21	-1.66	-1.46	-1.49	-1.56	-1.69	-1.57	0.12

Table 9 Vertical Magnitude Standard Deviations

	Traverse Location						
Elevation	0.0	44.0	89.9	138.0	183.7	Mean	max(abs diff)
44 to 56	0.11	0.13	0.11	0.10	0.10	0.11	0.02
27 to 43	0.15	0.18	0.15	0.16	0.14	0.16	0.02
22 to 26	0.24	0.24	0.20	0.21	0.18	0.22	0.04
17 to 21	0.30	0.27	0.23	0.26	0.25	0.26	0.04

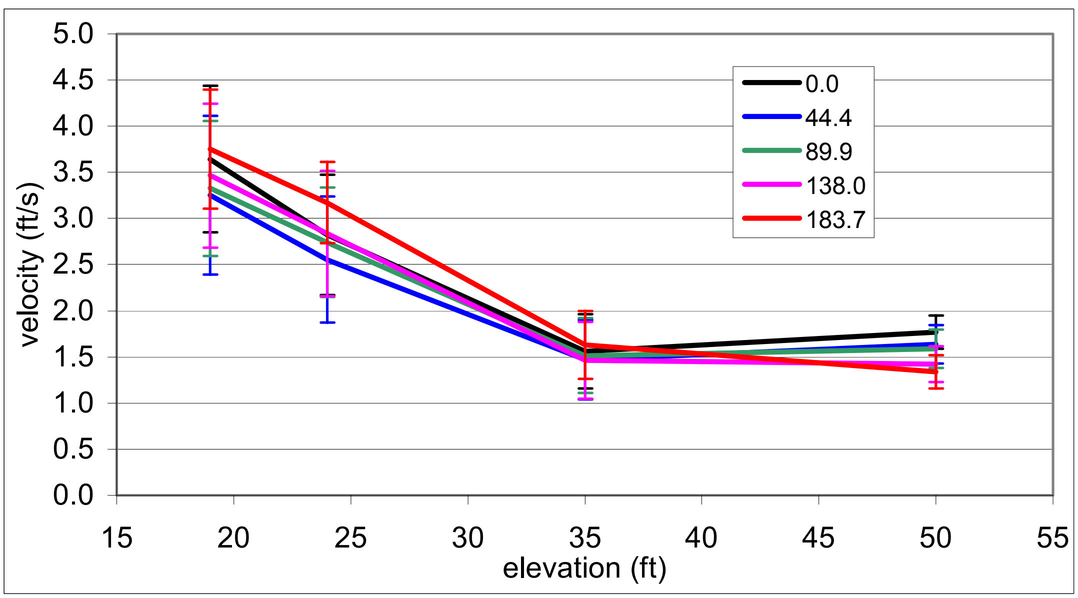


Figure 8 Lateral variations of horizontal magnitude

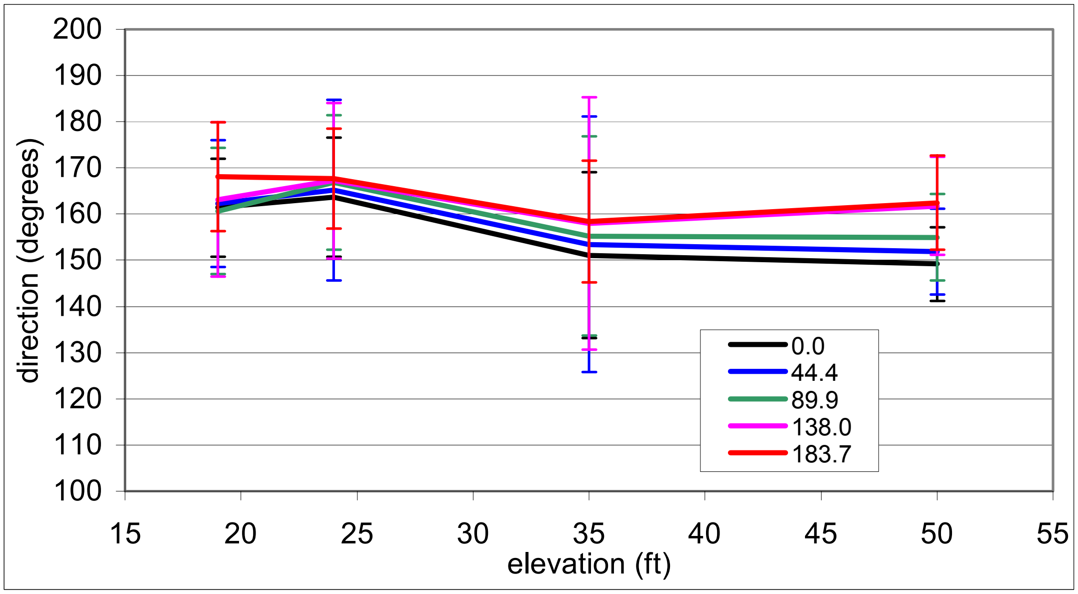


Figure 9 Lateral variations of horizontal velocity direction. The centerline of the intake is at 157-degrees.

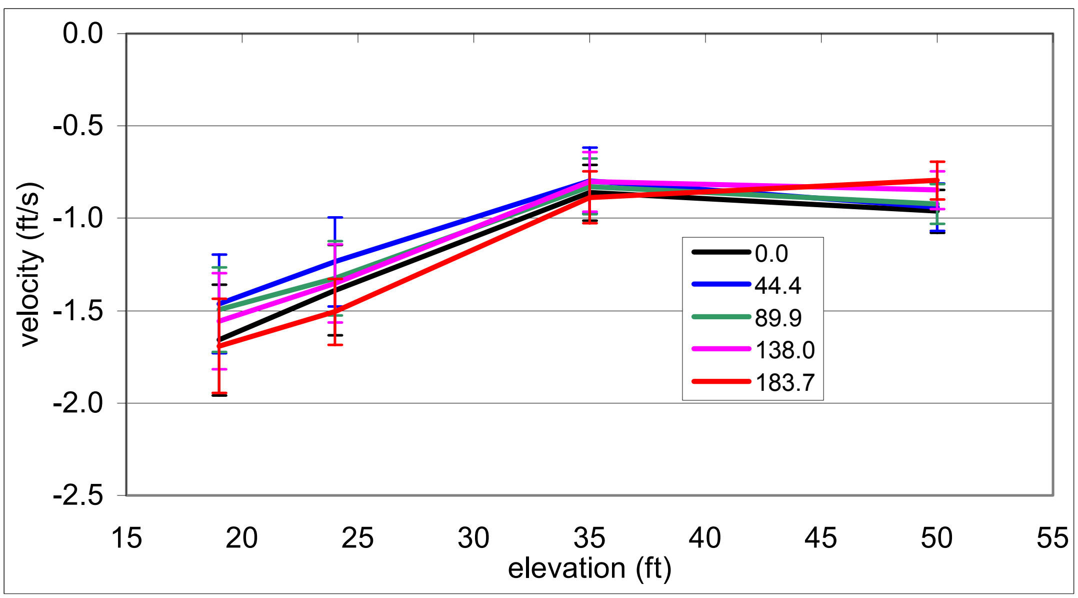


Figure 10 Lateral variations of vertical velocity magnitude. Negative values imply a downward orientation.

6 Variations with Turbine Flow Rate

This section of the report discusses velocity variations due to changes in flow rate through the turbine unit. The data was divided into four zones, as with the lateral variation section. All values in this section were observed along the intake centerline, 90-inches.

Velocity magnitudes generally increase with turbine flow rate, although standard deviations are approximately as large as the flow rate increases. Note that for horizontal and vertical magnitudes below 26 ft, velocities are approximately constant from 8.5 to 10 kcfs. Due to mass conservation, if the velocities are constant in the upper portion of the water column area (i.e. above the ESBS), velocities must be increasing below 18 ft.

Horizontal directions changed little with flow rate, although standard deviations decreased with increasing flows. This is a predictable result since increasing velocities in a closed conduit generally lead to net decrease in centerline turbulence.

Table 10Variation of Horizontal Velocity Magnitude with Flow

	Flow Rate (kcfs)					
Elevation	8 to 8.5	8.5 to 9	9 to 9.5	9.5 to 10	10 to 10.5	10.5 to 11
44 to 56	1.51	1.51	1.56	1.59	1.73	1.84
27 to 43	1.28	1.51	1.57	1.51	1.95	1.95
22 to 26	2.28	2.67	2.79	2.74	3.15	3.31
17 to 21	2.85	3.20	3.40	3.33	3.77	4.00

Table 11Variation of Horizontal Magnitude Standard Deviation with Flow

	Flow Rate (kcfs)					
Elevation	8 to 8.5	8.5 to 9	9 to 9.5	9.5 to 10	10 to 10.5	10.5 to 11
44 to 56	0.19	0.19	0.18	0.21	0.18	0.19
27 to 43	0.34	0.35	0.37	0.41	0.30	0.37
22 to 26	0.56	0.54	0.50	0.59	0.48	0.51
17 to 21	0.67	0.56	0.52	0.73	0.58	0.58

Table 12Variation of Horizontal Velocity Direction with Flow

	Flow Rate (kcfs)					
Elevation	8 to 8.5	8.5 to 9	9 to 9.5	9.5 to 10	10 to 10.5	10.5 to 11
44 to 56	153.81	153.81	156.71	154.99	156.64	156.16
27 to 43	148.32	152.91	154.83	155.27	158.15	157.40
22 to 26	164.20	163.66	163.95	166.83	165.94	165.16
17 to 21	160.18	161.43	161.93	160.66	162.53	162.27

Table 13Variation of Horizontal Direction Standard Deviation with Flow

	Flow Rate (kcfs)					
Elevation	8 to 8.5	8.5 to 9	9 to 9.5	9.5 to 10	10 to 10.5	10.5 to 11
44 to 56	10.02	10.02	8.77	9.32	7.87	7.83
27 to 43	27.02	20.61	20.21	21.64	9.87	13.35
22 to 26	20.52	18.61	10.57	14.58	8.48	8.01
17 to 21	13.07	18.13	8.66	13.62	6.17	6.50

Table 14Variation of Vertical Velocity Magnitude with Flow

	Flow Rate (kcfs)					
Elevation	8 to 8.5	8.5 to 9	9 to 9.5	9.5 to 10	10 to 10.5	10.5 to 11
44 to 56	-0.90	-0.90	-0.91	-0.92	-0.99	-1.05
27 to 43	-0.73	-0.83	-0.82	-0.83	-0.94	-0.98
22 to 26	-1.15	-1.30	-1.30	-1.33	-1.43	-1.51
17 to 21	-1.33	-1.45	-1.48	-1.49	-1.61	-1.71

Table 15 Variation of Vertical Magnitude Standard Deviation with Flow

	Flow Rate (kcfs)					
Elevation	8 to 8.5	8.5 to 9	9 to 9.5	9.5 to 10	10 to 10.5	10.5 to 11
44 to 56	0.15	0.15	0.10	0.11	0.11	0.11
27 to 43	0.16	0.16	0.16	0.15	0.13	0.17
22 to 26	0.24	0.22	0.22	0.20	0.19	0.22
17 to 21	0.28	0.24	0.23	0.23	0.22	0.24

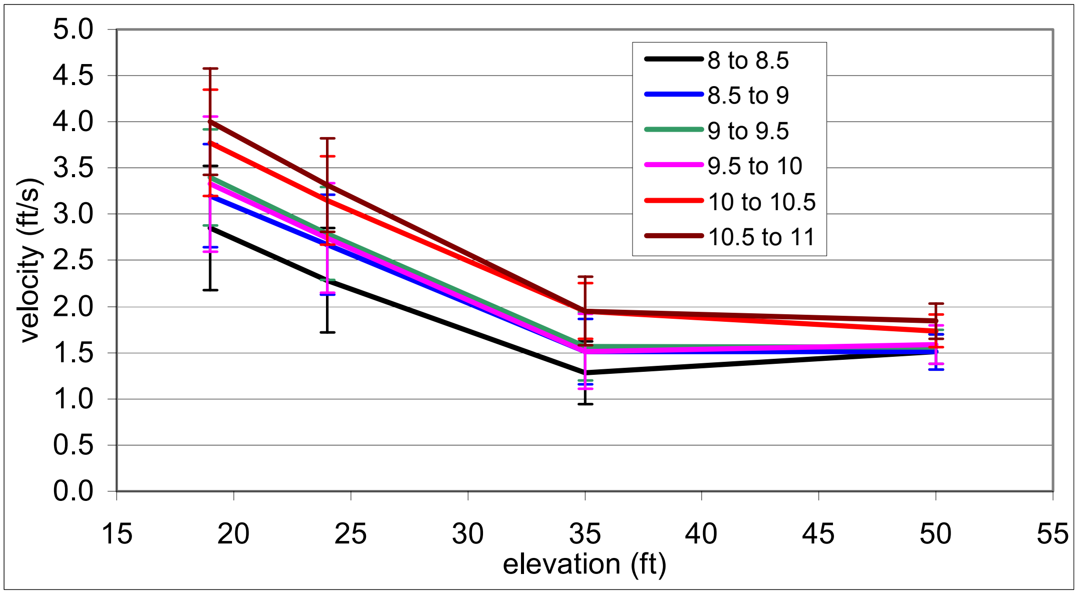


Figure 11Variation of Horizontal Velocity Magnitude with Flow (kcfs)

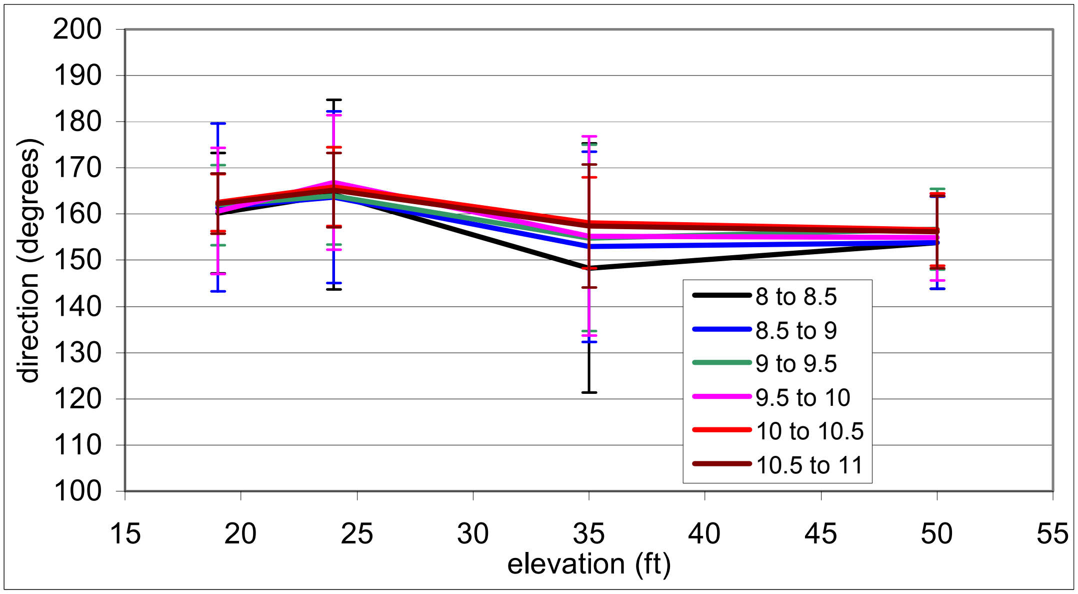


Figure 12 Variation of Horizontal Velocity Direction with Flow (kcfs). The centerline of the intake is at 157-degrees

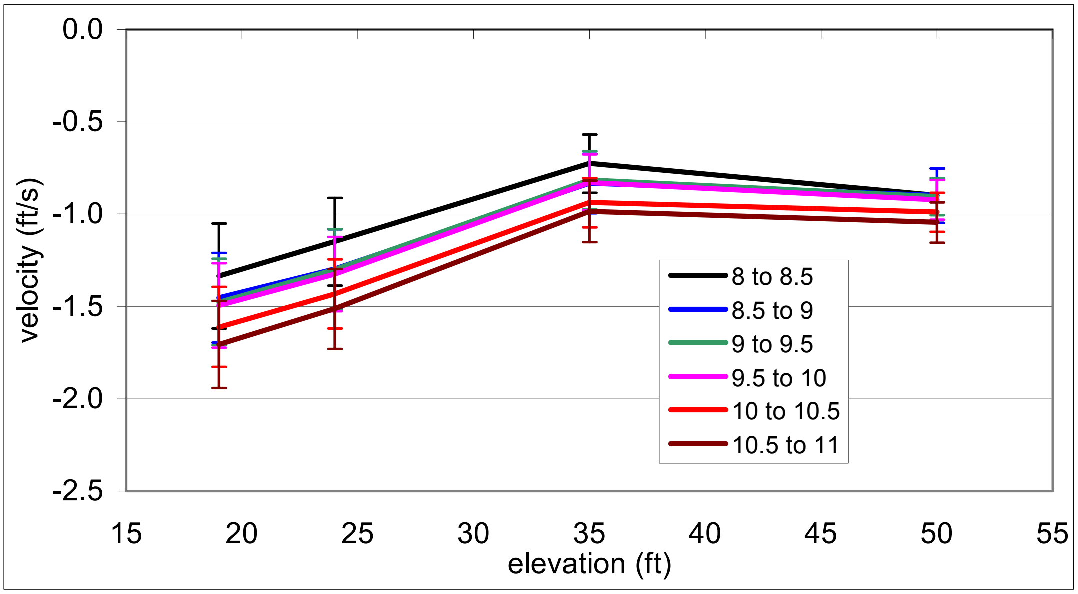


Figure 13 Variation of vertical velocity magnitude with flow. Negative values imply a downward orientation

7 Conclusions

This report examines flow conditions upstream of Unit 8, B-slot, between June 8 and 28, 2000. The focus of this report has been to distill velocity measurements performed using an ADCP unit. From this 20-day period the following conclusions were observed:

1) In general, the velocity vectors are:
    a) pointed downstream towards the dam face
    b) vertically oriented downwards
    c) larger in magnitude in the horizontal than the vertical.
2) Variations with depth can be summarized as follows:
    a) significant differences exist in horizontal and vertical velocity magnitudes above and below elevation 26 ft and,
    b) the water profile can be broken into three distinct zones:
        i. below 26 feet. A rapidly changing area impacted by converging flows as the water moved under the sloping roof and ESBS towards the turbine.
        ii. between 26 and 43 feet. An area with large oscillations in both horizontal and vertical magnitude. Directional standard deviations oscillated, however horizontal and vertical magnitude standard deviations were approximately constant.
        iii. above 44 feet. A zone of relatively uniform flow with little variation over depth.
3) Variations across the intake can be summarized as follows:
    a) Average lateral magnitude variations are smaller than the standard deviation of theses parameters during the time period. This would imply that there is no apparent lateral variation in flow structure (other than turbulence, of course).
    b) Standard deviations were greatest in the 26 to 43 foot range.
4) Variations with Turbine Operations can be summarized as follows:
    a) magnitudes generally increase with flow rate,
    b) magnitudes were constant between 8.5 and 10 kcfs, implying an increase in velocity magnitude below elevation 18 ft and,
    c) standard deviations were approximately constant with changes in flow rate.

8 Recommendations

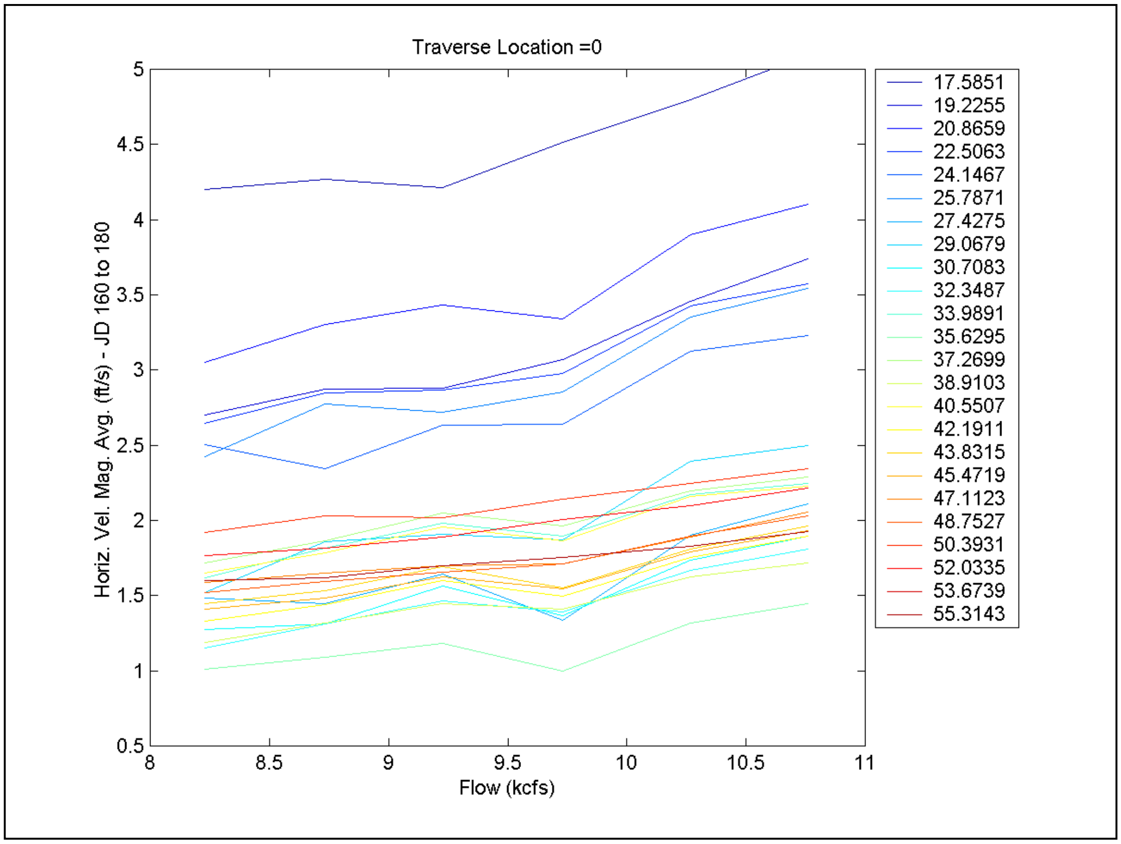
The following are a list of recommendations should this type of deployment be duplicated:

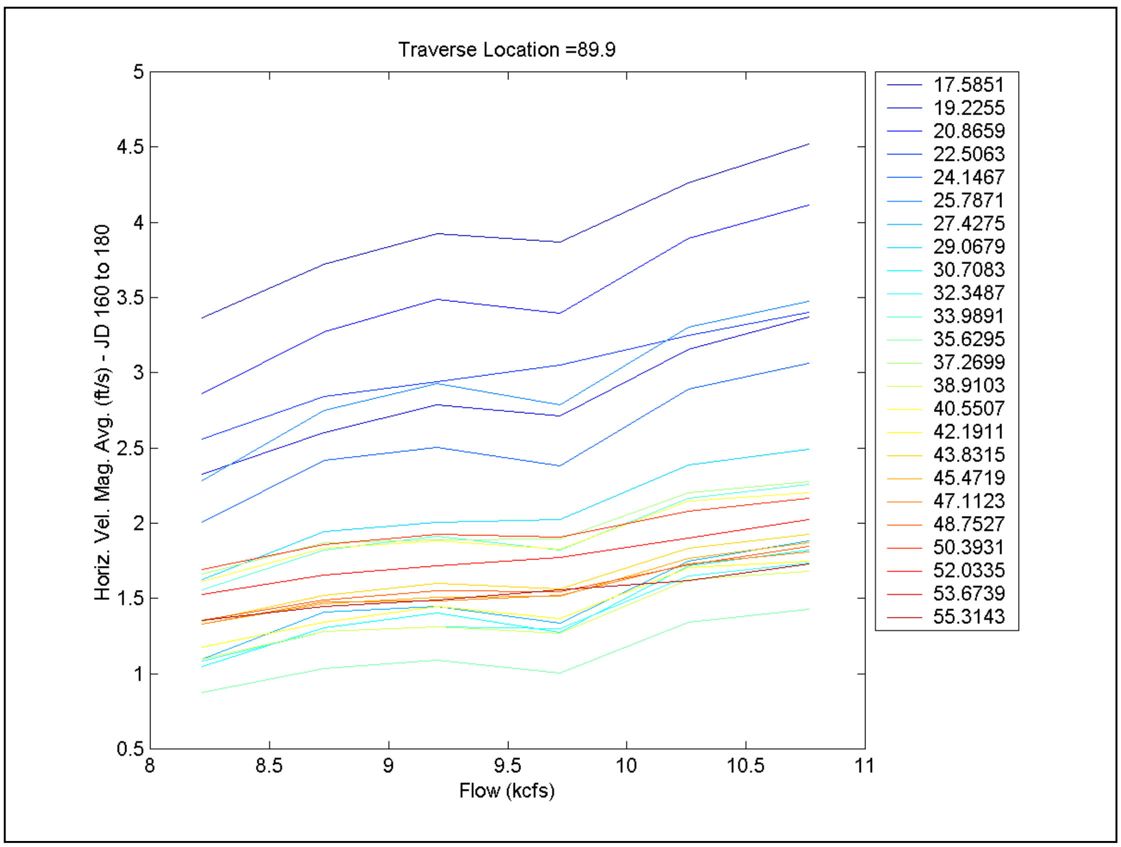
1) An attempt should be made to control the rate of flow through the unit. At present, observations at a particular flow rate are treated as equal regardless of whether the turbine was spinning up or down or holding constant
2) Velocities should be sampled with greater frequency at one location. This could be achieved by maintaining the present ADCP sampling rate and parking the instrument at one proximity sensor for a period of time. Stationary measurements would allow for an improved calculation of variability and fluid field turbulence.
3) The ADCP should be programmed to measure velocities to the bottom of the intake floor (i.e., not to stop recording at elevation 18 ft).

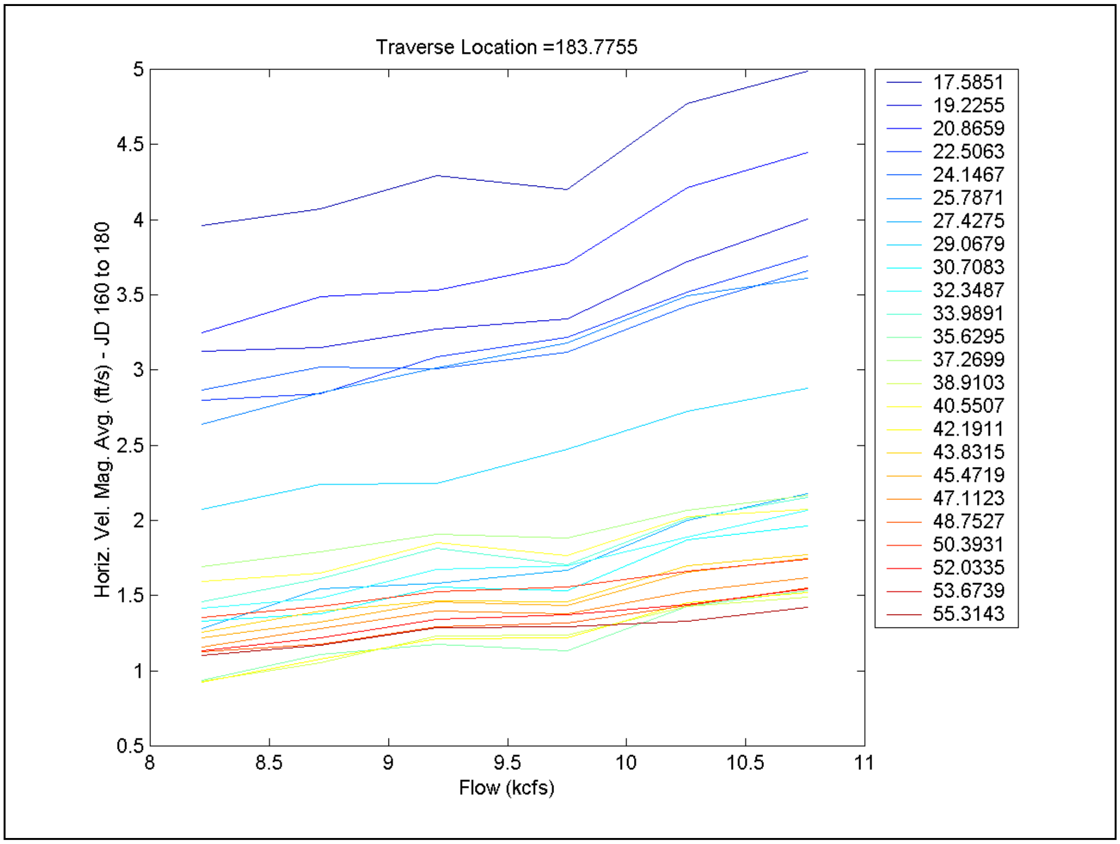
Appendix A

Horizontal Magnitude: Time Averaged Means

Color contours are of elevation (ft), and those less than 26 ft are above the black line.

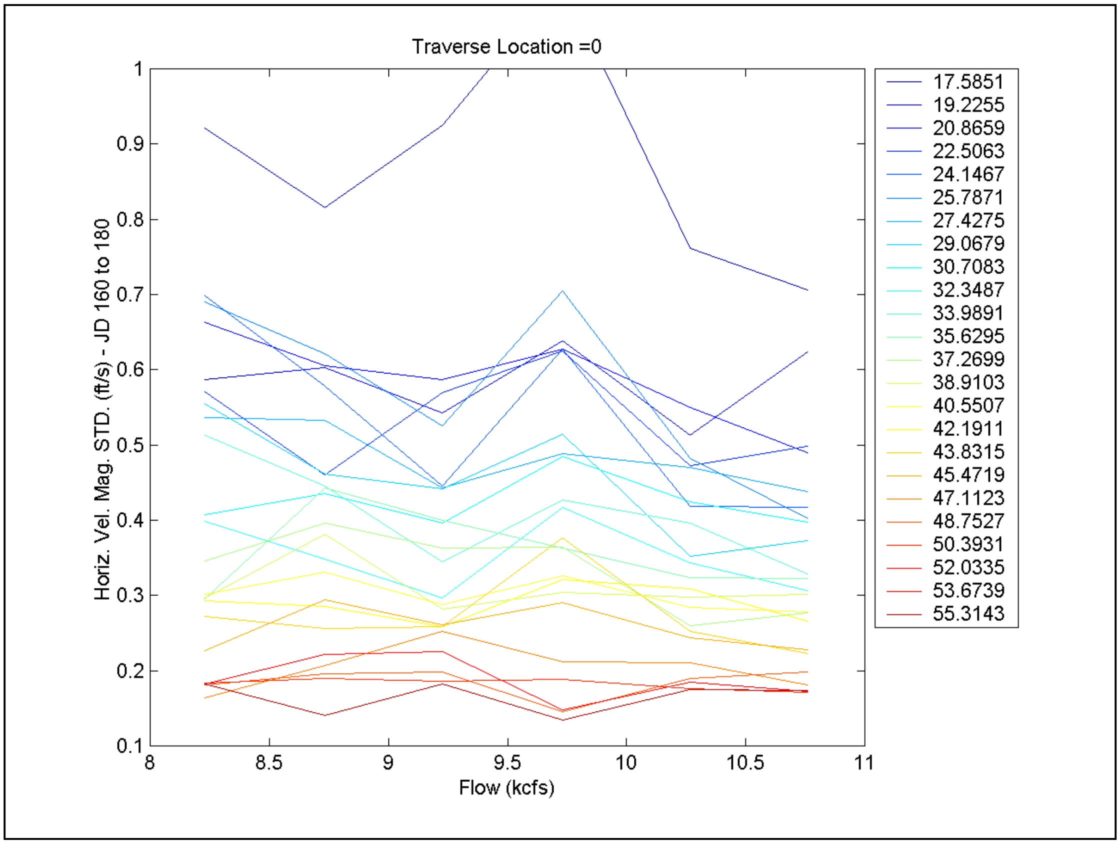


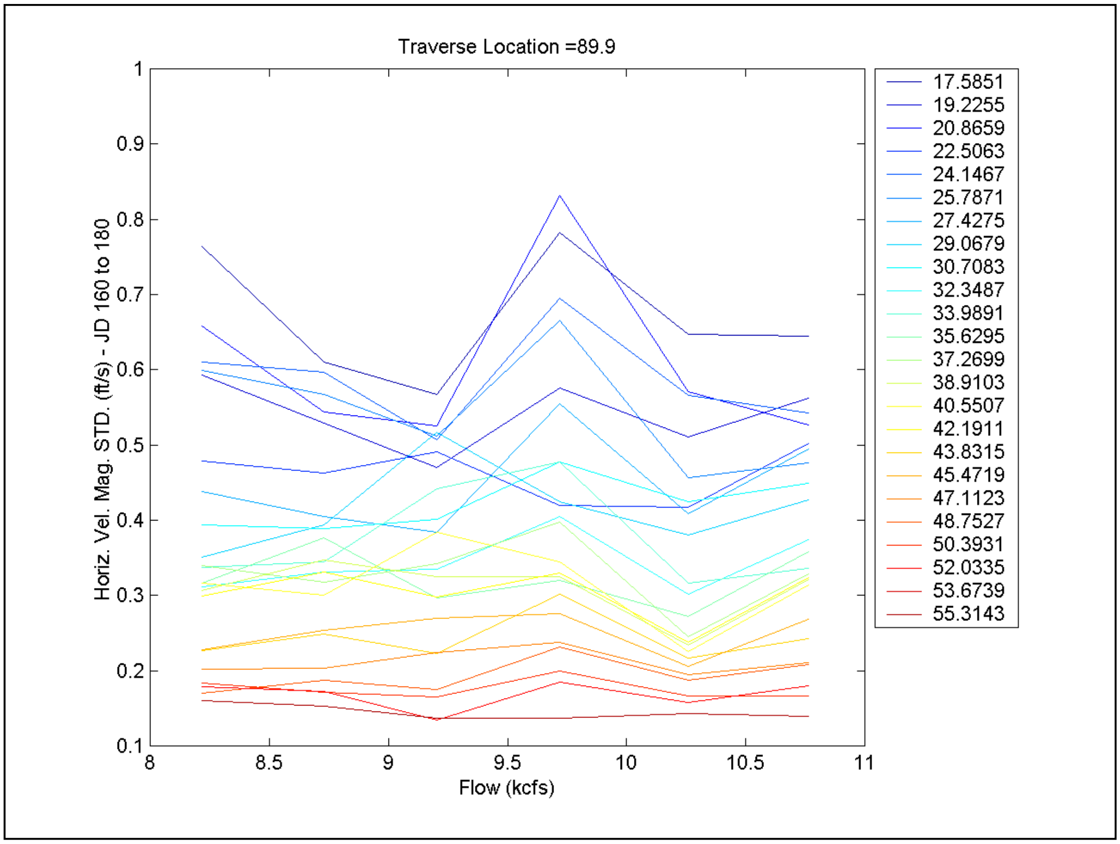


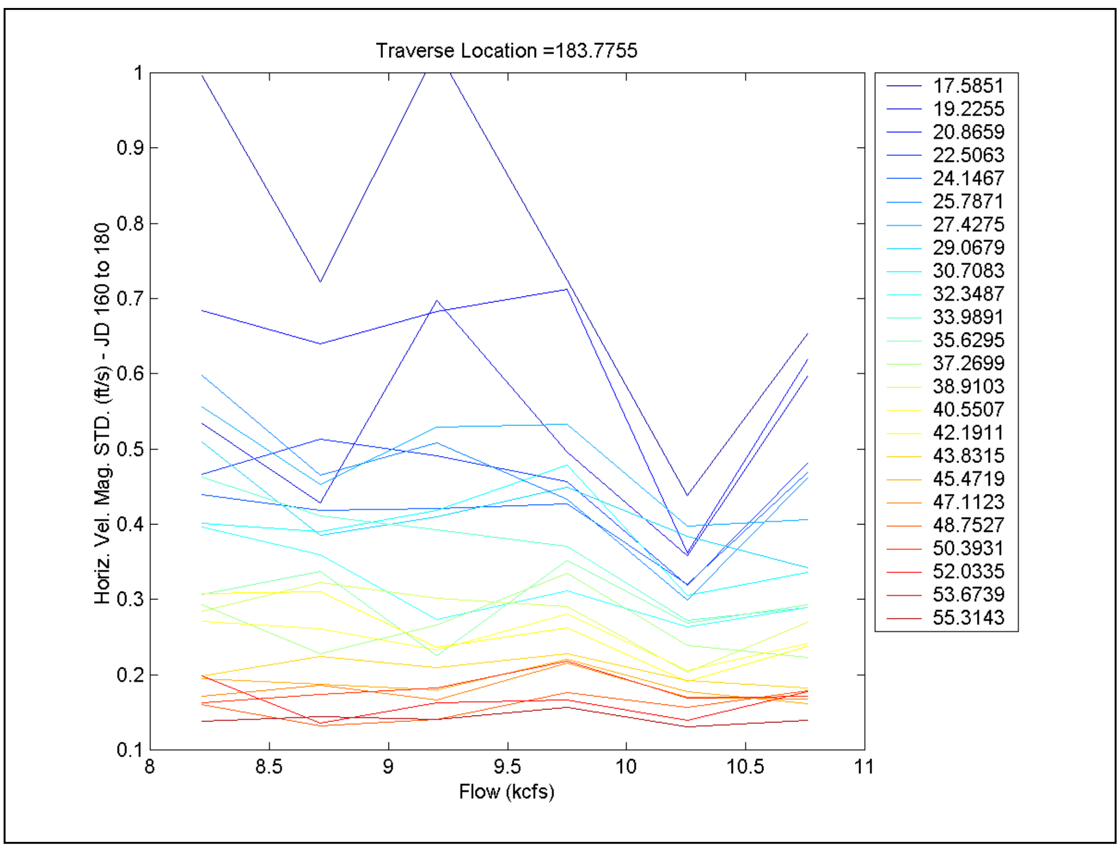


Horizontal Velocity Magnitude: Time Averaged Standard Deviations

Color contours are of elevation (ft) above mean sea level.

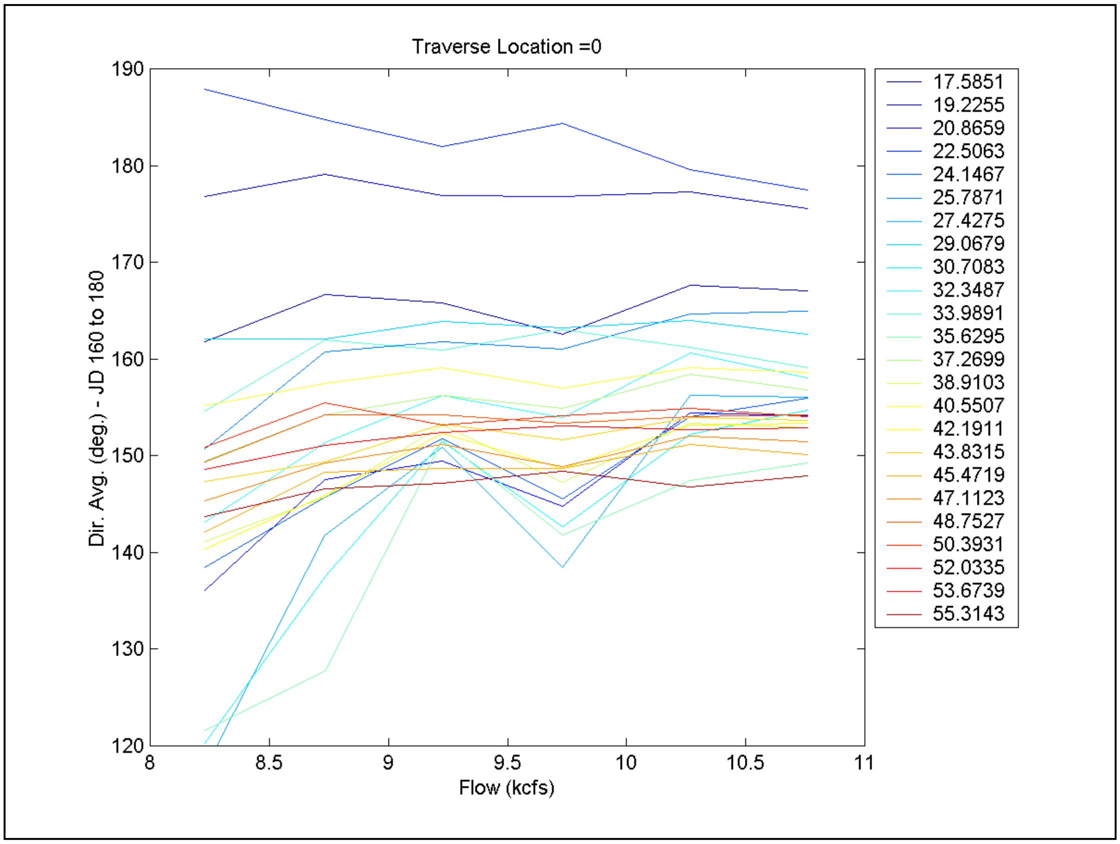


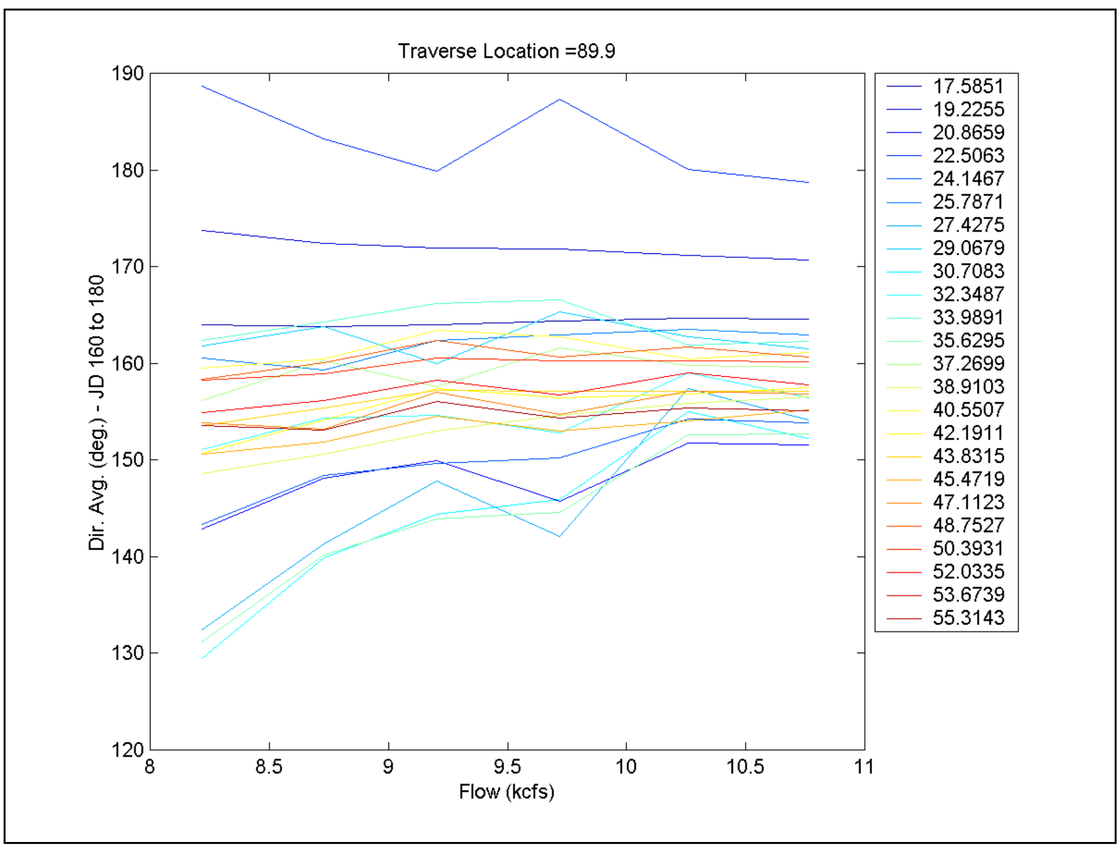

Traverse Location =89.9
Horiz. Vel. Mag. STD. (ft/s) - JD 160 to 180
Flow (kcfs)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
8
8.5
9
9.5
10
10.5
11
17.5851
19.2255
20.8659
22.5063
24.1467
25.7871
27.4275
29.0679
30.7083
32.3487
33.9891
35.6295
37.2699
38.9103
40.5507
42.1911
43.8315
45.4719
47.1123
48.7527
50.3931
52.0335
53.6739
55.3143

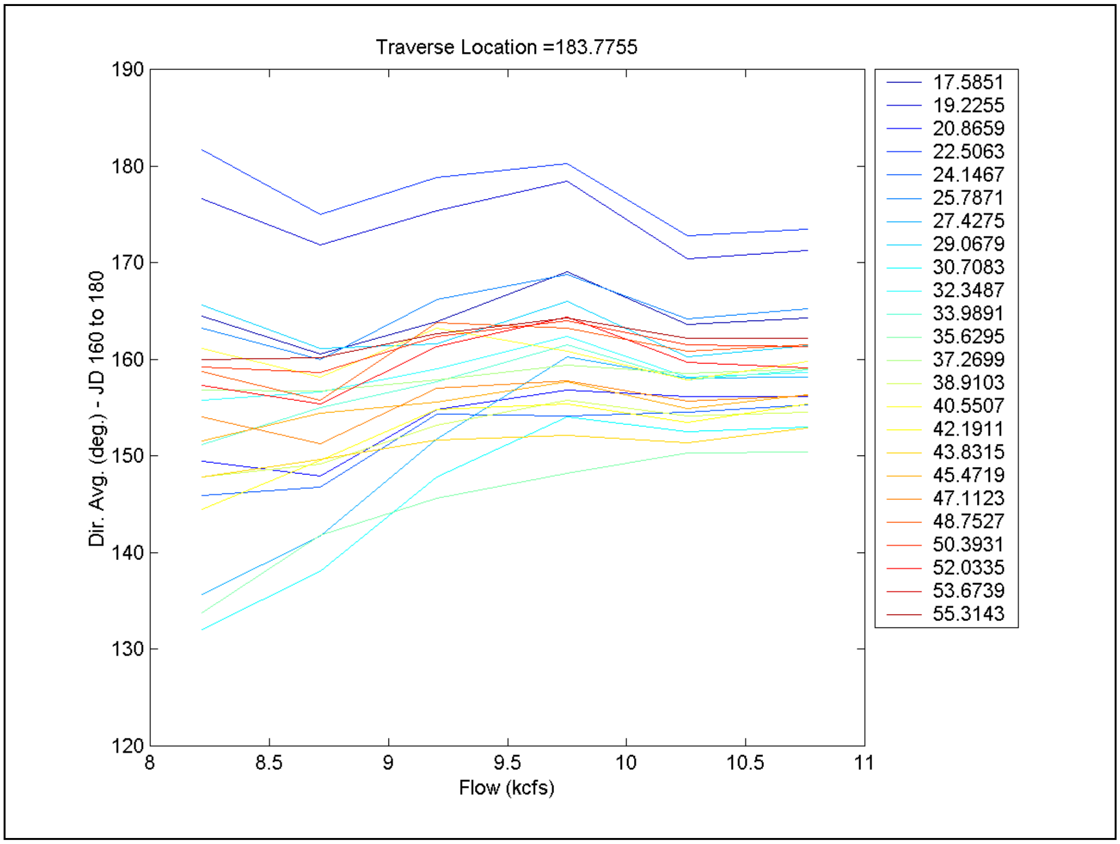

Traverse Location =183.7755
Horiz. Vel. Mag. STD. (ft/s) - JD 160 to 180
Flow (kcfs)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
8
8.5
9
9.5
10
10.5
11
17.5851
19.2255
20.8659
22.5063
24.1467
25.7871
27.4275
29.0679
30.7083
32.3487
33.9891
35.6295
37.2699
38.9103
40.5507
42.1911
43.8315
45.4719
47.1123
48.7527
50.3931
52.0335
53.6739
55.3143

Horizontal Velocity Direction: Time Averaged Means

Color contours are of elevation (ft) above mean sea level.

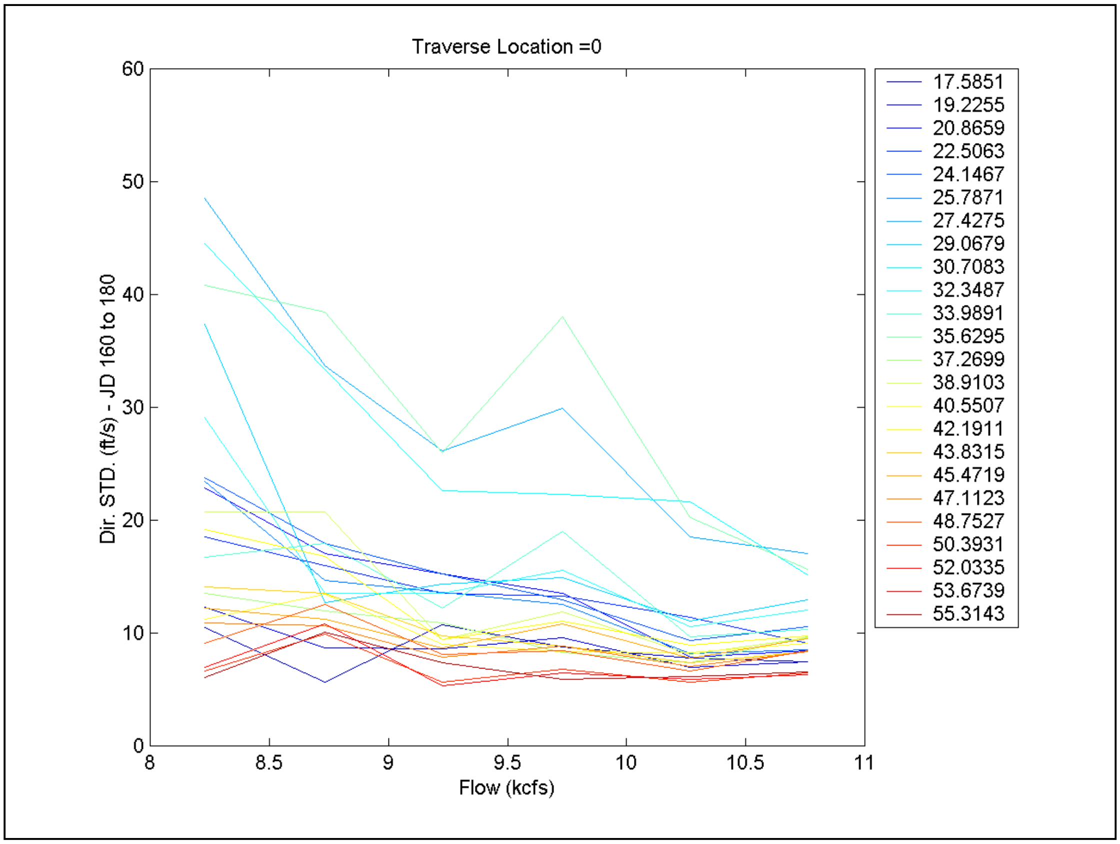


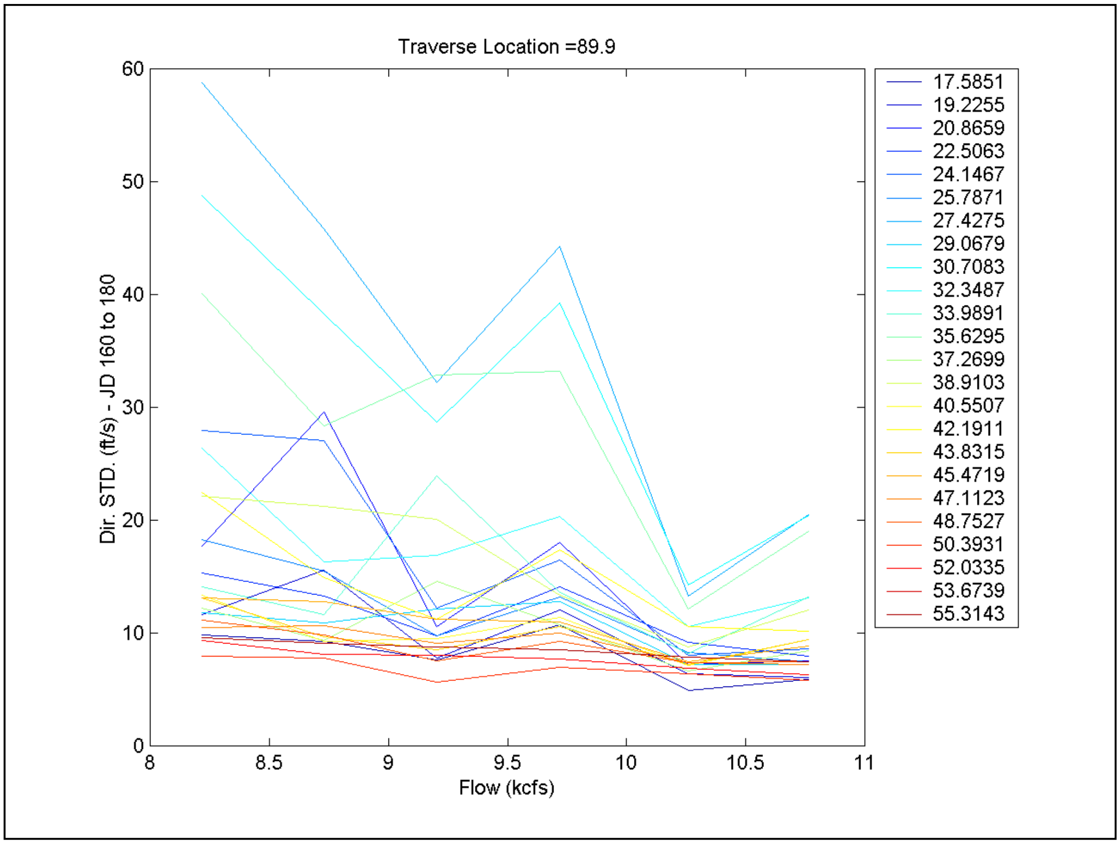


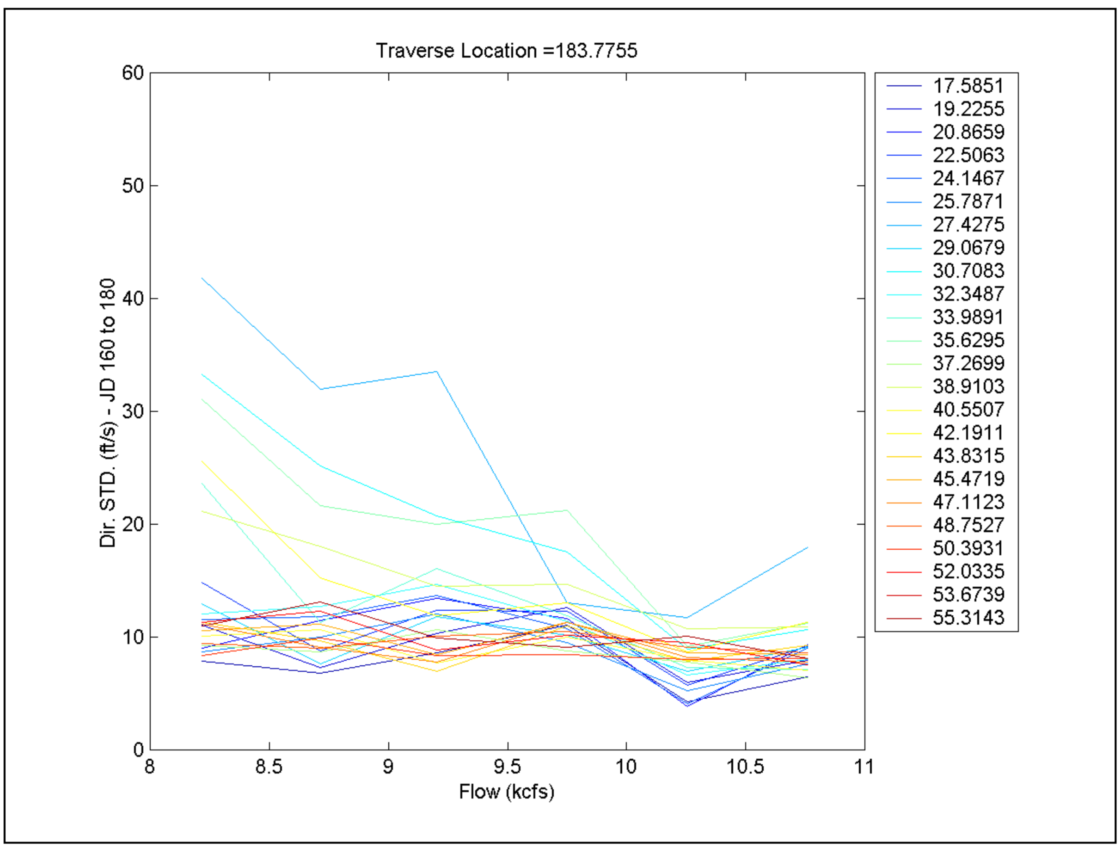


Horizontal Velocity Direction: Time Averaged Standard Deviation

Color contours are of elevation (ft) above mean sea level.

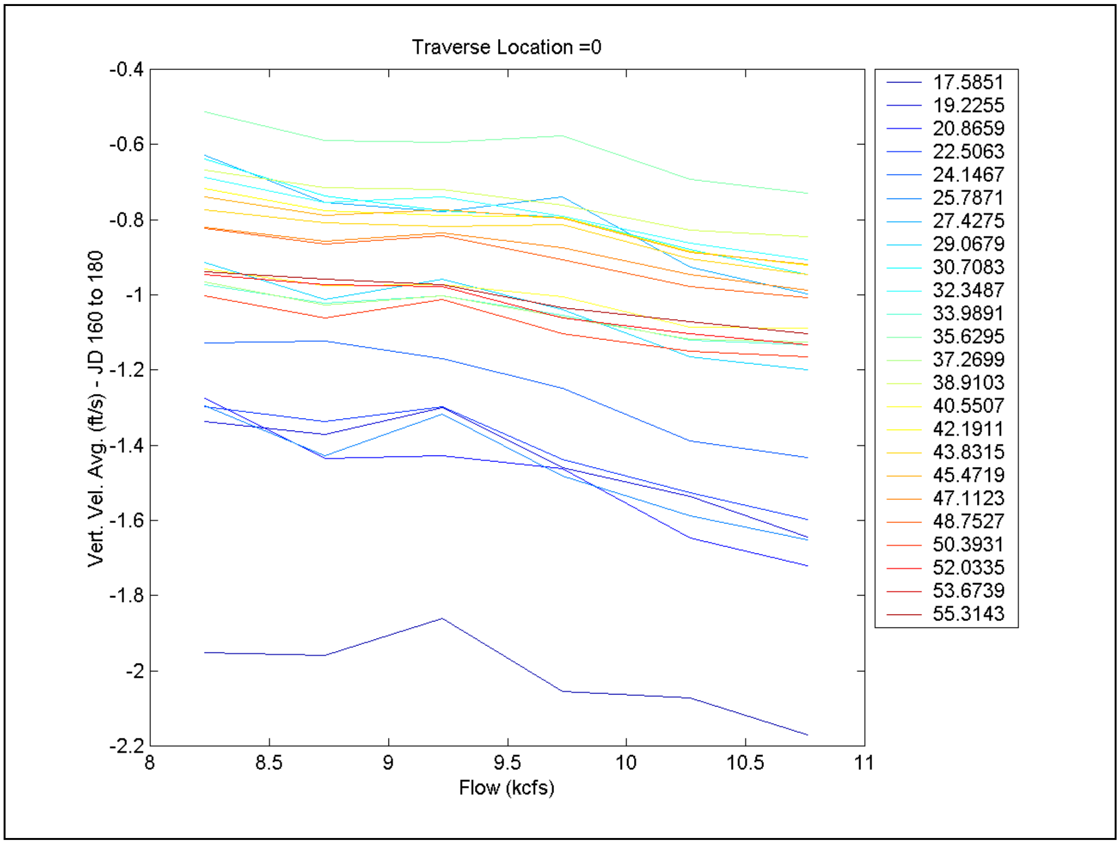


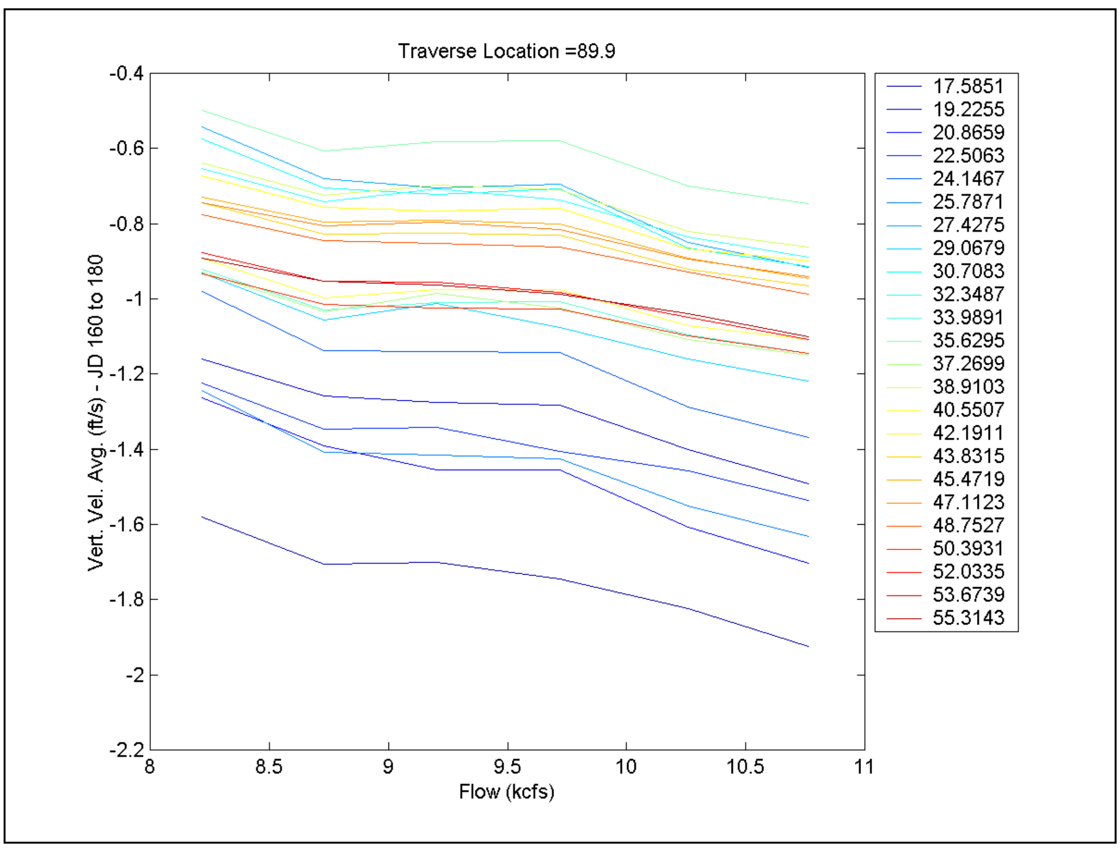

Traverse Location =89.9
Dir. STD. (ft/s) - JD 160 to 180
Flow (kcfs)
0
10
20
30
40
50
60
8
8.5
9
9.5
10
10.5
11
17.5851
19.2255
20.8659
22.5063
24.1467
25.7871
27.4275
29.0679
30.7083
32.3487
33.9891
35.6295
37.2699
38.9103
40.5507
42.1911
43.8315
45.4719
47.1123
48.7527
50.3931
52.0335
53.6739
55.3143

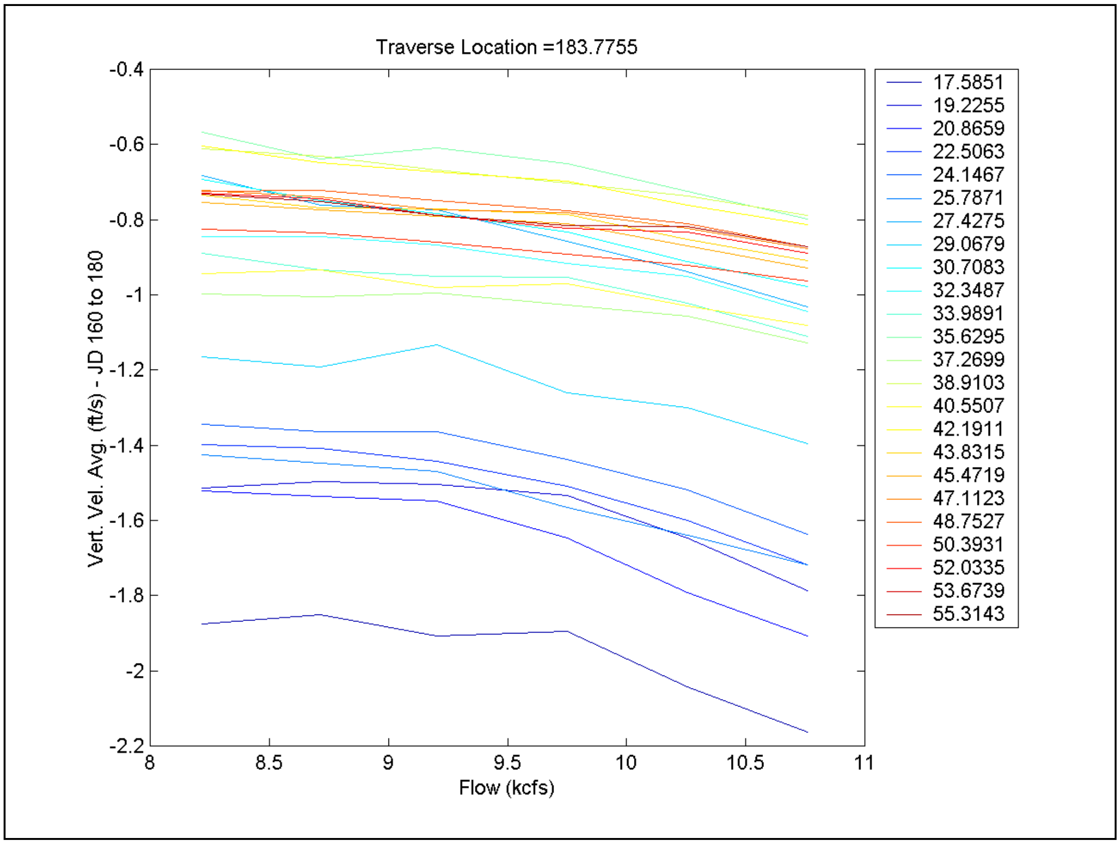

Traverse Location =183.7755
Dir. STD. (ft/s) - JD 160 to 180
Flow (kcfs)
0
10
20
30
40
50
60
8
8.5
9
9.5
10
10.5
11
17.5851
19.2255
20.8659
22.5063
24.1467
25.7871
27.4275
29.0679
30.7083
32.3487
33.9891
35.6295
37.2699
38.9103
40.5507
42.1911
43.8315
45.4719
47.1123
48.7527
50.3931
52.0335
53.6739
55.3143

Vertical Velocity Magnitude: Time Averaged Means

Color contours are of elevation (ft), and those less than 26 ft are below the black line.

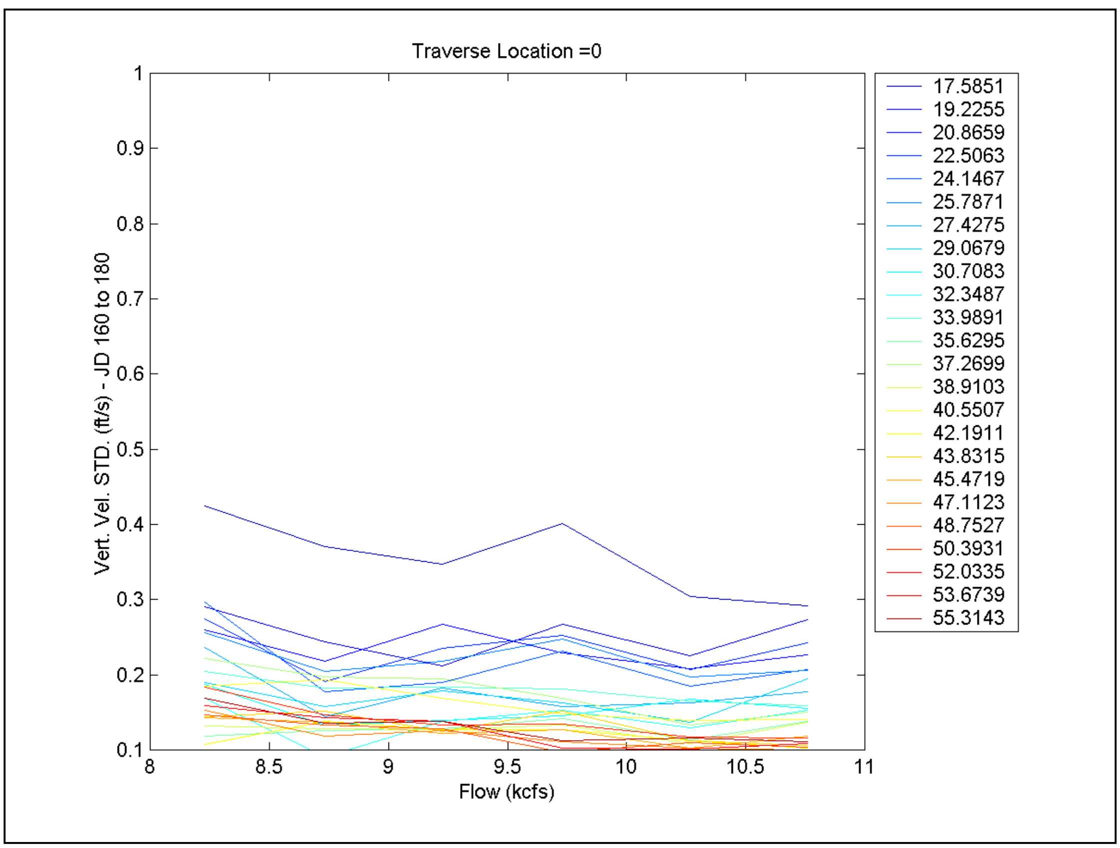


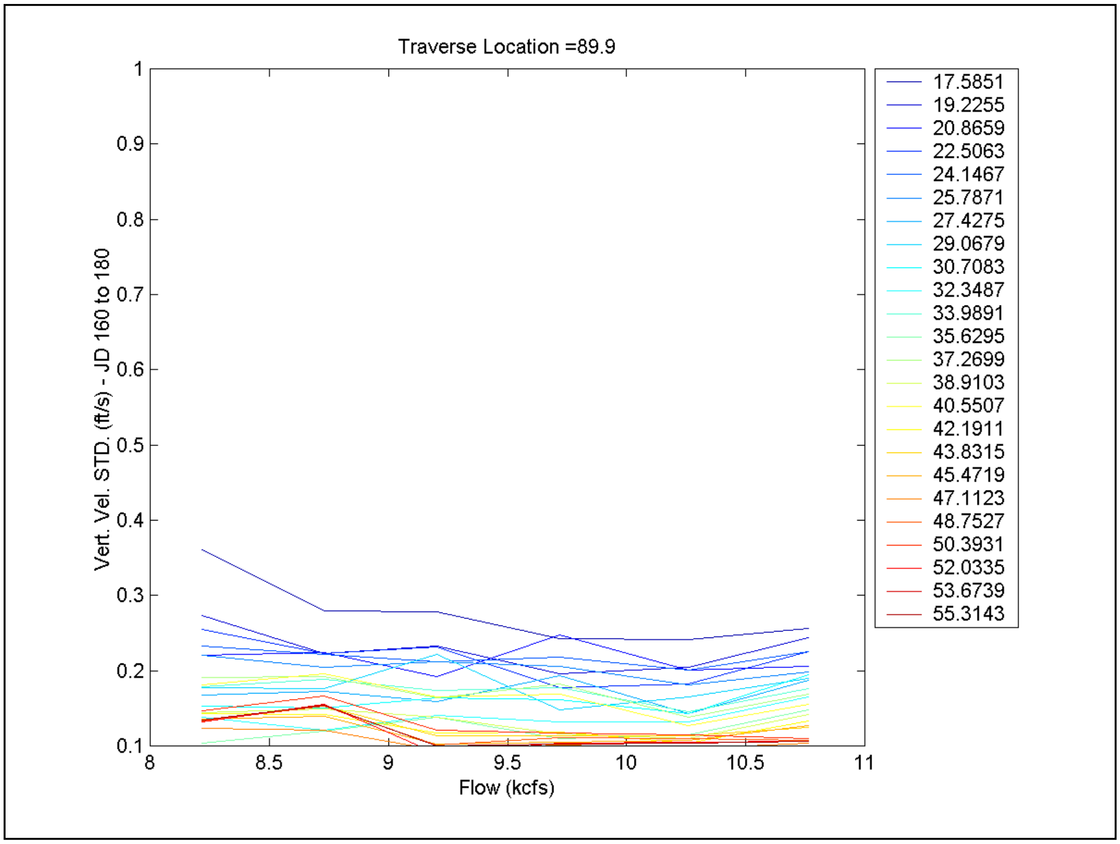




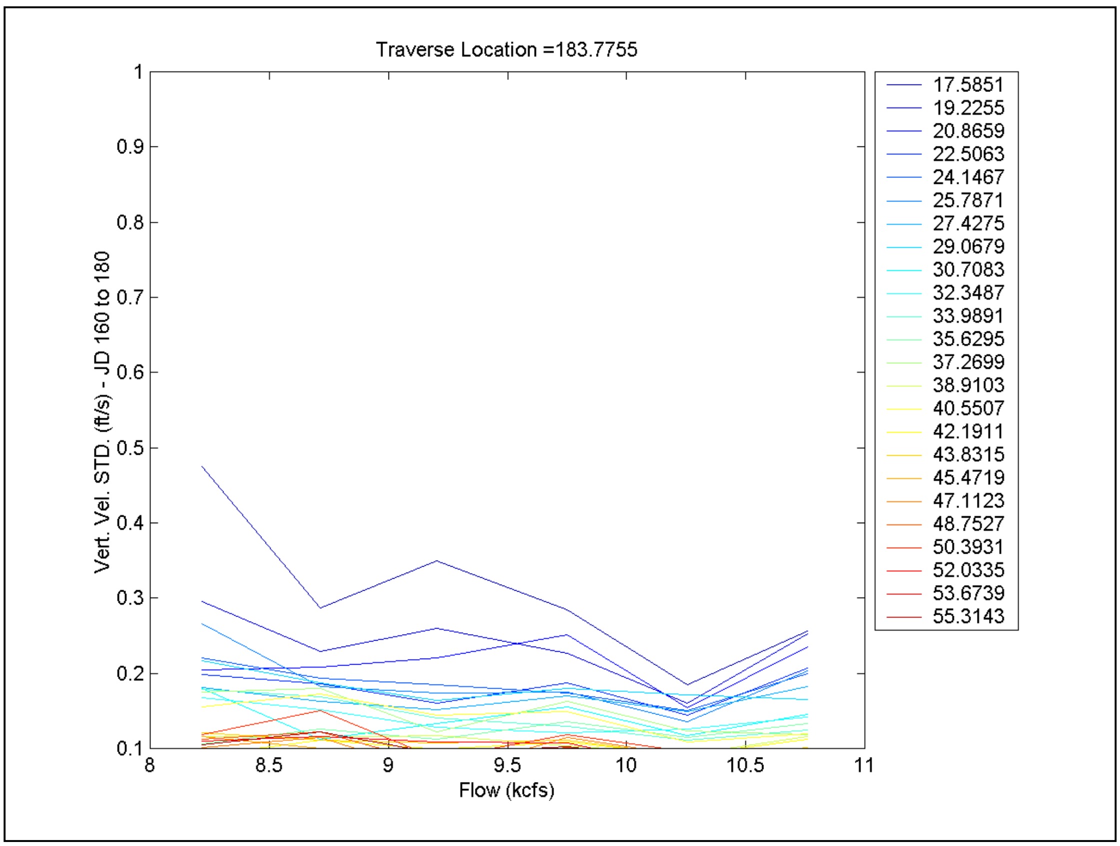
Vertical Velocity Magnitude: Time Averaged Standard Deviation

Color contours are of elevation (ft) above mean sea level.





Traverse Location =89.9
Vert. Vel. STD. (ft/s) - JD 160 to 180
Flow (kcfs)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
8
8.5
9
9.5
10
10.5
11
17.5851
19.2255
20.8659
22.5063
24.1467
25.7871
27.4275
29.0679
30.7083
32.3487
33.9891
35.6295
37.2699
38.9103
40.5507
42.1911
43.8315
45.4719
47.1123
48.7527
50.3931
52.0335
53.6739
55.3143



Traverse Location =183.7755
Vert. Vel. STD. (ft/s) - JD 160 to 180
Flow (kcfs)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
8
8.5
9
9.5
10
10.5
11
17.5851
19.2255
20.8659
22.5063
24.1467
25.7871
27.4275
29.0679
30.7083
32.3487
33.9891
35.6295
37.2699
38.9103
40.5507
42.1911
43.8315
45.4719
47.1123
48.7527
50.3931
52.0335
53.6739
55.3143