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CITY OF SACRAMENTO

EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS

TECHNICAL MEMORANDUM

FINAL
January 2016

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CITY OF SACRAMENTO

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TECHNICAL MEMORANDUM
DRINKING WATER INTAKES

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1.0 INTRODUCTION

The City of Sacramento (City) utilizes two river intake facilities on the Sacramento and American Rivers for its two drinking water plants. The Sacramento River Water Treatment Plant (SRWTP) Intake draws water from the Sacramento River and the E.A. Fairbairn Water Treatment Plant (EAFWTP) Intake draws water from the American River. Due to drought conditions, state hydrologists are predicting record low river levels in 2015, with significant uncertainty regarding future year river levels.

Both intake facilities reportedly operate well; however, future river levels may be lower than current design minimum river levels. To provide reliable pumping capacity at both intake facilities, the City is seeking to develop a long-term solution for future low river level conditions. This Technical Memorandum provides an evaluation of the intake at drought conditions for the SRWTP and EAFWTP Intakes and suggests modifications to address any identified inadequate hydraulic conditions.

2.0 SRWTP INTAKE

2.1 Pumping Capacity

The SRWTP Intake is located in a structure built in the Sacramento River channel. Flow enters the structure through wedge wire fish exclusion screens, followed by a porous plate that balances screen flows. The intake contains eight vertical turbine pumps, with four in an upstream gallery and four in a downstream gallery. Each set of four consists of one Fairbanks Morse 38A 7100AW vertical turbine pump and three Fairbanks Morse 44A 7100AW vertical turbine pumps.

A hydraulic evaluation of the existing SRWTP intake was performed to confirm the pump station capacity at the design river levels and estimate the reduction in pumping capacity at the minimum drought river levels. Table 1 provides a summary of the pumping capacity at various river levels for the SRWTP intake. Appendix A contains pump curves for the existing pumps and system curves generated as part of the evaluation.

The station capacity at the drought minimum river level is reduced to approximately 135 million gallons per day (mgd). The City has indicated that this capacity is sufficient.

Table 1 SRWTP Intake Design Criteria		
River Level	**Elevation (ft MSL)**	**Capacity (mgd)[1]**
Design River Level	6.0	160
Design Minimum River Level	1.5	140
Estimated Drought Minimum	-0.5	135

Notes:
(1) Station capacity is based on all pumps operating at 100 percent speed.

2.2 Pump Minimum Submergence

Pump minimum submergence is the recommended minimum operating water level above the inlet bell of the pump to prevent strong free surface air core vortices that can cause damage to the pump and reduce pumping capacity.

For both models of the Fairbank Morse pumps, the manufacturer-listed recommended minimum submergence is 84 inches. This equates to the minimum design river level of 1.5 feet MSL. Operating the pumps at an estimated drought minimum river level of -0.5 feet MSL would reduce the minimum submergence to 60 inches.

The recommended minimum submergence is an estimated value used for design purposes. In actual installation, there is the potential to operate below this value without formation of vortices and impacts to the pumps. Representatives of Fairbanks Morse were contacted during this evaluation about the potential to operate below a minimum submergence of 84 inches. Since these pumps will operate at flows that are less than that at the best efficiency point (listed minimum submergence is based off of best efficiency point); Fairbanks Morse indicated the pumps minimum submergence value could likely be reduced to 76 inches (river elevation of 0.8 feet MSL). Fairbanks Morse recommended additional investigations and/or intake improvements to confirm acceptability of operating at a minimum submergence level below 76 inches.

Since the drought minimum submergence level is below the listed value by Fairbanks Morse, a computational fluid dynamics (CFD) model was used to evaluate anticipated intake conditions at the minimum drought levels. In addition to vortices, the CFD model can evaluate other hydraulic conditions that can affect pump performance such as pre-swirl, relative level of turbulence, and velocity distribution. Additionally, the CFD model can be utilized to evaluate the ability to improve intake conditions through the use of improvements, such as vortex breakers. The results of the CFD model are presented in Section 4.0.

3.0 EAFWTP INTAKE

3.1 Pumping Capacity

The EAFWTP Intake is located in a structure built in the American River channel. Flow enters the structure through wedge wire fish exclusion screens, followed by a porous plate that balances screen flows. The intake contains eight vertical turbine pumps, with five in individual bays on the upstream side, and three in a common gallery on the downstream side. There is a vacant pump bay on the upstream side. The pumps are numbered 1 through 9 from downstream to upstream (currently there is no pump 4, as this is a vacant bay). The station contains pumps from three manufactures: Peerless, Johnson, and Prime Pumps. Because of the age and varying installation dates and manufacturers, as well as the many modifications made to the intake over the years, existing conditions and accurate pump information was not as easily available or complete as at SRWTP. Evaluations were done based on best available information.

A hydraulic evaluation of the existing EAFWTP intake was performed to evaluate the pump station capacity at the design river levels and estimate the reduction in pumping capacity at the minimum drought river levels. Table 2 summarizes the design minimum river levels and estimated drought minimum river level.

Table 2 EAFWTP Intake River Level Criteria

American River Level	Elevation (ft)
Design Minimum River Level, Bay 1-3	12.0
Design Minimum River Level, Bay 5-9	14.1
Estimated Drought Minimum River Level	10.0

Pump minimum submergence is the recommended minimum operating water level above the inlet bell of the pump to prevent strong free surface air core vortices that can cause damage to the pump and reduce pumping capacity. The pump models were all acquired at different times, and some have been rebuilt with modified components. The pump minimum submergence was estimated based on available information and is summarized in Table 3. Based on the available information, all of the pumps are below the recommended minimum submergence at the estimated drought minimum water level. The net positive suction head (NPSH) requirements were calculated from available information and summarized in Table 4.

Since the drought minimum submergence level is below recommended levels for all pumps, a CFD model was used to evaluate anticipated intake conditions at the minimum drought levels and develop modifications to improve pump performance during the low water level period. In addition to vortices, the CFD model can evaluate other hydraulic conditions that

Table 3 EAFWTP Intake Design Criteria

Pump No.	Floor Elevation (ft)	Bottom of Bell Elevation (ft)	Submergence @ EL 10 (in)	HI Recommended Submergence (Based on Flow Rate at EL 10) (in)	Manuf. Recommended Submergence (in)	Existing Screen Height (in)	Notes
1	3	31.1	5.59	52.88	85	N/A	9.5
2	3	41.0	6.42	43.00	85	76	9
3	3	43.0	6.58	41.00	85	NA	
5	3	28.5	5.38	55.50	60	52	9
6	3	29.3	5.44	54.75	68	60	
7	3	29.5	5.46	54.50	74	66	9
8	3	28.0	5.33	56.00	80	84	
9	3	27.0	5.25	57.00	80	84	
1	3	31.1	5.59	52.88	85	N/A	9.5

Table 4 EAFWTP Intake Design Criteria

Pump No.	Bottom of Bell Elevation (ft)	Impeller Guess(3) (ft) (Bottom to Top of Bell)	Impeller Guess Elevation (ft)	Suction Static Height (EL 10) (ft)	NPSHa (EL 10) (ft)	NPSHr by Manuf. (ft)	NPSH Margin Ratio		NPSH Margin		Notes
							Calculated	HI4	Calculated (ft)	HI4 (ft)	
1	5.59	1.44	7.03	2.97	36.15	34	1.06	1.2	2.1	5	
2	6.42	1.54	7.96	2.04	35.22	23	1.53	1.2	12.2	5	1
3	6.58	1.50	8.08	1.92	35.09	34	1.03	1.2	1.1	5	
5	5.38	0.90	6.27	3.73	36.91	30	1.23	1.2	6.9	5	1
6	5.44	0.96	6.40	3.60	36.78	23	1.60	1.2	13.8	5	1
7	5.46	1.17	6.63	3.38	36.55	21	1.74	1.2	15.6	5	1
8	5.33	0.67	6.00	4.00	37.18	N/A	N/A	1.2	N/A	5	
9	5.25	0.67	5.92	4.08	37.26	N/A	N/A	1.2	N/A	5	

Notes:

(1) Submergence and NPSH required (NPSHr) based off manufacturer estimation for trimmed impeller.
(2) Centerline of impeller approximated. Actual centerline not available on manufacturer cut sheets.
(3) Based on dimensions provided by client/divers 10/21/14.
(4) Recommended by Hydraulic Institute (HI).
(5) NPSHa = NPSH available.

can affect pump performance, such as pre-swirl, relative level of turbulence, and velocity distribution. Additionally, the CFD model can be utilized to evaluate the ability to improve intake conditions through the use of improvements, such as vortex breakers. The results of the CFD model are presented in Section 4.0.

4.0 CFD MODELING

4.1 Pump Station Hydraulics

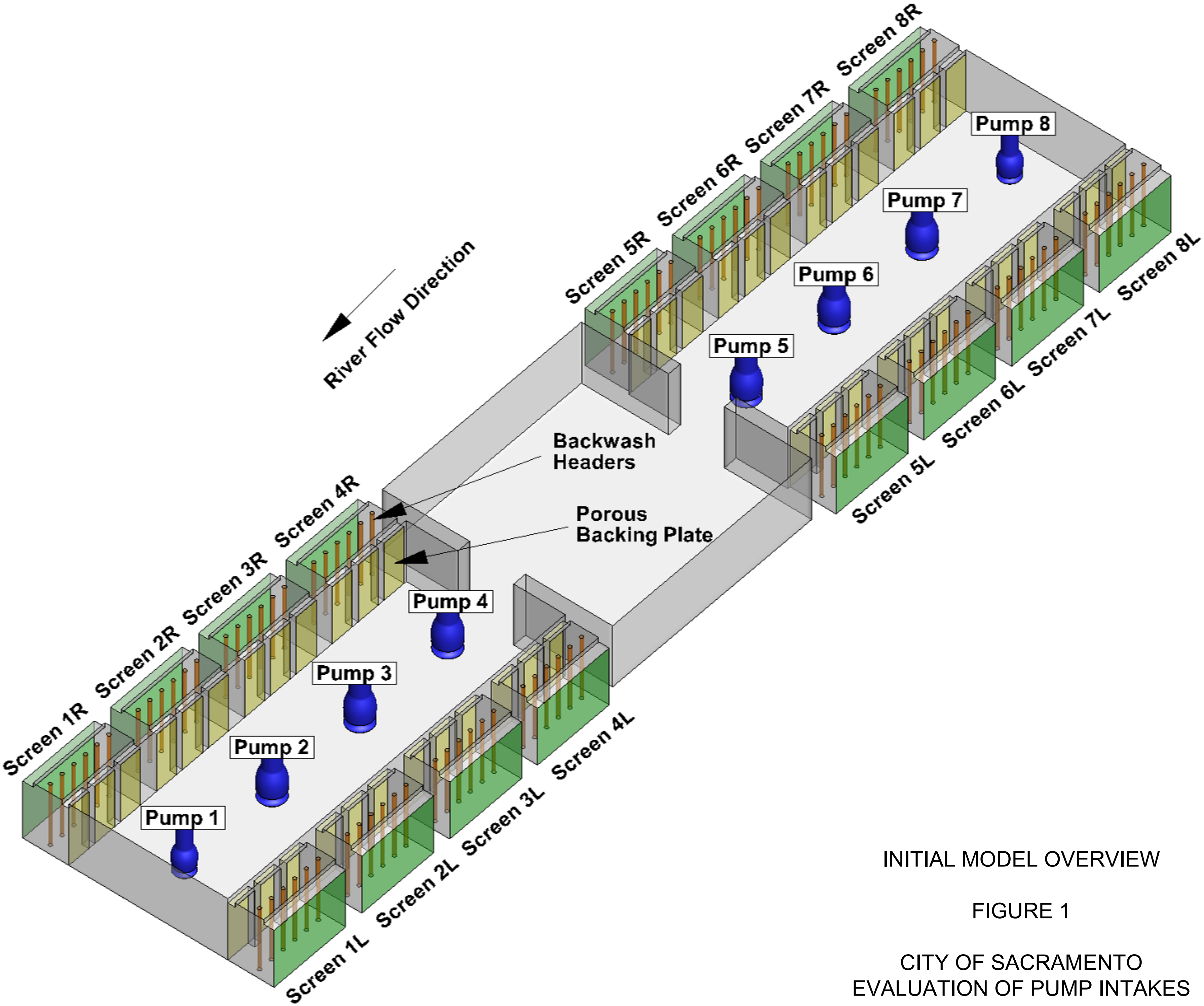
Pump intake hydraulics are a function of many factors including the geometry of the structure, operating water levels, pump operating combinations, flow rates, and turbulence. The interaction of these parts can lead to poor approach hydraulics at the rotating pump impeller, particularly as turbulent flow conditions create uncertainty within designs. Poor hydraulic conditions such as air entrainment, vortex formation, flow rotation, excessive turbulence, and poor velocity distribution from flow separation can lead to a range of pump problems from loss to capacity to destructive cavitation. Further discussion of pump intake hydraulics can be found in Appendix B. For this study, CFD modeling was used to evaluate the pump intake hydraulic conditions and develop preliminary modifications to improve hydraulic conditions. Details of CFD modeling can be found in Appendix C.

Several metrics were used to quantify the pump performance based on the Hydraulic Institute (HI) recommendations for pump intake conditions. Data were extracted from points within the model pump column to determine the level of pre-swirl (α), the relative level of turbulence (Ti), and the velocity distribution ($V_{max}/V_{avg,}$ V_{min}/V_{avg}) at the pump suction location for the operating pumps. HI recommends the velocity distribution be within standard of +/- 10 percent (1.10 to 0.90) of the average for all operating pumps in all cases. The relative turbulence levels should be under 10 percent (<0.10). The pre-swirl should be with +/- 5 degrees from axial for all pumps. In addition, there should not be surface or subsurface vortices that enter the pumps.

4.2 SRWTP INTAKE

4.2.1 <u>Existing Configuration</u>

The model was developed from a number of sources including the 2005 Record Drawings, and the 2004 Fish Screen Hydraulic Evaluation Report. The existing configuration model domain is shown in Figure 1 and includes the interior details of the intake from the downstream side of the wedge wire screens to the pumps. The pumps are numbered sequentially 1 to 8, from the downstream to upstream end of the structure. The model included the submerged details of the backwash headers, and a porous surface representing the screen backing plates. The actual backing plates are made from ½-inch thick plates with ½-inch diameter holes at approximately 7.9 percent porosity. The complete plate detail was not modeled. Instead a porous baffle model was used that imparted appropriate head loss and straightening effects on the flow.



INITIAL MODEL OVERVIEW

FIGURE 1

CITY OF SACRAMENTO
EVALUATION OF PUMP INTAKES
FOR DROUGHT CONDITIONS

Table 5 SRWTP Initial Model Test Conditions

Scenario	Total Flow (mgd)	No. of Pumps	Pump 1 (gpm)	Pump 2 (gpm)	Pump 3 (gpm)	Pump 4 (gpm)	Pump 5 (gpm)	Pump 6 (gpm)	Pump 7 (gpm)	Pump 8 (gpm)	WSE (ft)
S13	135.5	7	0	14,474	14,474	14,474	14,474	14,474	14,474	7,237	2.0
S14	132.8	7	0	14,181	14,181	14,181	14,181	14,181	14,181	7,090	0.8
S15	127.5	7	0	13,620	13,620	13,620	13,620	13,620	13,620	6,810	-0.5
S16	46.0	2	0	0	0	0	15,970	15,970	0	0	2.0
S17	45.0	2	0	0	0	0	15,623	15,623	0	0	0.8
S18	43.325	2	0	0	0	0	15,015	15,015	0	0	-0.5
S21	22.5	1	0	0	0	0	0	15,623	0	0	-0.5

A number of possible operating scenarios were initially identified. Modeling first focused on three representative pump operating combinations at three water levels. Table 5 summarizes the operating pumps, their flows, and water levels for the initial modeling. The facility operates in a cross current, with a screen approach velocity of less than 0.2 ft/s. To appropriately simulate these conditions, a cross current of 1.5 ft/s was applied at the screen face, with the flow through the individual screens scaled to meet the total intake flow and proportionally distributed based on the Fish Screen Hydraulic Evaluation Report. Table 6 summarizes the screen flow distribution from the report. In general, the intake flows are higher on the side of the intake closer to the bank (L screens) and toward the center of the structure (screens 2 through 7).

The model was run for the scenarios listed in Table 5, in the respective order listed. Pumps 5 and 6 were selected for analysis in Scenarios 16, 17, 18, and 21 as they appeared the most prone to surface vortex formation when evaluating results from Scenarios 13 through 15. The single pump operation was only tested at the extreme low water level.

The results of the model are shown in Table 7. In general, the results show the pump intake conditions meet the HI standards at water surface elevation (WSE) 2.0 for the conditions tested, with the exception of slightly high turbulence levels in pump 7 in Scenario 13. The HI metrics start to move outside of criteria as the water level is lowered. The highest pre-swirl was 6.8 degrees in Pump 4 in Scenario 15, which also had the highest turbulence level of 0.15.

Figure 2 through Figure 4 show the velocity through the structure at elevation -2.75 feet MSL for Scenarios 15, 18, and 21. The flow field characteristics are most pronounced at the low water level, but similar at higher operating depth. Therefore, only the low levels are shown in this report. The velocity is generally high along the screen face, circulating between the screens and porous backing plate. For Scenarios 18 and 21, there is higher velocity through the center gallery from the downstream end of the intake to the upstream end where the operating pumps are located.

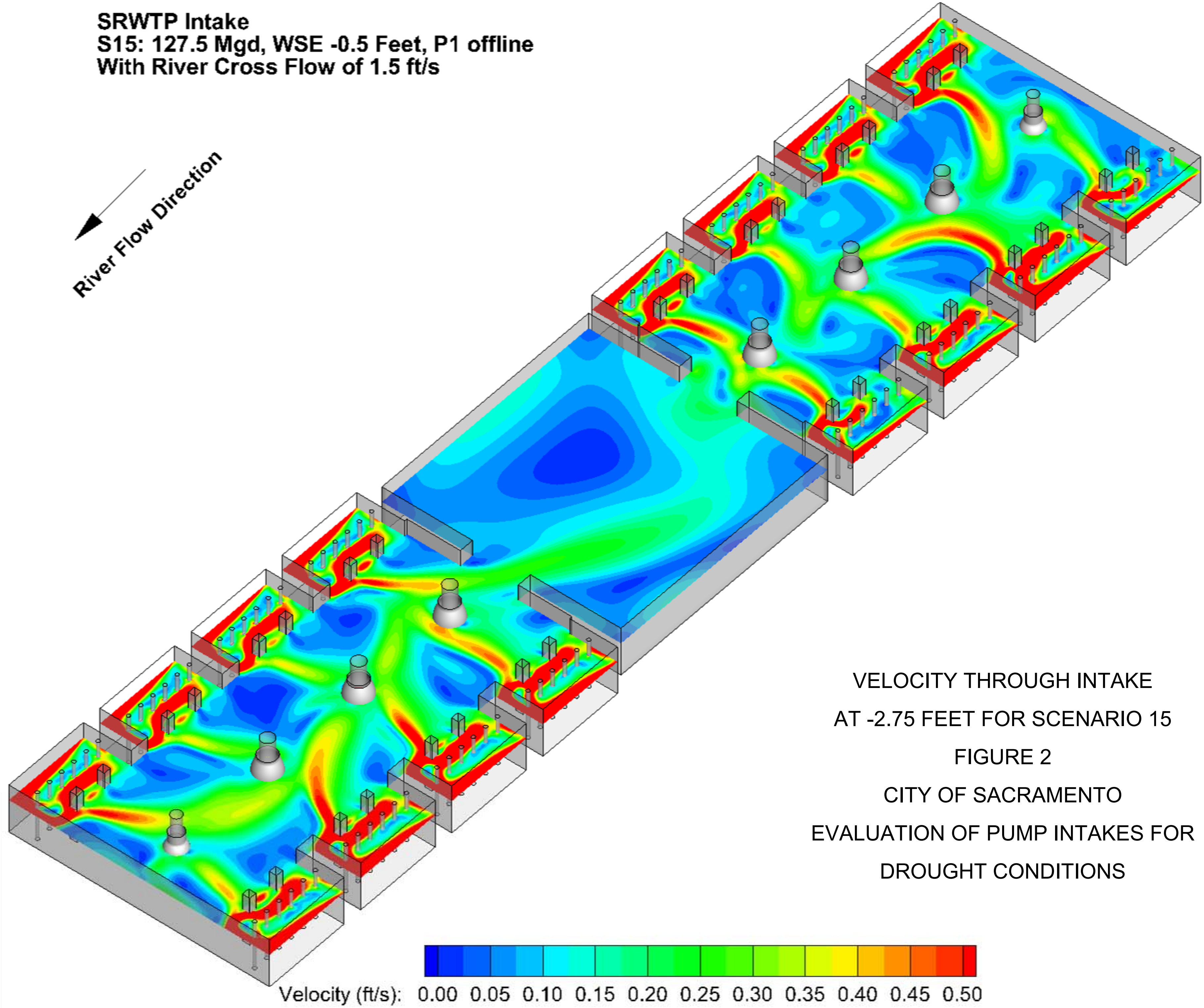
The surface vortex activity increases with decreasing depth, as expected. Figure 5, Figure 6, and Figure 7 show surface vortex development near operating pumps for Scenarios 15, 18, and 21, respectively. In all cases, there are surface vortices near operating pumps. It is unclear how stable they will be with the turbulence levels in the intake.

One model run variation was performed for Scenario 15, with the cross flow increased to 3.0 ft/s (two times the assumed cross flow for the base scenarios). The results are summarized in Table 8. Doubling the cross flow led to maximum flow rotation increase of 37 percent, and 27 percent increase in turbulence levels. The value for 1.5 ft/s was used for subsequent modification testing, as the model did not include any straightening influence of the wedge wire.

Table 6 SRWTP Screen Flow Percentage	
Screen	**Percent of Flown**
1L	5.95
1R	5.95
2L	7.57
2R	4.86
3L	7.57
3R	4.86
4L	8.11
4R	5.41
5L	4.86
5R	5.41
6L	7.03
6R	5.41
7L	10.81
7R	5.95
8L	3.78
8R	6.49

Table 7	Initial SRWTP Test Results						
Scenario	**Pump No.**	**Q (gpm)**	**V_{max}/V_{avg}**	**V_{min}/V_{avg}**	**α_{max}**	**α_{min}**	**Ti**
S13[1]	2	14,474	1.01	0.99	2.0	-3.0	0.09
	3	14,474	1.01	0.99	1.5	-2.6	0.09
	4	14,474	1.01	0.99	2.5	1.7	0.09
	5	14,474	1.01	0.99	0.2	-2.0	0.10
	6	14,474	1.00	1.00	3.4	-4.1	0.10
	7	14,474	1.01	0.99	4.3	-5.0	0.13
	8	7,237	1.01	0.99	2.5	-0.9	0.10
S14[1]	2	14,181	1.01	0.99	1.9	-2.3	0.10
	3	14,181	1.00	1.00	0.6	-0.9	0.09
	4	14,181	1.01	1.00	4.8	3.0	0.11
	5	14,181	1.01	0.98	0.5	-1.4	0.10
	6	14,181	1.00	0.99	2.1	-0.7	0.09
	7	14,181	1.01	0.99	4.0	-4.2	0.13
	8	7,090	1.01	0.99	6.5	5.1	0.16
S15[1]	2	13,620	1.01	0.99	3.4	-4.3	0.12
	3	13,620	1.01	0.99	0.8	-1.9	0.10
	4	13,620	1.01	1.00	6.8	5.0	0.15
	5	13,620	1.01	0.98	2.9	1.8	0.10
	6	13,620	1.01	0.98	1.8	-2.9	0.10
	7	13,620	1.01	0.99	4.2	-4.6	0.13
	8	6,810	1.01	0.99	6.7	6.0	0.14
S16[1]	5	15,970	1.01	0.99	1.8	-0.6	0.10
	6	15,970	1.01	0.99	3.3	-3.7	0.09
S17[1]	5	15,623	1.01	0.98	1.8	-0.6	0.12
	6	15,623	1.00	0.99	3.9	-3.7	0.09
S18[1]	5	15,015	1.01	0.98	2.4	-1.1	0.12
	6	15,015	1.00	0.99	4.4	-4.2	0.10
S21[1]		15,623	1.00	1.00	5.0	-5.5	0.08

Notes
(1) Only operating pumps listed



VELOCITY THROUGH INTAKE

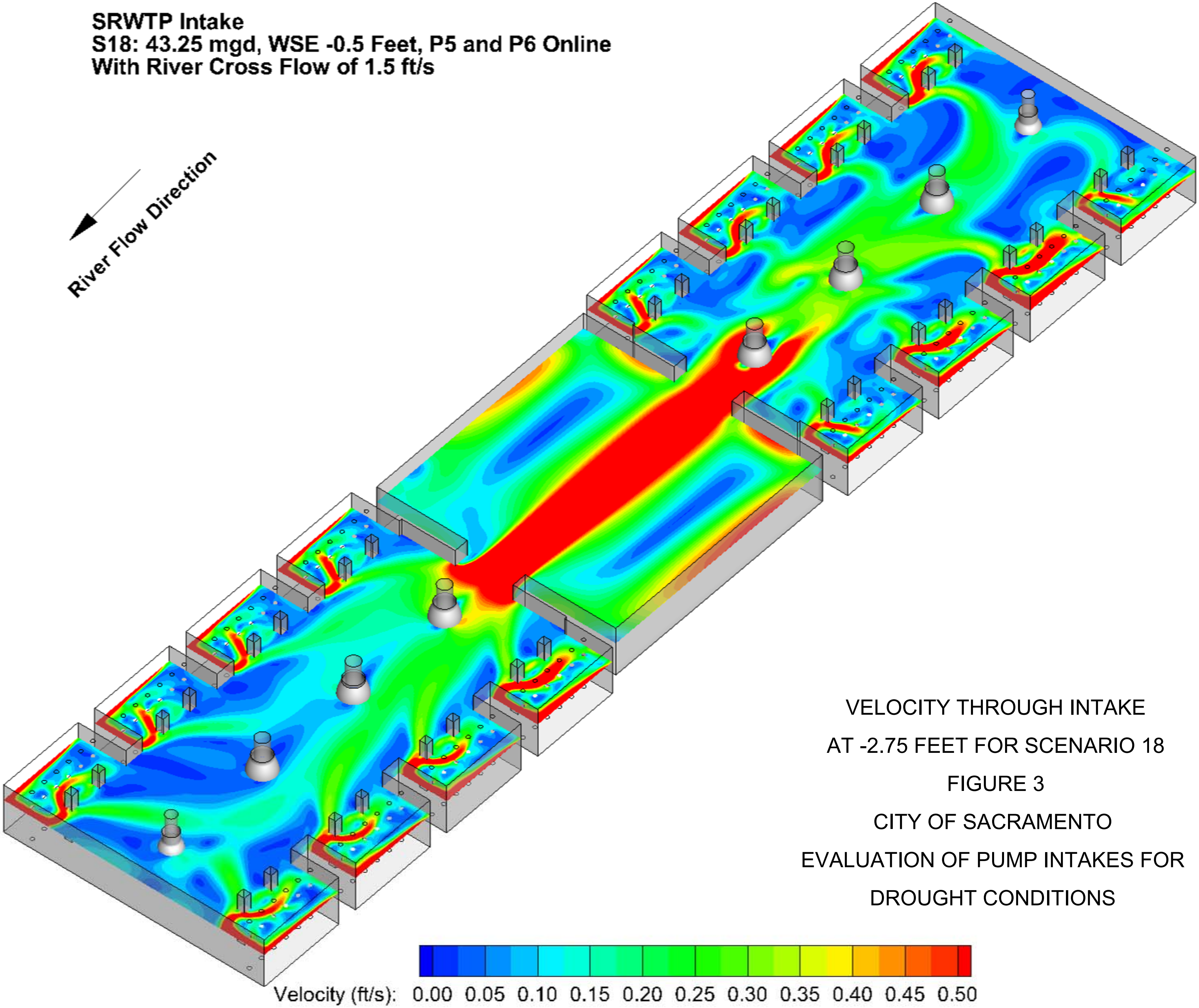
AT -2.75 FEET FOR SCENARIO 15

FIGURE 2

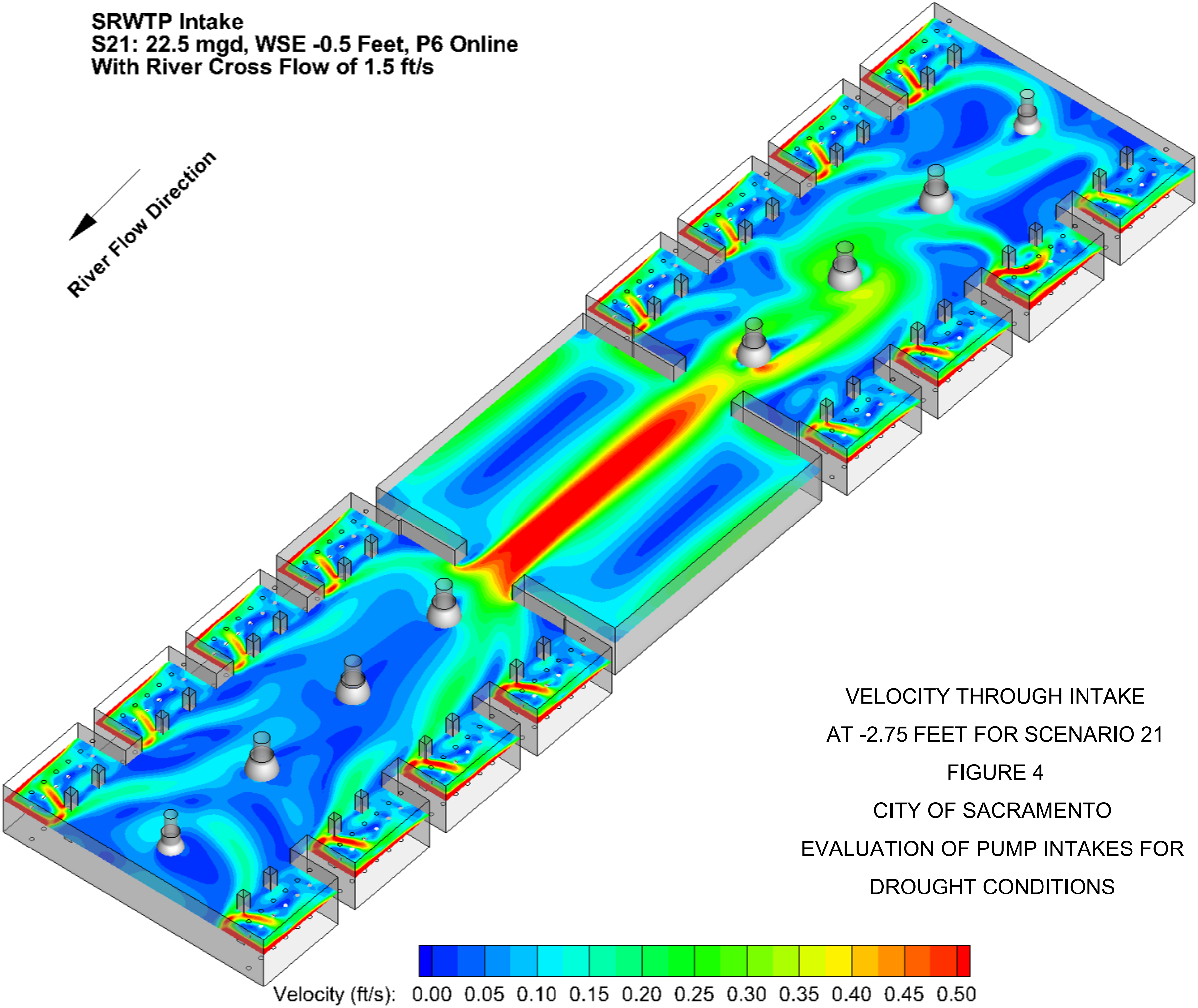
CITY OF SACRAMENTO

EVALUATION OF PUMP INTAKES FOR

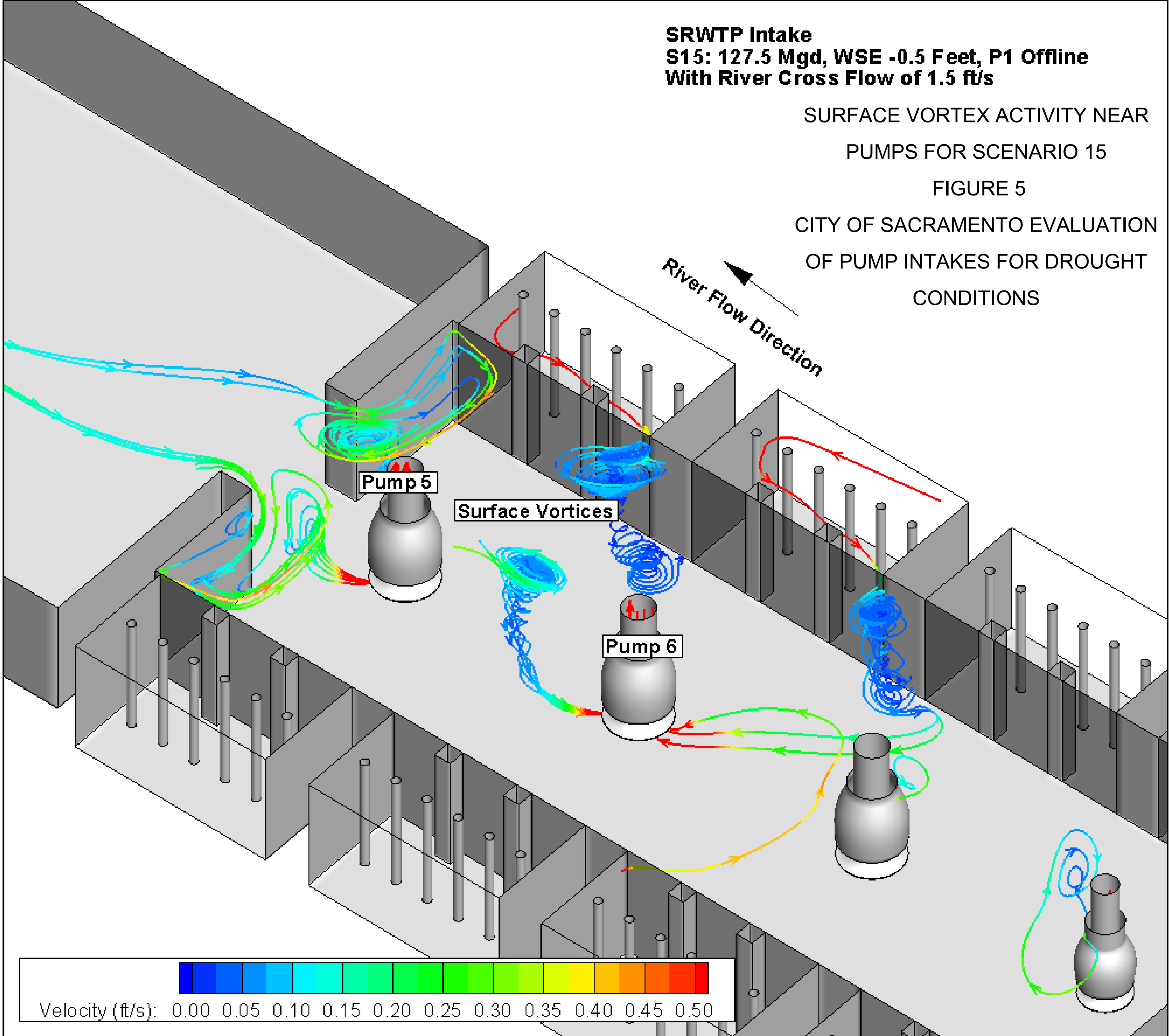
DROUGHT CONDITIONS

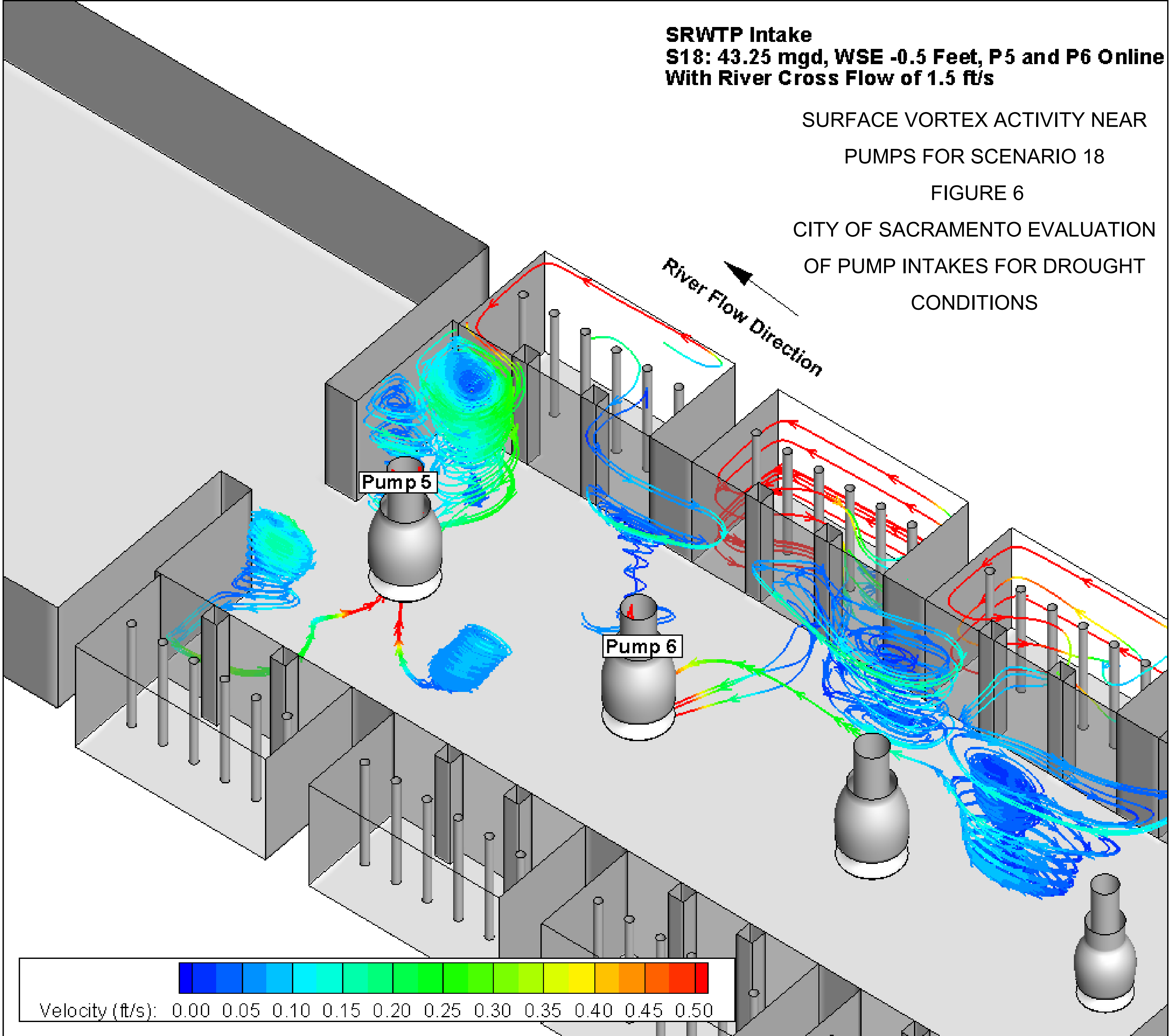


VELOCITY THROUGH INTAKE
AT -2.75 FEET FOR SCENARIO 18
FIGURE 3
CITY OF SACRAMENTO
EVALUATION OF PUMP INTAKES FOR
DROUGHT CONDITIONS



VELOCITY THROUGH INTAKE
AT -2.75 FEET FOR SCENARIO 21
FIGURE 4
CITY OF SACRAMENTO
EVALUATION OF PUMP INTAKES FOR
DROUGHT CONDITIONS

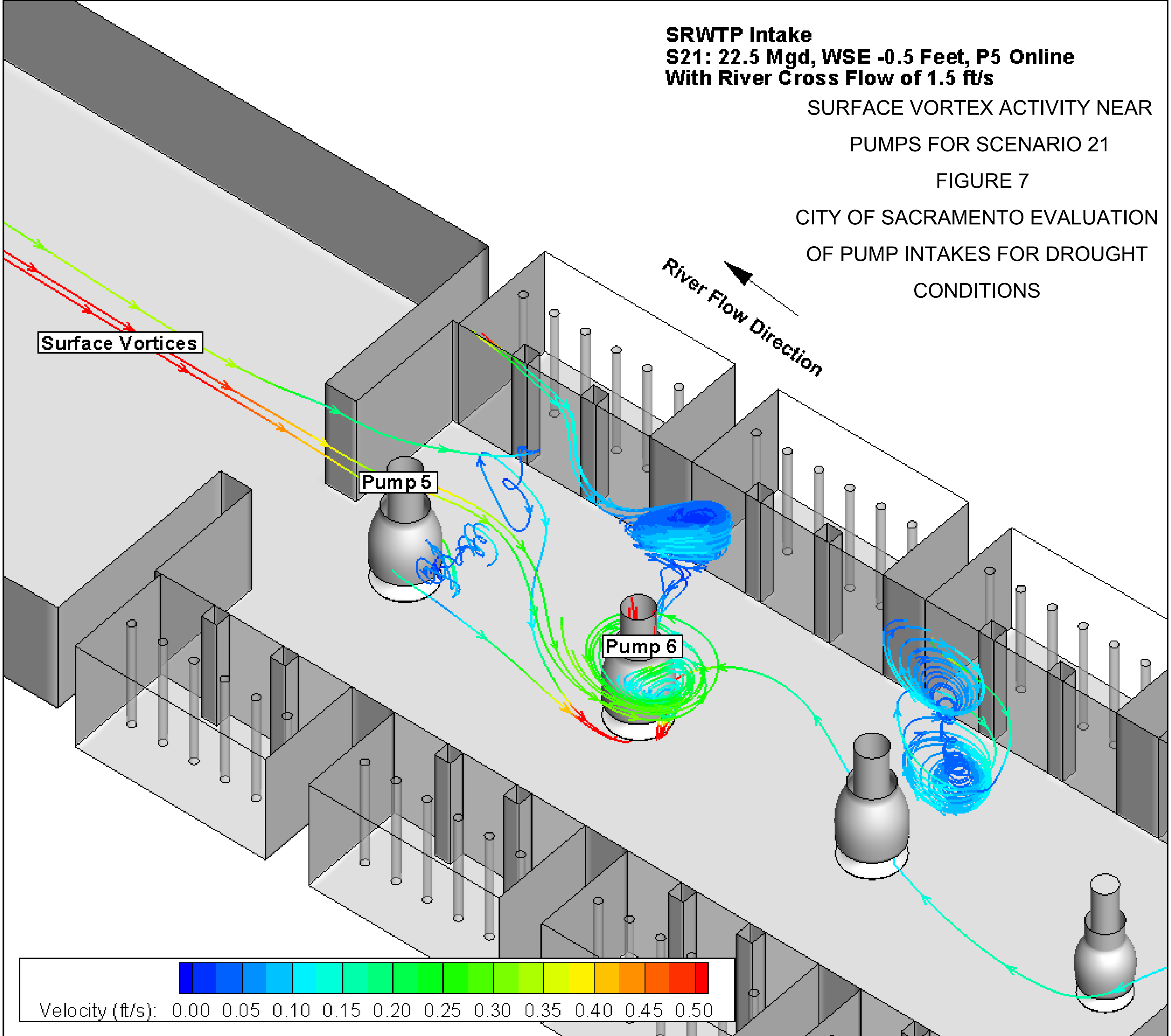

SRWTP Intake
S15: 127.5 Mgd, WSE -0.5 Feet, P1 Offline
With River Cross Flow of 1.5 ft/s
SURFACE VORTEX ACTIVITY NEAR
PUMPS FOR SCENARIO 15
FIGURE 5
CITY OF SACRAMENTO EVALUATION
OF PUMP INTAKES FOR DROUGHT
CONDITIONS
River Flow Direction
Pump 5
Surface Vortices
Pump 6
Velocity (ft/s): 0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 18

FIGURE 6

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 21

FIGURE 7

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS

Table 8	Cross Flow Sensitivity Test						
Scenario	**Pump No.**	**Q (gpm)**	V_{max}/V_{avg}	V_{min}/V_{avg}	α_{max}	α_{min}	**Ti**
S15_2x[1]	2	13,620	1.01	0.99	4.1	-5.1	0.15
	3	13,620	1.01	0.99	0.6	-0.6	0.11
	4	13,620	1.01	0.99	8.2	7.0	0.18
	5	13,620	1.00	1.00	8.7	8.2	0.17
	6	13,620	1.01	0.99	9.1	-9.3	0.19
	7	13,620	1.01	0.99	8.5	6.1	0.19
	8	6,810	1.02	0.97	7.0	-7.1	0.15

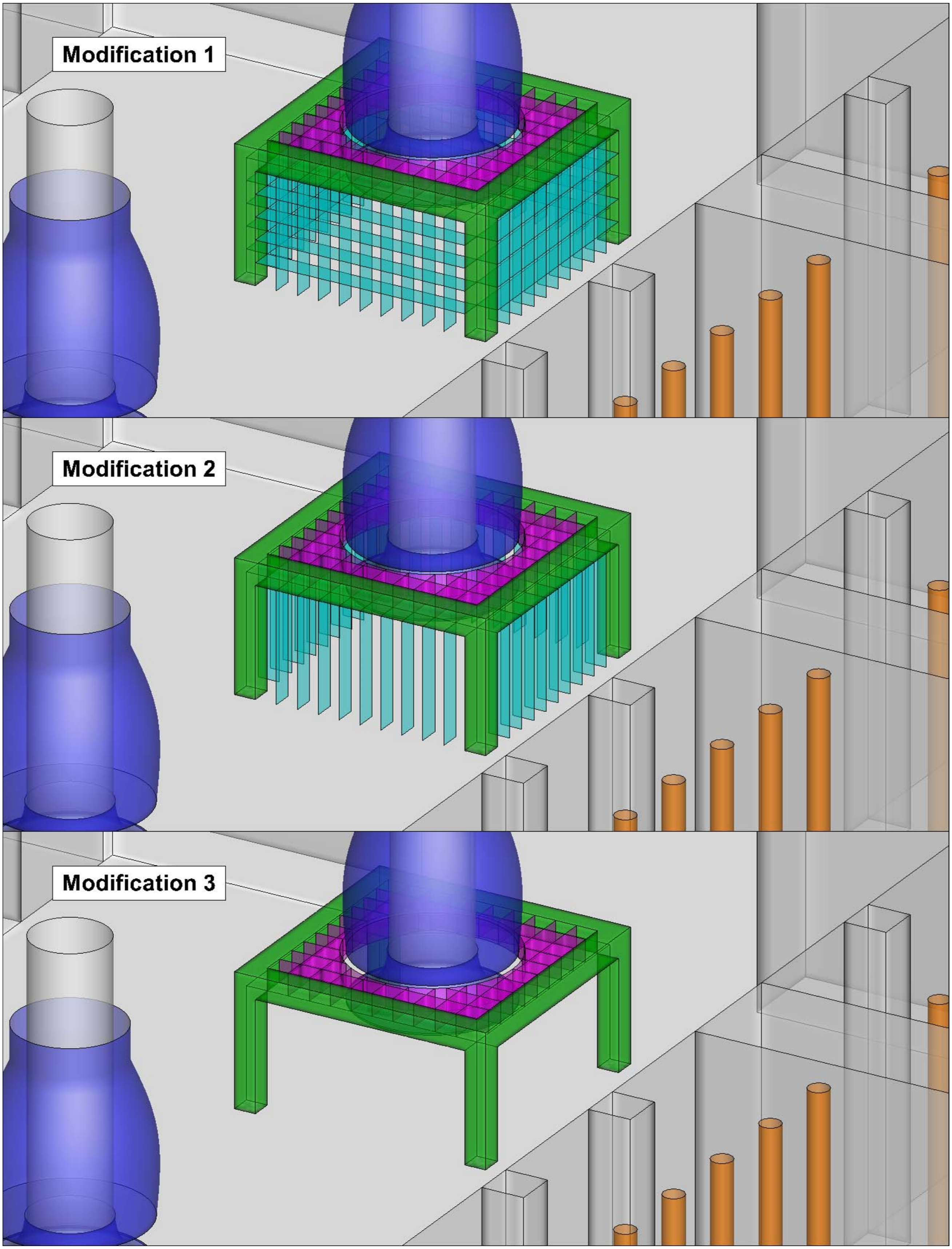
Notes

(1) Only operating pumps listed

4.2.2 Modification Tests

The pumps will not meet HI recommended intake standards at lower water levels due to flow rotation, turbulence levels, and surface vortex formation. Three modifications were evaluated that could be easily installed into the existing structure to improve the pump intake hydraulics at the lower water levels. The modifications are shown in Figure 8. They are based on a frame around the pump intake that attaches to the floor and contains grating or vanes to improve approach hydraulics to the pumps. Modification 1 (M1) has grating on the top and sides of the frame, modification 2 (M2) has grating on the top of the frame, and vertical vanes on the side, and modification 3 (M3) has grating only on the top. The grating has a square opening, with a depth equal to opening width.

The model was run for the same conditions as previously evaluated, and the results are summarized in Table 9. Modifications 1 and 2 significantly reduce flow rotation and turbulence levels at the pump intake. Modification 3 reduces flow rotation and turbulence as well, compared to the existing conditions, but the change is less dramatic than seen with modifications 1 and 2.



THREE MODIFICATION DEVICES TESTED

FIGURE 8

CITY OF SACRAMENTO

EVALUATION OF PUMP INTAKES FOR

DROUGHT CONDITIONS

Table 9	SRWTP Modification Test Results						
Scenario	**Pump No.**	**Q (gpm)**	**V_{max}/V_{avg}**	**V_{min}/V_{avg}**	**α_{max}**	**α_{min}**	**Ti**
S15M1[1]	2	13,620	1.00	1.00	0.2	-1.8	0.04
	3	13,620	1.00	1.00	0.6	-1.3	0.04
	4	13,620	1.00	1.00	0.4	-0.6	0.04
	5	13,620	1.00	1.00	0.5	0.0	0.04
	6	13,620	1.00	1.00	1.4	-1.6	0.04
	7	13,620	1.00	0.99	1.8	-3.1	0.04
	8	6,810	1.00	0.99	1.1	-1.3	0.10
S15M2[1]	2	13,620	1.00	1.00	0.4	-1.6	0.05
	3	13,620	1.00	1.00	0.7	-1.6	0.05
	4	13,620	1.00	1.00	0.7	-0.8	0.05
	5	13,620	1.00	1.00	0.7	-0.3	0.05
	6	13,620	1.00	1.00	1.3	-1.8	0.05
	7	13,620	1.00	0.99	1.8	-2.6	0.05
	8	6,810	1.00	0.99	1.2	-1.4	0.10
S15M3[1]	2	13,620	1.01	0.99	2.2	-2.8	0.08
	3	13,620	1.00	1.00	0.4	-2.1	0.08
	4	13,620	1.00	1.00	0.9	-0.7	0.07
	5	13,620	1.00	0.99	3.7	2.9	0.09
	6	13,620	1.01	0.99	2.9	-3.6	0.12
	7	13,620	1.00	0.99	0.8	0.4	0.08
	8	6,810	1.00	1.00	7.4	-7.5	0.16
S18M1[1]	5	15,015	1.00	1.00	0.8	-1.1	0.04
	6	15,015	1.00	1.00	1.3	-1.3	0.04
S18M2[1]	5	15,015	1.00	1.00	1.3	-2.3	0.05
	6	15,015	1.00	1.00	1.6	-1.9	0.05
S18M3[1]	5	15,015	1.01	0.99	1.1	-0.4	0.08
	6	15,015	1.00	1.00	4.1	-4.2	0.09
S21M1[1]	6	15,623	1.00	1.00	1.3	-1.5	0.03
S21M2[1]	6	15,623	1.00	1.00	1.0	-1.3	0.04
S21M3[1]	6	15,623	1.00	1.00	4.2	-4.1	0.06

Notes

(1) Only operating pumps listed

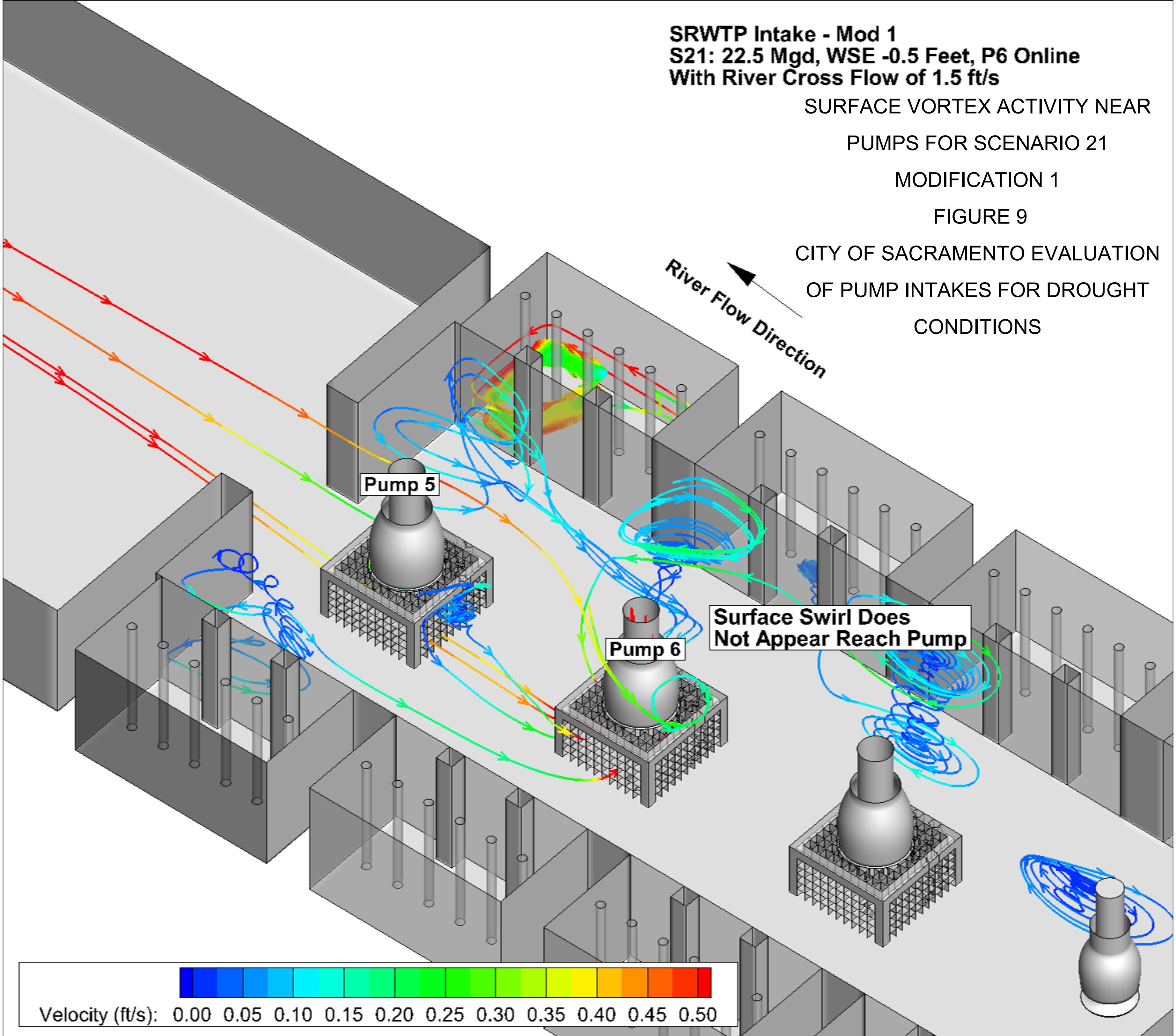
The WSE -0.5 feet Scenario 21 was used to evaluate surface vortex formation and extents. Figure 9 shows that with modification 1, surface swirl is present but appears to diffuse before the grating structure. Figure 10 shows that with modification 2, the surface swirl may be a little more intense. Figure 11 shows that with modification 3, surface swirling exists but does not appear to reach the pumps. All three modifications appear to reduce the likelihood of surface vortices reaching the pump intakes.

Since the drought minimum water level of -0.5 feet MSL is potentially conservative, the model was additionally run at WSE 0.0 feet MSL with modification 3, as it had slightly more variability in the HI metrics than modifications 1 and 2. The results are summarized in Table 10 The intake hydraulics are better than the initial runs and the HI results fall between the results at WSE's -0.5 and 0.8 feet.

Table 10 SRWTP Modification 3 Test Results at WSE 0.0 Feet

Scenario	Pump No.	Q (gpm)	V_{max}/V_{avg}	V_{min}/V_{avg}	α_{max}	α_{min}	Ti
M3[1]	2	13,836	1.01	0.99	0.7	-1.6	0.07
	3	13,836	1.00	1.00	0.7	-0.4	0.07
	4	13,836	1.00	1.00	0.5	-1.3	0.06
	5	13,836	1.01	1.00	1.0	0.4	0.07
	6	13,836	1.01	1.00	2.3	-2.2	0.09
	7	13,836	1.00	1.00	0.9	-0.5	0.07
	8	6,918	1.01	0.98	2.9	-2.8	0.09
M3[1]	5	15,249	1.00	0.99	1.0	-0.5	0.08
	6	15,249	1.00	1.00	2.8	-2.7	0.08
M3[1]	6	15,756	1.00	1.00	3.6	-4.2	0.07

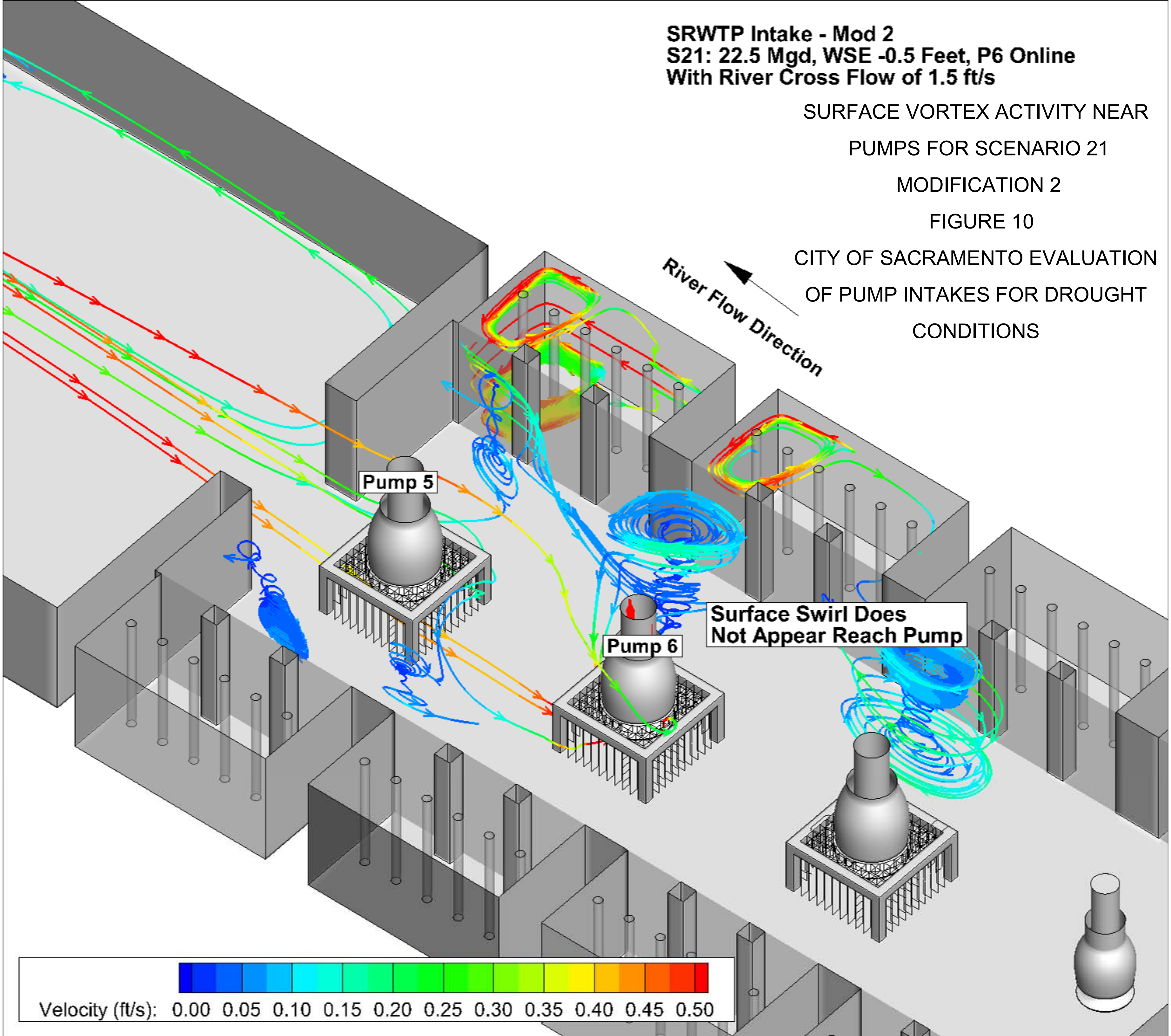
Notes
(1) Only operating pumps listed



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 21 MODIFICATION 1

FIGURE 9

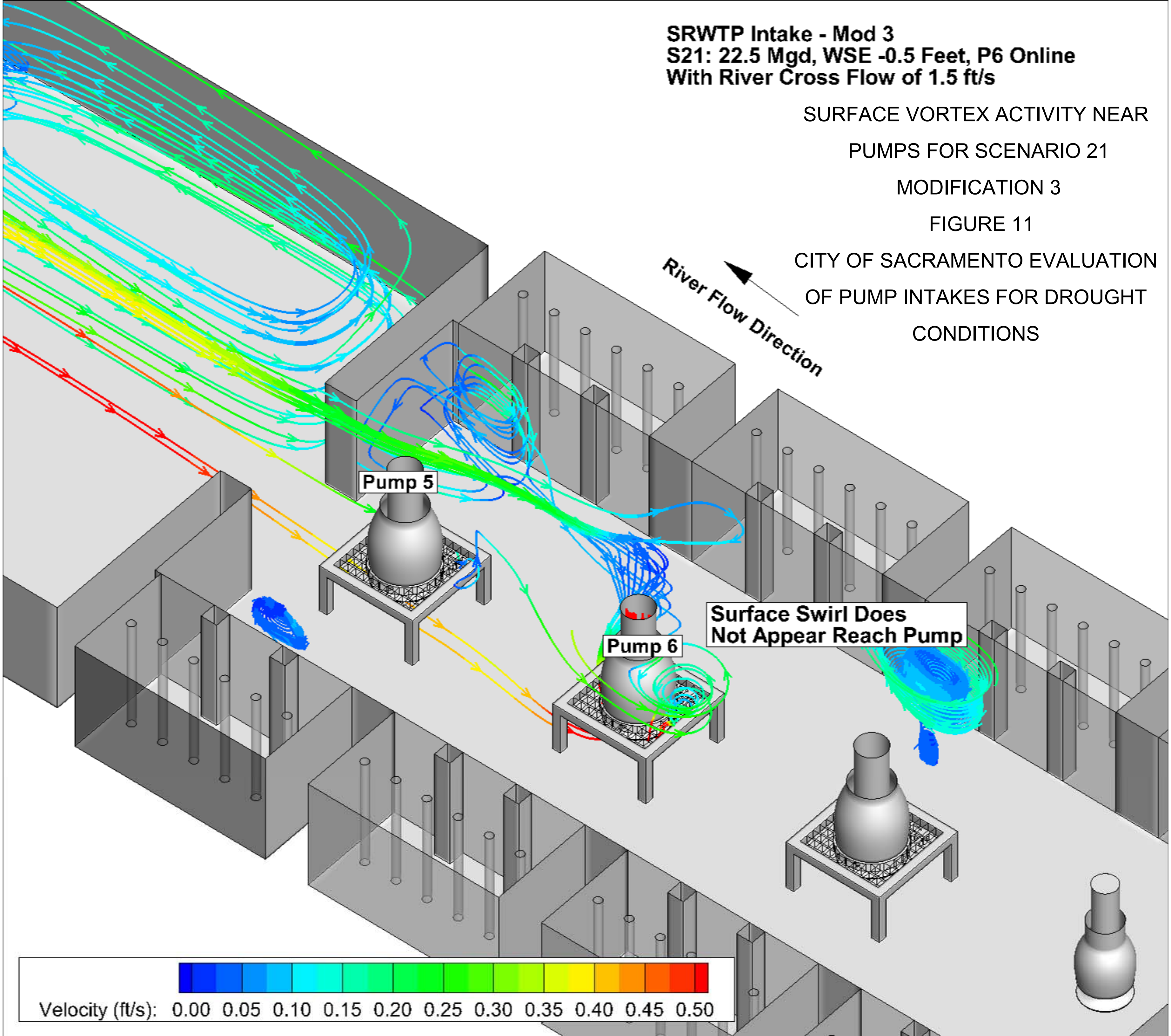
CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 21 MODIFICATION 2

FIGURE 10

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 21 MODIFICATION 3

FIGURE 11

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS

Based on the model results, modification 1 was selected as it showed the best overall performance improvement for the conditions modeled. Additional tests were conducted to determine the best combination of pumps to install the modification if it is not installed for all pumps. Configuration 1 (C1) adds the modification to Pumps 2, 3, 6, and 7. Configuration 2 (C2) adds the modification to Pumps 2, 4, 5, and 7. Both scenarios were tested at a WSE of 0.0 feet MSL for a seven pump operation at a total intake flow of 129.5 mgd, and four pump operation (S22) at a total intake flow of 90 mgd.

The model results are summarized in Table 11. Configuration C1 had slightly better results with lower turbulence levels at the pump intake. Figure 12 and Figure 13 compare vortex activity between the scenarios for the seven pump operating condition. Overall there appears to be more vortex activity in the vicinity of pump 6. Based on these results, configuration 1 is preferable over configuration 2.

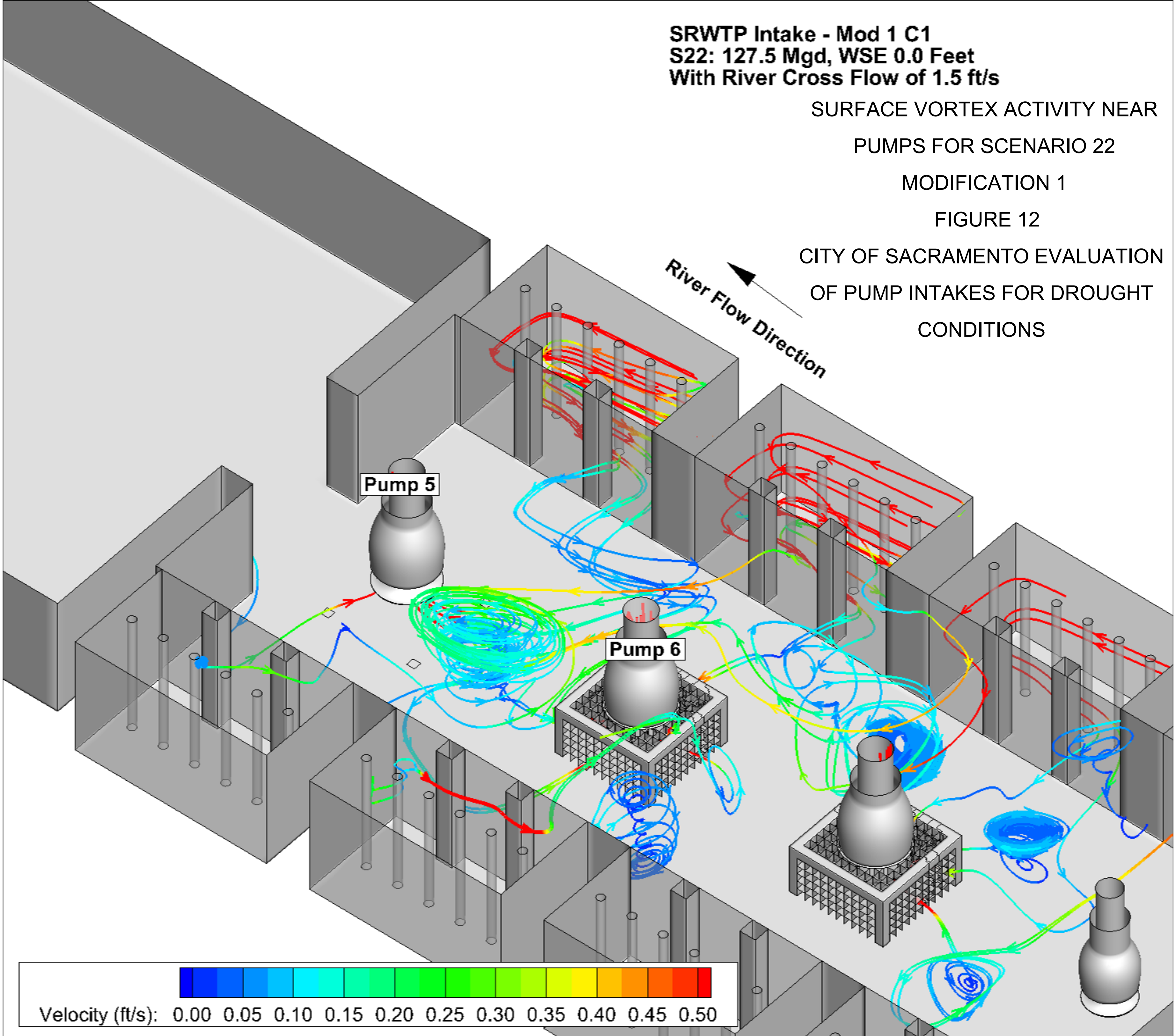
4.2.3 <u>Modification Design</u>

Preliminary drawings for the recommended vortex breakers are included in Appendix D.

Table 11	SRWTP Modification 1 Installed on Select Pumps						
Scenario	**Pump No.**	**Q (gpm)**	**V_{max}/V_{avg}**	**V_{min}/V_{avg}**	**α_{max}**	**α_{min}**	**Ti**
S25C1M1[1]	2	15,623	1.00	1.00	0.3	-0.2	0.04
	3	15,623	1.00	1.00	0.3	-0.4	0.04
	6	15,623	1.00	1.00	0.3	-0.2	0.04
	7	15,623	1.00	1.00	0.3	-0.4	0.04
S22C1M1[1]	2	13,836	1.00	1.00	0.3	-0.8	0.04
	3	13,836	1.00	1.00	0.4	-0.5	0.04
	4	13,836	1.00	0.99	0.3	-0.2	0.08
	5	13,836	1.00	1.00	0.3	-0.1	0.09
	6	13,836	1.00	1.00	1.4	-1.3	0.04
	7	13,836	1.00	1.00	0.6	-0.8	0.04
	8	6,918	1.01	0.98	2.7	-2.8	0.09
S25C2M1[1]	2	15,623	1.00	1.00	0.3	-0.4	0.04
	4	15,623	1.00	1.00	0.3	-0.3	0.04
	5	15,623	1.00	1.00	0.5	-0.2	0.04
	7	15,623	1.00	1.00	0.4	-0.2	0.04
S22C2M1[1]	2	13,836	1.00	1.00	0.3	-0.9	0.04
	3	13,836	1.00	1.00	0.5	-0.3	0.09
	4	13,836	1.00	1.00	0.4	-0.5	0.04
	5	13,836	1.00	1.00	0.7	-0.1	0.04
	6	13,836	1.01	0.99	1.2	-1.2	0.10
	7	13,836	1.00	1.00	0.7	-0.8	0.04
	8	6,918	1.01	0.98	2.8	-2.8	0.09

Notes

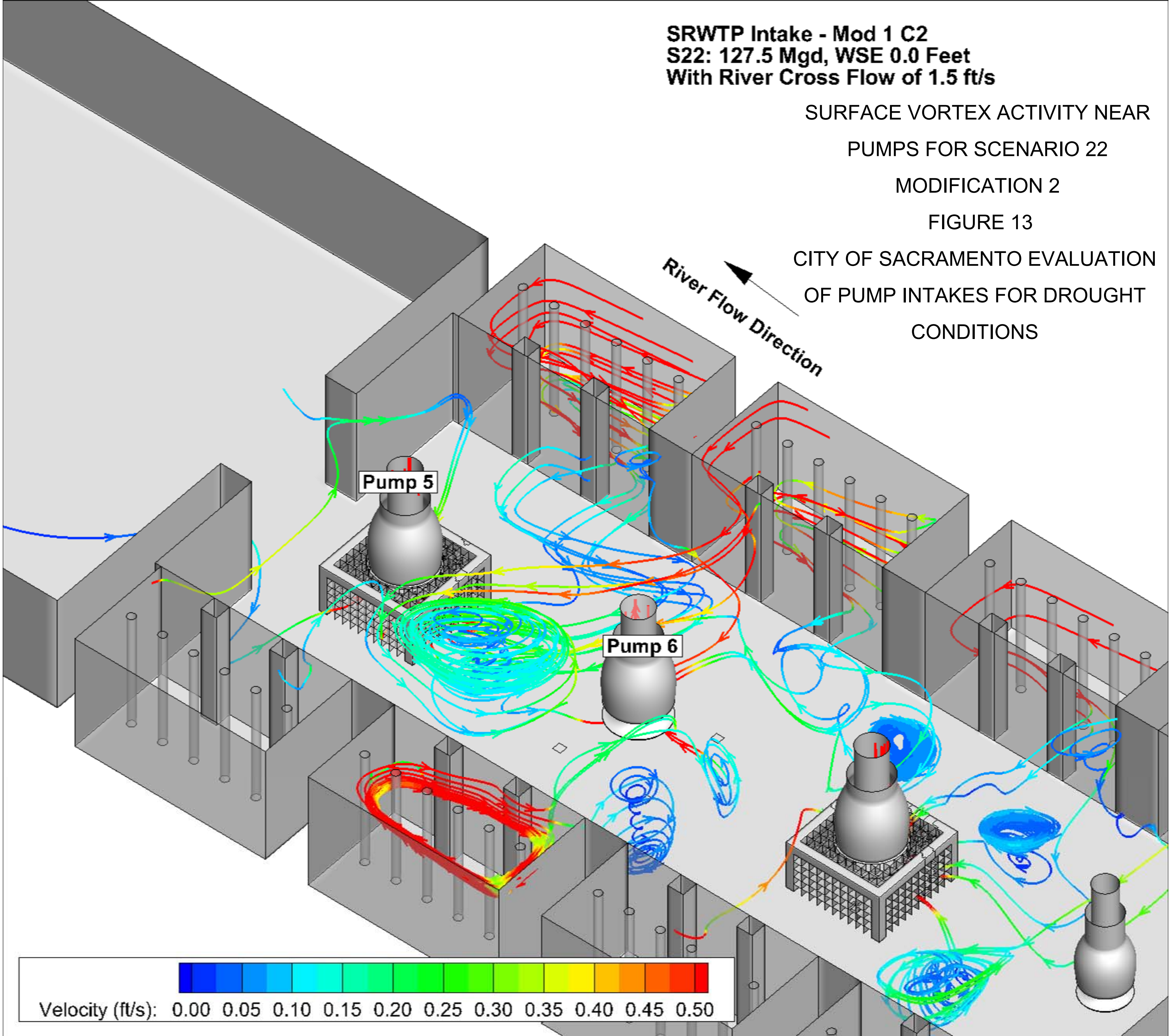
(1) Only operating pumps listed



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 22 MODIFICATION 1

FIGURE 12

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS



SURFACE VORTEX ACTIVITY NEAR PUMPS FOR SCENARIO 22 MODIFICATION 2

FIGURE 13

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS

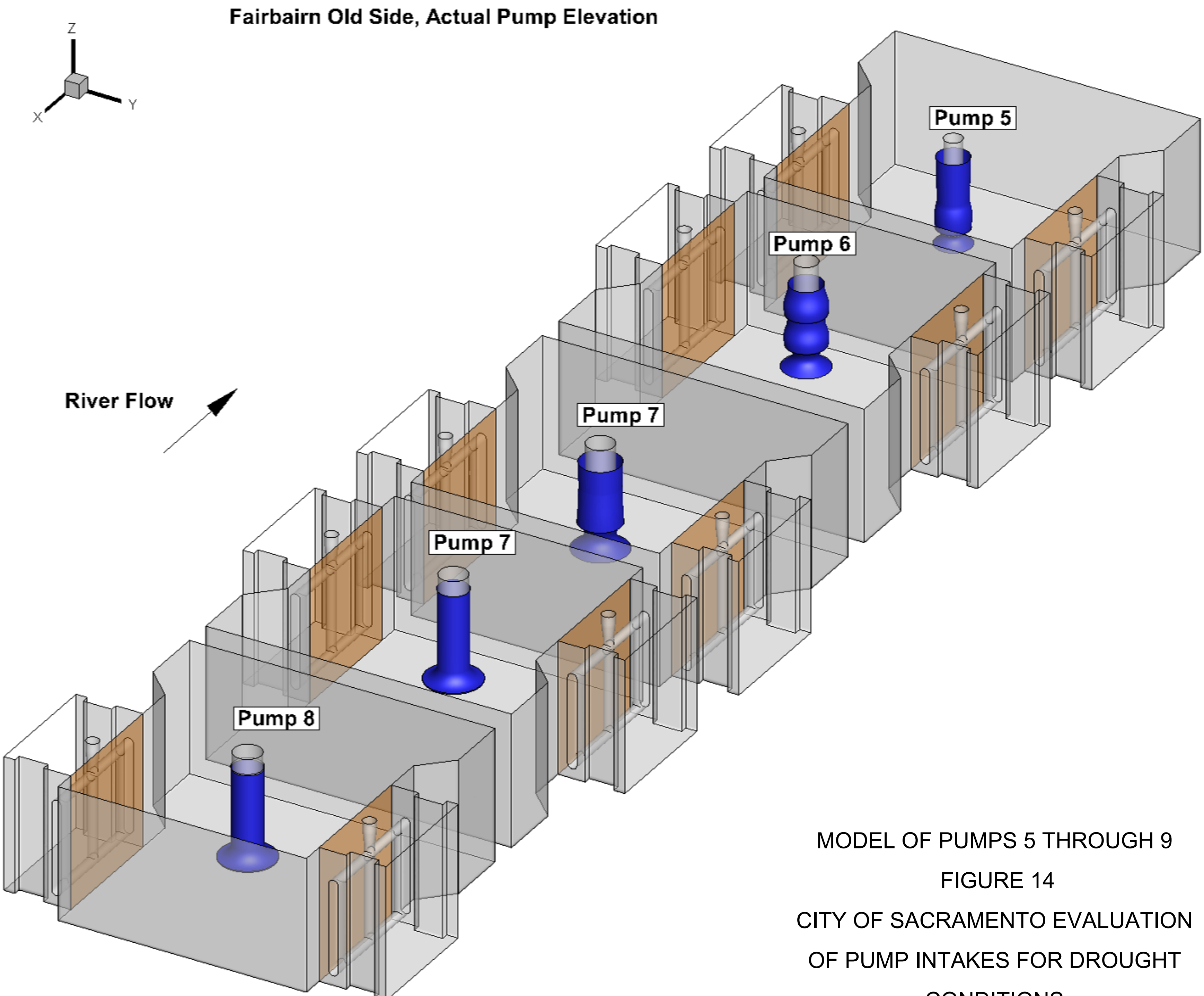
4.3 EAFWTP INTAKE

4.3.1 Existing Configuration

The existing configuration was modeled for one condition at the minimum drought water level of 10 feet MSL. The old side with pumps 5 through 9 is shown in Figure 14, and the new side with pumps 1 through 3 is shown in Figure 15. The model was run with all pumps to evaluate system hydraulics and the results are shown in Table 12 and graphically in Figure 16 and Figure 17. The model results are within HI standards for all metrics with the exception of turbulence levels, which are slightly high. The model results do show some surface vortex activity on the old side, as well as on the new side.

Table 12 Initial EAFWTP Test Results

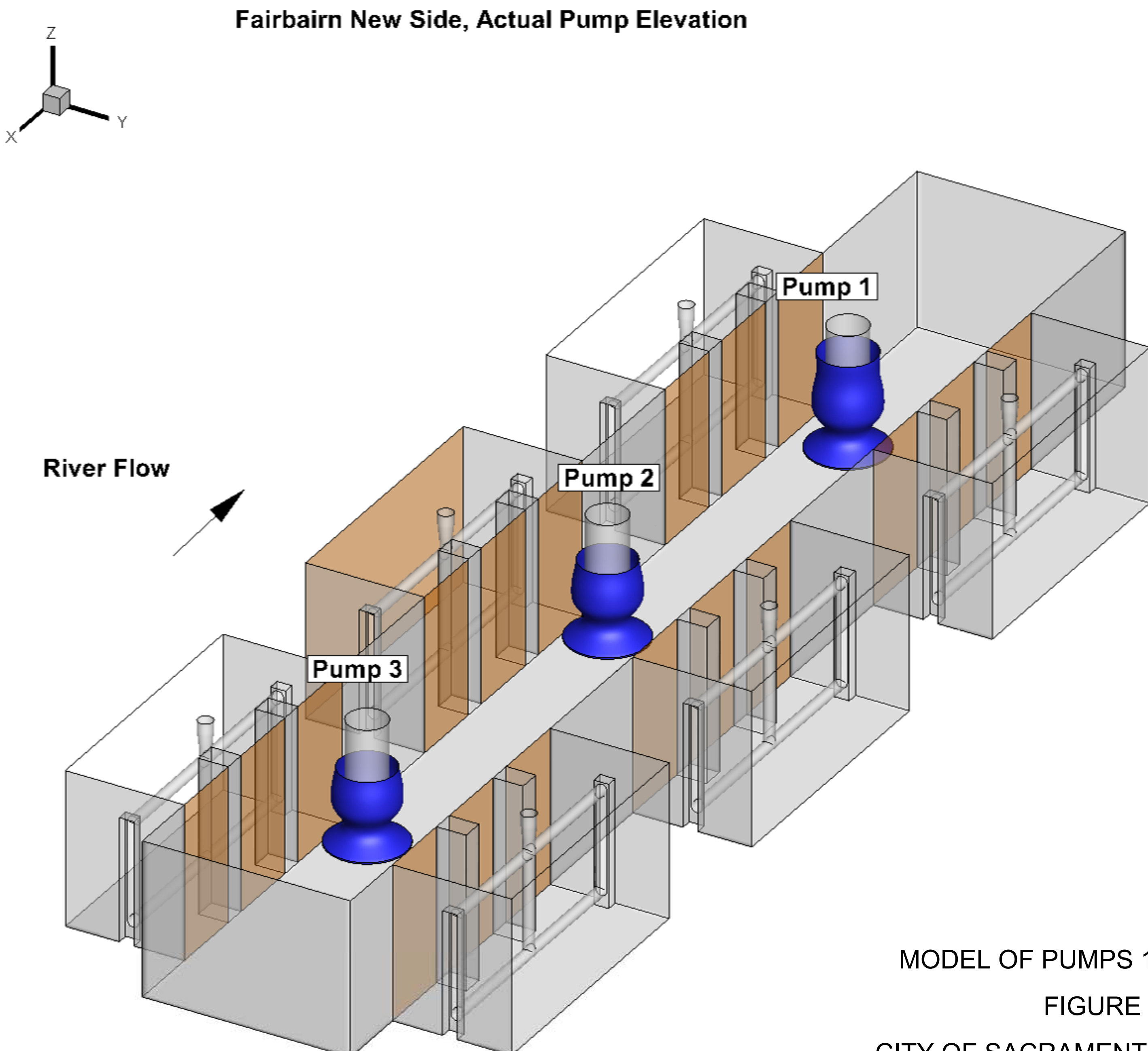
Scenario	Pump No.	Q (gpm)	V_{max}/V_{avg}	V_{min}/V_{avg}	α_{max}	α_{min}	Ti
Initial	1	20,500	1.01	0.99	0.5	-0.3	0.10
	2	20,500	1.01	0.99	0.9	0.1	0.09
	3	20,500	1.00	0.99	0.6	-0.6	0.10
	4	6,800	1.01	0.99	4.0	2.8	0.11
	5	10,400	1.01	0.99	1.7	1.1	0.11
	6	13,500	1.01	0.99	4.9	3.8	0.12
	7	15,800	1.01	0.99	0.2	-0.6	0.10
	8	15,800	1.01	0.98	4.8	2.3	0.11
	9	20,500	1.01	0.99	0.5	-0.3	0.10



MODEL OF PUMPS 5 THROUGH 9

FIGURE 14

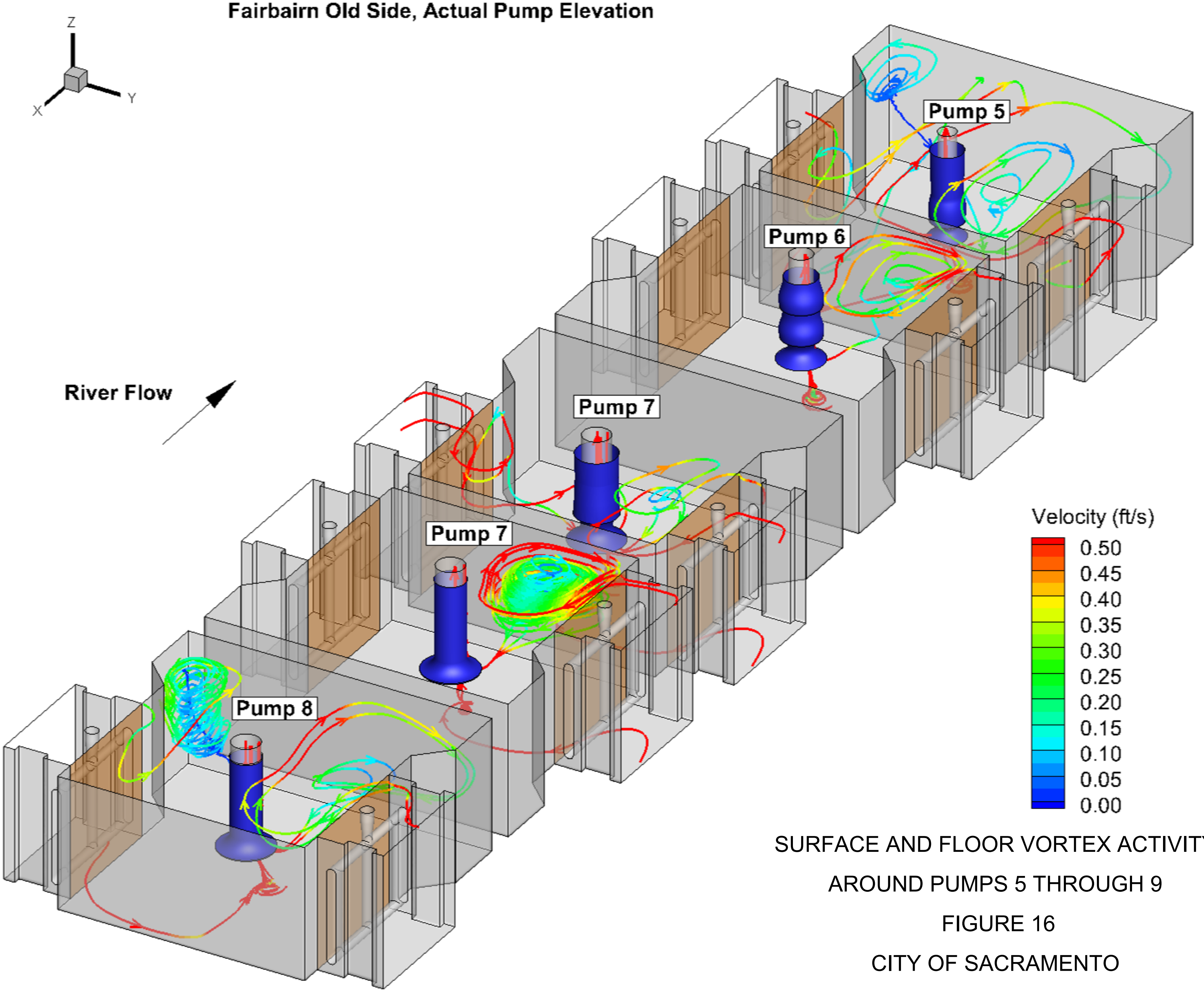
CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS



MODEL OF PUMPS 1 THROUGH 3

FIGURE 15

CITY OF SACRAMENTO EVALUATION OF PUMP INTAKES FOR DROUGHT CONDITIONS



SURFACE AND FLOOR VORTEX ACTIVITY

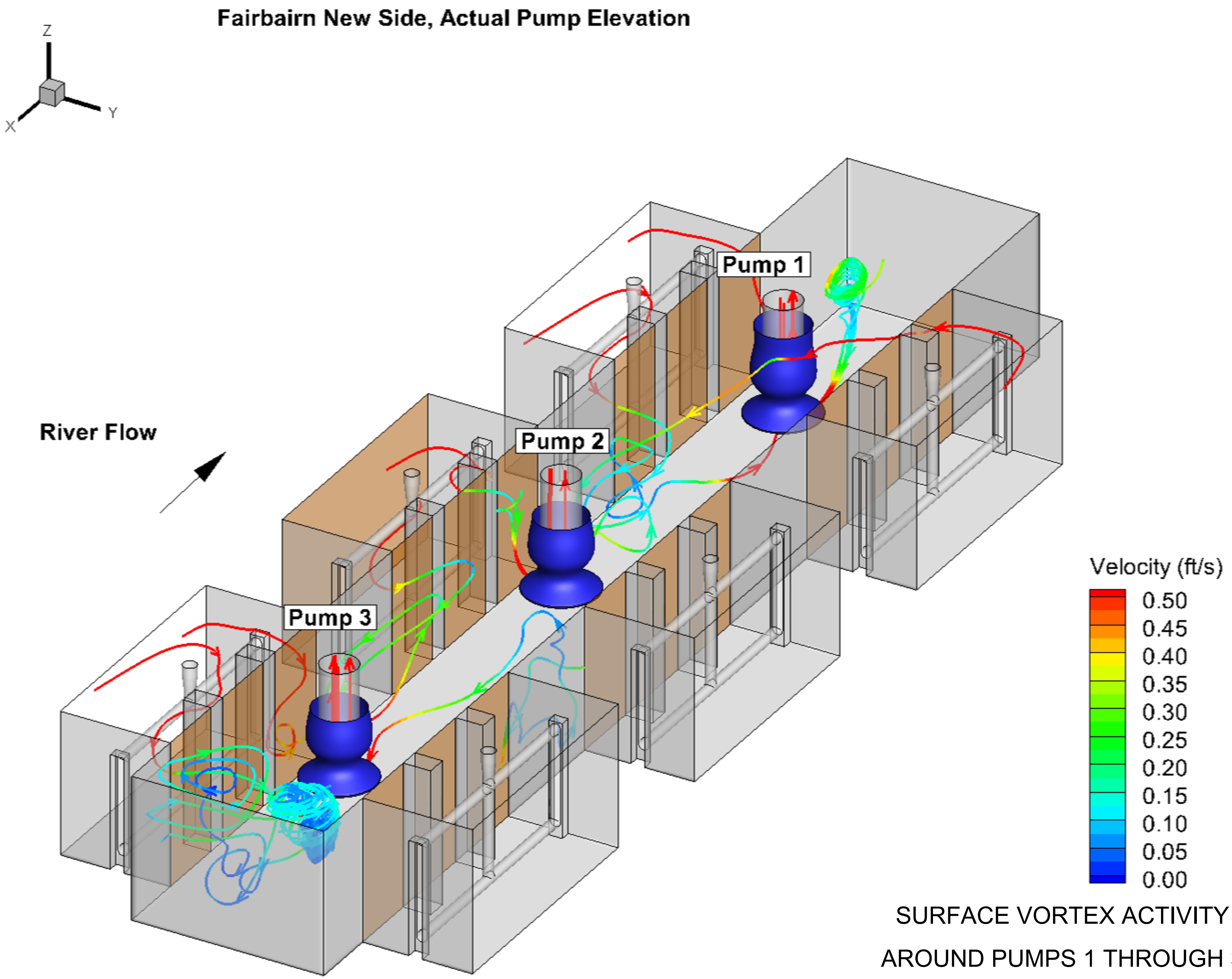
AROUND PUMPS 5 THROUGH 9

FIGURE 16

CITY OF SACRAMENTO

EVALUATION OF PUMP INTAKES FOR

DROUGHT CONDITIONS



SURFACE VORTEX ACTIVITY
AROUND PUMPS 1 THROUGH 3
FIGURE 17
CITY OF SACRAMENTO EVALUATION
OF PUMP INTAKES FOR DROUGHT
CONDITIONS

4.3.2 Modification Test and Design

All of the pumps evaluated are close to their NPSH limits and are recommended to be lowered. In the interim, vortex cages were developed and tested to improve the likelihood of successful interim operation during immediate pumping needs. Pumps 1, 6, and 7 were selected for the interim solution, as they could provide the minimum required flow, had the best NPSH at the low water level, or had been most recently rebuilt. The detail design of the vortex cages is included in Appendix D. It should be noted that City staff fabricated and had cages installed that were similar but not exactly as shown in the drawing developed by Carollo based on their best judgment for fabrication and installation.

The cages were tested in the model and results are summarized in Table 13. In all cases, the cages further improved the hydraulic conditions at the pumps and prevented vortices from entering the pumps.

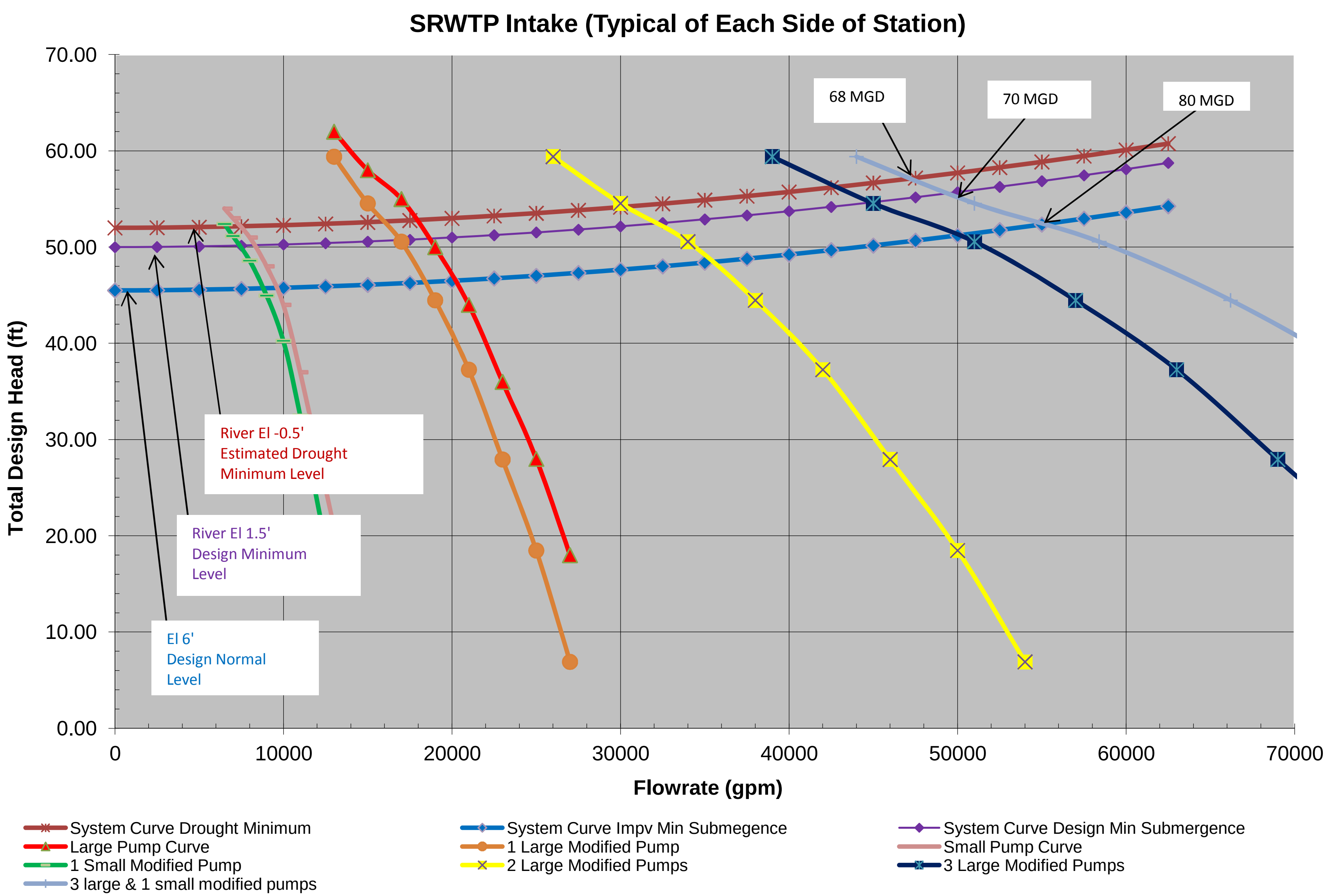
Table 13 Final Fairbairn Test Results

Scenario	Pump No.	Q (gpm)	V_{max}/V_{avg}	V_{min}/V_{avg}	α_{max}	α_{min}	Ti
Initial	1	20,500	1.00	1.00	1.1	-1.1	0.03
	2	---	---	---	---	---	---
	3	---	---	---	---	---	---
	4	---	---	---	---	---	---
	5	10,400	1.00	1.00	1.4	-1.3	0.04
	6	13,500	1.00	1.00	0.8	-0.3	0.03
	7	---	---	---	---	---	---
	8	---	---	---	---	---	---
	9	20,500	1.00	1.00	1.1	-1.1	0.03

5.0 SUMMARY AND CONCLUSIONS

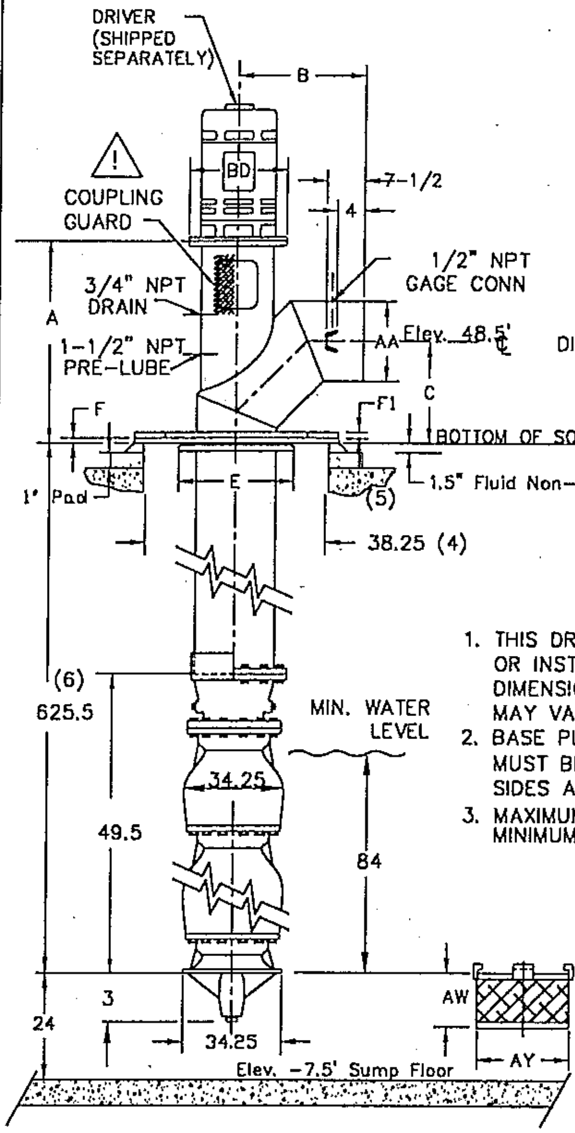
Both the Sacramento River Water Treatment Plant and E. A. Fairbairn Water Treatment Plant Intakes were modeled in detail to evaluate operating the stations below minimum design water levels. For both intakes, modeling showed that as the water level drops below the design minimum, the pump intake hydraulics fall outside of the Hydraulic Institute recommended levels. CFD modeling shows the addition of vaned grating structures around the pump intakes improve the intake hydraulic conditions sufficiently to meet HI recommended levels down to the target drought river levels at both intakes. The vaned grating structures can be attached to the floor, and reduce flow rotation and turbulence level at the pump intake. In addition, the vaned grating structures reduce the possibility of surface vortices from reaching the pump inlets. The pumps at the EAFWTP Intake should be lowered to improve the submergence and NPSH as soon as possible if the drought water levels are going to become a more common operating condition.

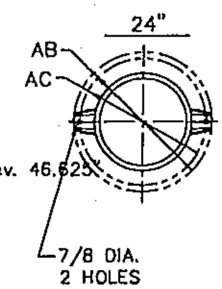
APPENDIX A – PUMP AND SYSTEM CURVES

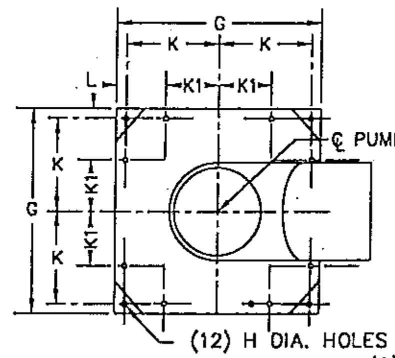

SRWTP Intake (Typical of Each Side of Station)
Total Design Head (ft)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Flowrate (gpm)
0
10000
20000
30000
40000
50000
60000
70000
68 MGD
70 MGD
80 MGD
River El -0.5'
Estimated Drought
Minimum Level
River El 1.5'
Design Minimum
Level
El 6'
Design Normal
Level
System Curve Drought Minimum
System Curve Impv Min Submegence
System Curve Design Min Submergence
Large Pump Curve
1 Large Modified Pump
Small Pump Curve
1 Small Modified Pump
2 Large Modified Pumps
3 Large Modified Pumps
3 large & 1 small modified pumps

SRWTP Pumps 1, 8

DISCHARGE HEAD DIMENSIONS															
DISCH SIZE	COL SIZE	A "BD" DIM 30.5	B	C	E	F	F1	G	H	K	K1	L	AA	AB	AC
24	24	62.88	34	22.5	28	1.5	1	78	1.38	34.5	12	4.5	24	33	30.5







PLAN VIEW OF SOLE PLATE (2)

1. THIS DRAWING NOT FOR CONSTRUCTION OR INSTALLATION UNLESS CERTIFIED. DIMENSIONS SHOWN ARE TYPICAL AND MAY VARY DUE TO VARIOUS TOLERANCES.
2. BASE PLATE (OR OPTIONAL SOLE PLATE) MUST BE SUPPORTED ON ALL FOUR (4) SIDES AND GROUTED IN PLACE.
3. MAXIMUM SUBMERGENCE REQUIRED AT MINIMUM FLOW.
4. MINIMUM DIAMETER REQUIRED TO REMOVE BOWL ASSEMBLY
5. DETAIL SHOWN FOR ILLUSTRATION AND IS NOT INTENDED TO REPRESENT THE ACTUAL INSTALLATION.
6. CUSTOMER TO VERIFY OR ADVISE OVERALL LENGTH PRIOR TO RELEASE.

⚠ WARNING

DO NOT OPERATE THIS MACHINE WITHOUT PROTECTIVE GUARD IN PLACE. ANY OPERATION OF THIS MACHINE WITHOUT PROTECTIVE GUARD CAN RESULT IN SEVERE BODILY INJURY.

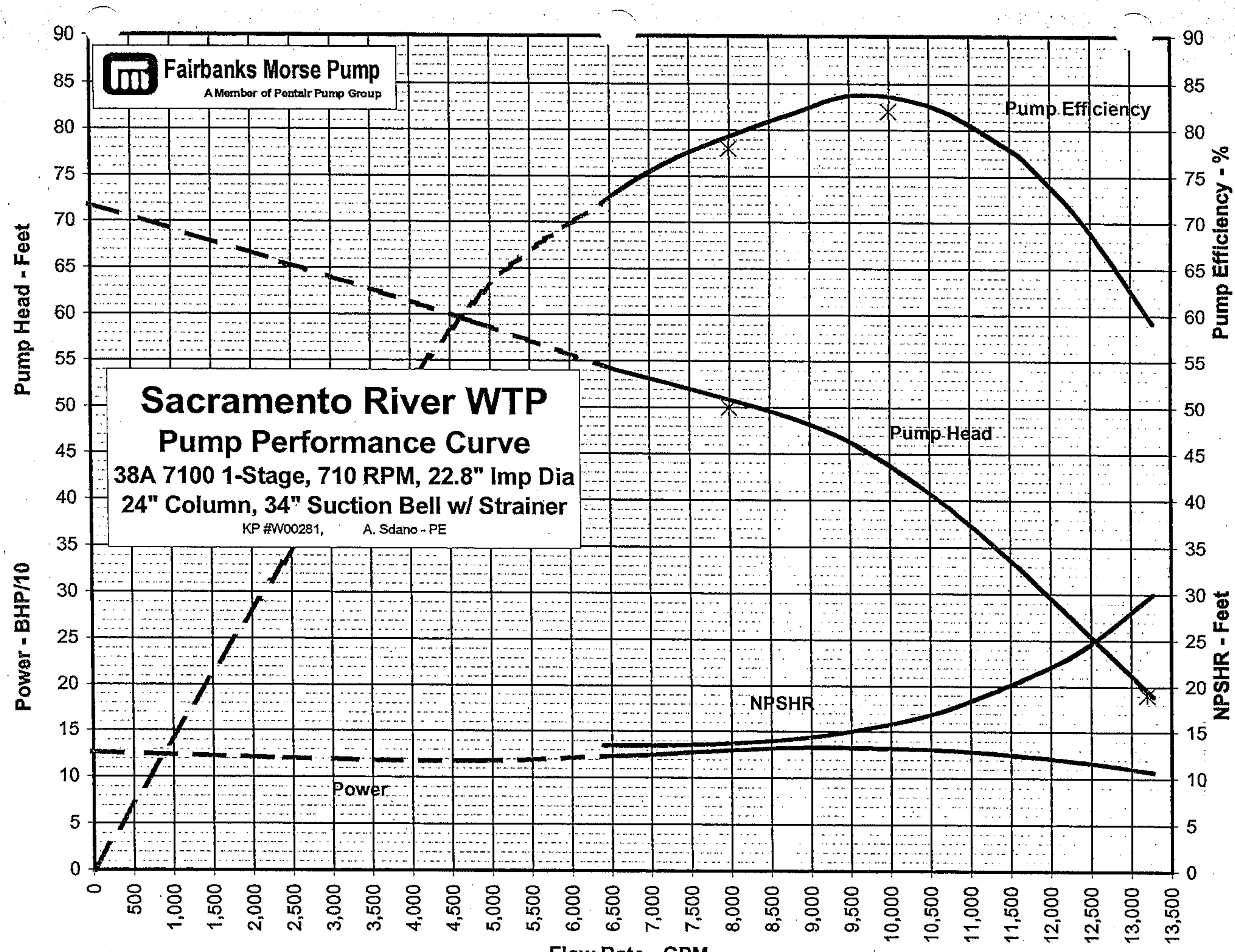
Vortex Suppressor	
AW	AY
16	34.25

CUSTOMER: SACRAMENTO RIVER WATER TREATMENT PLANT				P.O.		
JOB NAME: SACRAMENTO RAW WATER INTAKE			SERVICE			
PUMP SIZE & MODEL: 38A 7100AW	STAGES: 1	GPM: 8000	TDH: 50	RPM: 710	ROT: CCW	
MOTOR: US ELECTRIC	HP: 150 ✓	FRAME: 5808P	PHASE: 3	HERTZ: 60	VOLTS: 4000	ENCL
CERTIFIED FOR: PROJECT NO. 063133		CERTIFIED BY: BHW		DATE: 9/19/01		

Fairbanks Morse Pump Corporation

SETTING PLAN
38A 7100AW
TYPE "F" SURFACE HEAD
WITH SOLEPLATE

DWG. NO. S-063133 REV 4

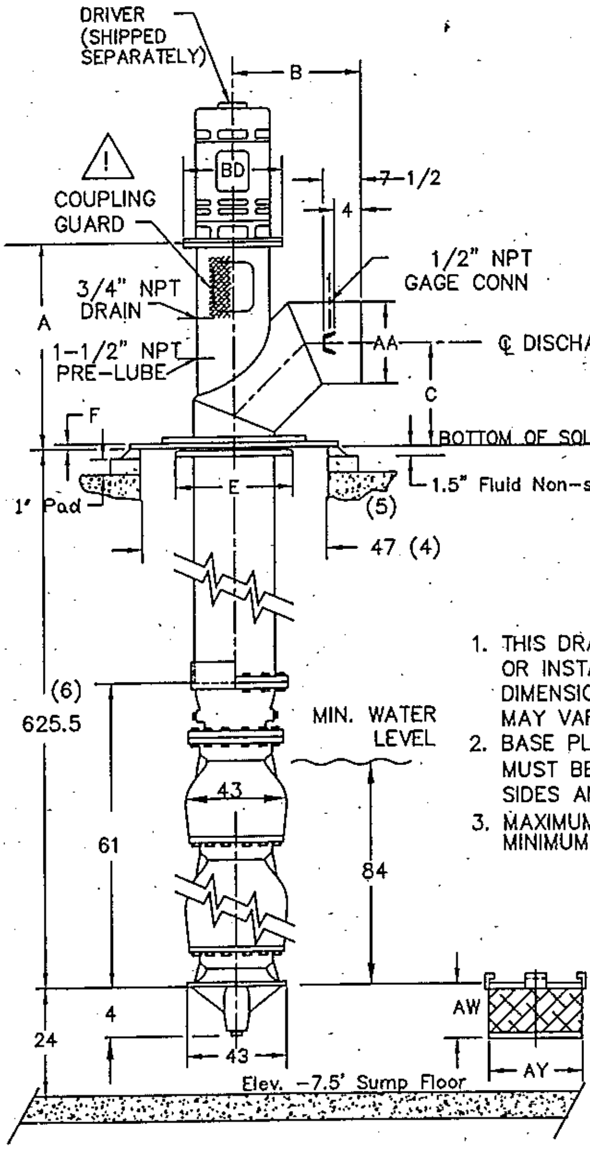


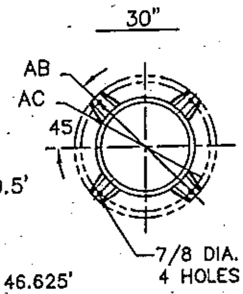
A. Sdano -PE

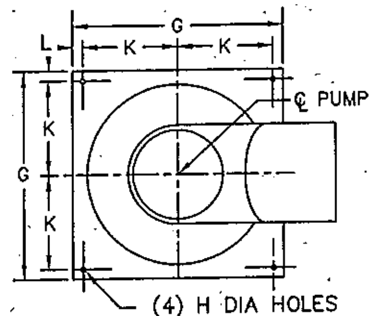
063133 38A 7100, Printed 3/29/01

SRWTP Pumps 2,3,4,5,6,7

DISCHARGE HEAD DIMENSIONS														
DISCH SIZE	COL SIZE	A "BD" DIM 36	B	C	E	F	G	H	K	L	AA	AB	AC
30	30	75.00	40	34.5	34	1.5	78	1.38	34.5	4.5	30	39	36.5







PLAN VIEW OF SOLE PLATE (2)

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2. BASE PLATE (OR OPTIONAL SOLE PLATE) MUST BE SUPPORTED ON ALL FOUR (4) SIDES AND GROUTED IN PLACE.
3. MAXIMUM SUBMERGENCE REQUIRED AT MINIMUM FLOW.
4. MINIMUM DIAMETER REQUIRED TO REMOVE BOWL ASSEMBLY
5. DETAIL SHOWN FOR ILLUSTRATION AND IS NOT INTENDED TO REPRESENT THE ACTUAL INSTALLATION.
6. CUSTOMER TO VERIFY OR ADVISE OVERALL LENGTH PRIOR TO RELEASE.

⚠ WARNING

DO NOT OPERATE THIS MACHINE WITHOUT PROTECTIVE GUARD IN PLACE. ANY OPERATION OF THIS MACHINE WITHOUT PROTECTIVE GUARD CAN RESULT IN SEVERE BODILY INJURY.

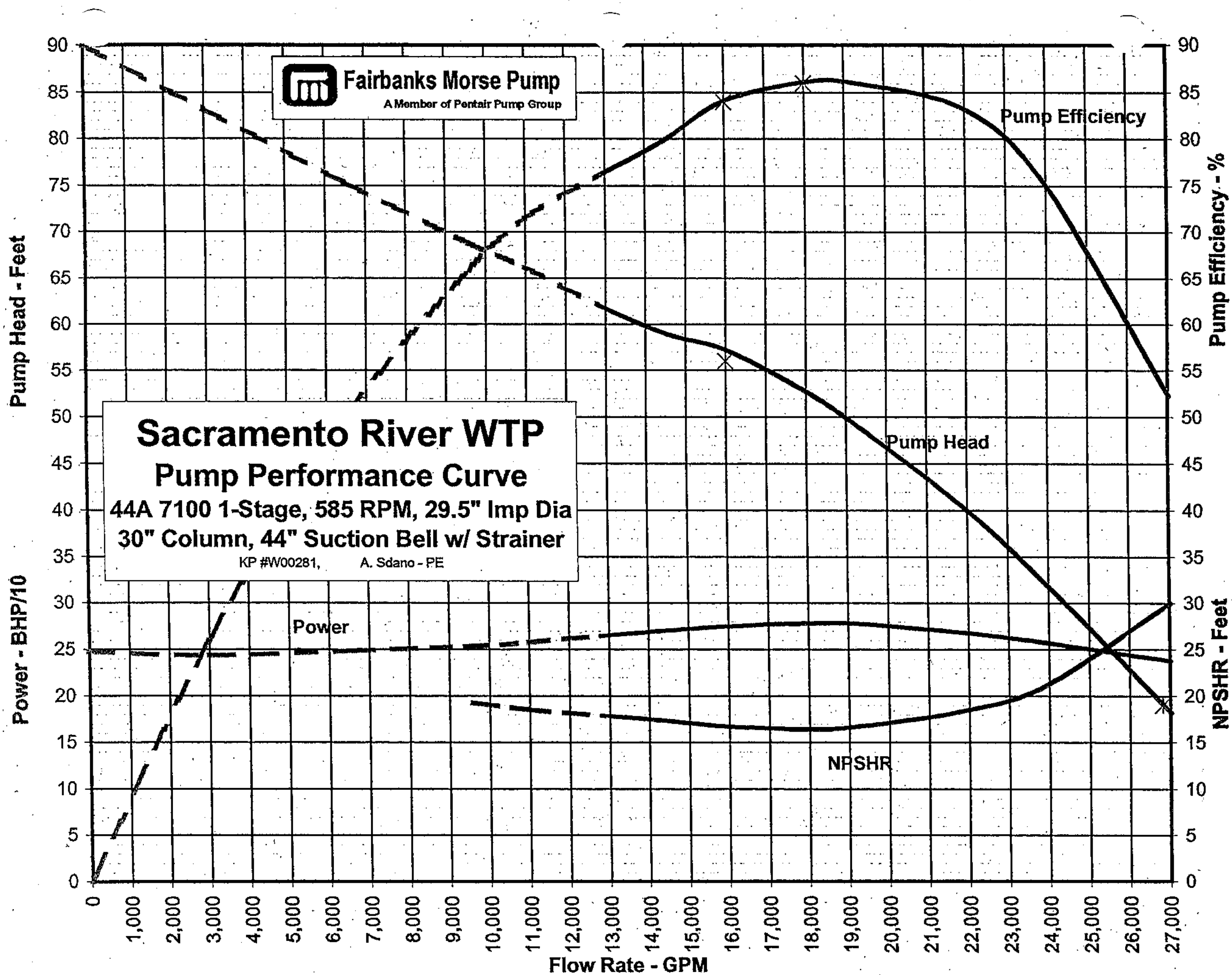
Vortex Suppressor	
AW	AY
20	43

CUSTOMER: SACRAMENTO RIVER WATER TREATMENT PLANT				P.O.		
JOB NAME: SACRAMENTO RAW WATER INTAKE			SERVICE			
PUMP SIZE & MODEL: 44A 7100AW	STAGES: 1	GPM: 16000	TDH: 56	RPM: 585	ROT: CCW	
MOTOR: US ELECTRIC	HP: 300 ✓	FRAME: 6800PA	PHASE: 3	HERTZ: 60	VOLTS: 4000	ENCL
CERTIFIED FOR: PROJECT NO. 063134		CERTIFIED BY: BHW			DATE: 7/17/01	

Fairbanks Morse Pump Corporation

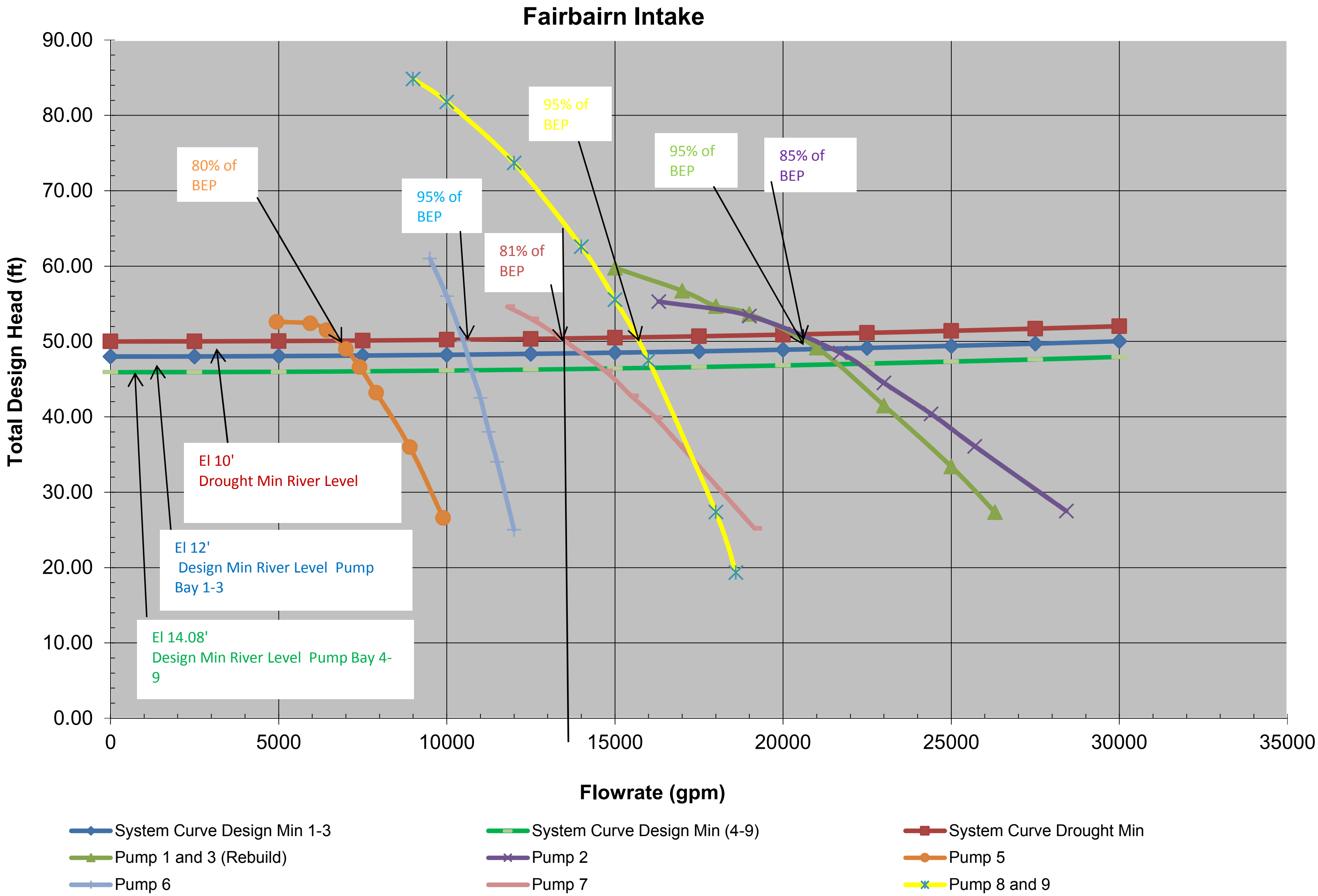
SETTING PLAN
44A 7100AW
TYPE "F" SURFACE HEAD
WITH SOLEPLATE

DWG. NO. S-063134 REV 2



A. Sdano -PE

063134 44A 7100, Printed 3/29/01


Fairbairn Intake
Total Design Head (ft)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
5000
10000
15000
20000
25000
30000
35000
Flowrate (gpm)
80% of BEP
95% of BEP
81% of BEP
95% of BEP
95% of BEP
85% of BEP
El 10' Drought Min River Level
El 12' Design Min River Level Pump Bay 1-3
El 14.08' Design Min River Level Pump Bay 4-9
System Curve Design Min 1-3
System Curve Design Min (4-9)
System Curve Drought Min
Pump 1 and 3 (Rebuild)
Pump 2
Pump 5
Pump 6
Pump 7
Pump 8 and 9

APPENDIX B – PUMP INTAKE HYDRAULICS

1.0 PUMP INTAKE HYDRAULIC PROBLEMS

Hydraulic conditions have been identified, such as air entrainment, vortex action, pre-swirl, and excessive turbulence, in the approach flow to pumps that can lead to fluctuating loads on pump impellers, vibration, cavitation, loss of pump capacity, and decreased efficiency (Sweeney and Rockwell 1982). It has been shown that these problems are strongly influenced by the approach flow hydraulics upstream from the pump, caused by the wet well geometry coupled with the influent conditions. Straight and uniform approach flow reduces the tendency for pump problems, whereas variable approach flow direction and non-uniform velocity distribution generates eddies and circulation patterns, which may adversely affect pump operation.

Uniform approach flow conditions may reduce the potential for pre-swirl and vortex formation. Tullis (1979) and Sweeney et al. (1982) have documented repeated cases in which preclusion of submerged vortices has required the installation of anti-vortex devices such as flow splitters, guide vanes, and/or cones.

The geometry of the wet well, operation of the pump(s), and depth of water in the sump influence the approach flow hydrodynamics and can result in the following adverse hydraulic phenomena (Sweeney and Rockwell 1982):

- pre-swirl of flow approaching the pump impeller;
- free surface vortex formation;
- submerged vortex formation;
- spatial asymmetry of the flow approaching the pump impeller; and
- temporal fluctuations (turbulence) in the flow approaching the pump impeller.

Pump impellers are designed with the assumption that flow approaches the impeller axially. Pre-swirl of the flow in a pump inlet causes the flow to approach the impeller at an angle, which can result in a change in pump performance (head and flow). Pre-swirl may also reduce the minimum pressure on the impeller blade if the direction of pre-swirl is opposite the direction of rotation of the impeller. Excessive low pressure on the suction side of the pump impeller blades may ultimately cause cavitation damage. In addition, if the pre-swirl is not constant, it will result in load fluctuations.

Free surface vortices and submerged vortices can also influence pump operation. Strong free surface vortices may cause air to be entrained into the pump, potentially resulting in loss of prime and loss of pump capacity. Submerged and free surface vortices entering the pump, even without air entertainment, will impose a fluctuating load on the pump impeller blades as each blade passes through the lower pressure vortex core. Stable vortices produce load fluctuations at blade pass frequency (or multiples thereof) capable of causing vibration, accelerated bearing wear and, in extreme cases, impeller and diffuser component fatigue. If the natural frequency of the pump vibration approaches the blade pass frequency, destructive resonance results. The low-pressure vortex cores may reduce the local pressure at the impeller below the fluid pressure and induce cavitation of the impeller blades.

Spatial asymmetry in the distribution of velocities around the pump may cause an unbalanced loading on the impeller and vibration, while temporal fluctuations (turbulence) in the velocities at a particular point may result in broad-spectrum noise and vibration. Deviations in the spatial and temporal velocity distributions also can produce cavitation.

2.0 PUMP STATION HYDRAULIC ANALYSIS METHODS

Traditionally, scale model studies have been conducted to optimize the design of large pump stations; however, an emerging technology for pump station analysis is through CFD modeling. Applications of CFD models to simulate flow fields associated with pump intakes have been underway for several years. There have been reports on the use of CFD modeling for analysis of pump station hydraulics, including reports by: Constantinescu and Patel (1998); Nagahara et al. (2001); Li et al. (2001); and Ansar et al. (2002). Much of this research has focused on the simulation of vortex formation in pump sumps and circulation for pump stations with a single operating pump. Wicklein et al. (2002) have shown that a CFD model can accurately reproduce the flow field associated with cooling water pump intakes with multiple bays for a range of pump operations and water levels. Wicklein and Rashid (2006) have demonstrated that CFD models are very valuable tools for investigating pump station hydraulics and developing modifications to address performance deficiencies.

3.0 MODEL PERFORMANCE CRITERIA

The Hydraulic Institute (HI) established criteria for evaluating performance of pump station designs through the use of physical hydraulic model studies. The details of physical modeling procedures and results interpretation are explained in ANSI/HI 9.8-1998. The summarized minimum performance criteria for physical models are:

- No organized free surface and/or subsurface vortices of greater magnitude than a Type 2 shall enter the pump for Froude-scaled model operation (referring to HI 1998 Figure 9.8.23). Dye cores must not be coherent for more than ten percent of the time.
- The level of pre-swirl should be less than five degrees from axial and should be steady.
- Time-averaged velocities measured at eight locations in the pump throat should be within ± ten percent of the spatial mean of time-averaged velocities.
- The temporal fluctuations of velocities measured at each of the eight locations should be less than ten percent of the average measured at that location.

To date, HI has not established a universal set of performance criteria for evaluation of pump station performance using numerical methods.

The key difference between current CFD model results and the results from physical model studies is that physical models are run in a quasi-steady state, whereas CFD models are run in an absolute steady state. A physical model has a fixed inflow, outflow, and average water level, but the velocity and water level at a given point fluctuate due to turbulence and local flow instabilities. Currently, CFD models provide the averaged solution of velocity at all points in the domain, and have a non-fluctuating water surface. The CFD model results therefore cannot be exactly compared with the current physical model criteria, as the fluctuating components of the flow field are averaged out.

For comparison and presentation of pre-rotation and velocity results, point data were extracted from the CFD results in the pump suction piping to replicate the data taken from physical model. Eight points were taken on 45-degree increments on a radial traverse at the impeller elevation, and eight points were taken on second 45-degree radial traverse downstream from the pump impeller elevation. The data taken at the second downstream traverse were used to calculate a rotational velocity within the pump suction piping.

The angle of flow rotation approaching the impeller, θ, is reported in degrees from axial, and typically referred to as pre-swirl. The angle is calculated by Equation 1:

$$\theta = \mathrm{Tan}^{-1}(U_t/U_a) \quad (1)$$

where:

U_t = tangential component of velocity; and

U_a = axial component of velocity.

In this case the approach angle was calculated for each of the eight points, and averaged to find the average flow angle.

The maximum and minimum velocity is found by dividing the velocity found at each of the eight points by the cross sectional average velocity. The velocity is then expressed as a non-dimensional ratio, which facilitates comparison between different flow rates and scales.

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APPENDIX C – CFD MODELING OVERVIEW

Commercially available computational fluid dynamics (CFD) models numerically solve the fundamental equations of fluid flow, and conservation of mass and momentum, known as the Reynolds-averaged Navier-Stokes (RANS) equations. These equations do not form a closed set (ASCE Task Committee 1988), owing to the non-linearity of the original Navier-Stokes equations and their temporal averaging. Current CFD models solve additional equations representing the turbulence characteristics of a flow field, which is a key parameter in determining the nature of flow, eddy formation, circulation, flow separation, and flow interaction with structures. The turbulence models commonly used in hydraulic engineering have been reviewed by the ASCE Task Committee (1988) and Rodi (1980). Commercial CFD models offer various turbulence closure models, the most common of which are based on second order closures using k-ε and k-ω formulations.

In their general form, RANS equations cannot be solved analytically. Commercial CFD models approximate the differential equations by the finite difference method, which resolves the equations into a set of algebraic equations (Lomax et al. 2003). These algebraic equations are solved to provide hydraulic information (e.g., velocity, water surface elevation, and pressure) at a finite number of discrete points within the flow domain. Most finite difference-based CFD models use the finite volume method, as this approach allows the use of unstructured computational grids.

As the RANS equations are typically solved by the finite difference method, it is necessary to discretize the flow domain into a computational grid to define the actual locations where equations of flow will be solved. Traditionally the individual computational cells are hexahedral (six faces), pyramidal (five faces), prismatic (five faces), or tetrahedral (four faces) as defined by the corner vertices. The task of grid generation is accomplished through the use of grid generating software that allows for definition of the model geometry, computational cell size, and grid density, and provides tools for grid quality analysis. Unstructured computational grids are the most common type, as they allow the greatest flexibility in defining the model domain and meshing properties.

The flow field computed by the CFD model is a direct function of the flow conditions applied at the domain boundaries, known as boundary conditions. Typical boundaries include inflow, outlet, pressure, symmetry, and wall boundaries. Inlet boundaries provide a constant velocity in the three vector components into or out of the model domain, as well as constant turbulence characteristics. Pressure boundaries have constant pressure and turbulence characteristics, and flow can move in or out of the domain. Outlet boundaries only allow flow to travel out of the domain, and have no pressure or turbulence constraints. Symmetry boundaries allow no vector component normal to the boundary. Wall boundaries are considered solid with no flow through the boundary. The wall boundary type can be either no-slip with a roughness component, or a slip wall with no roughness component. Typically the law of the wall function is used to approximate the transition from zero velocity at the boundary through the boundary layer into the free stream, which models the effective drag from the roughness at the wall, without requiring the large number of computational elements required to resolve the flow field within the boundary layer. Typically the boundary layer is not resolved when investigating large-scale flow features due to significant computational overhead requirements in resolving this flow feature.

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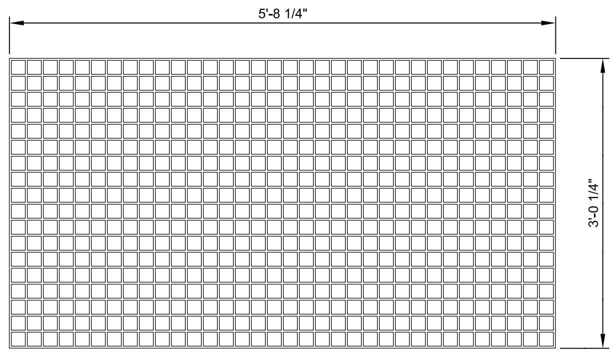
APPENDIX D – VORTEX BREAKER DRAWINGS



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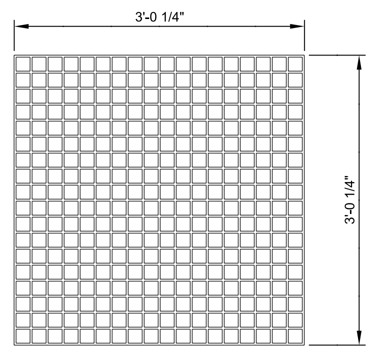

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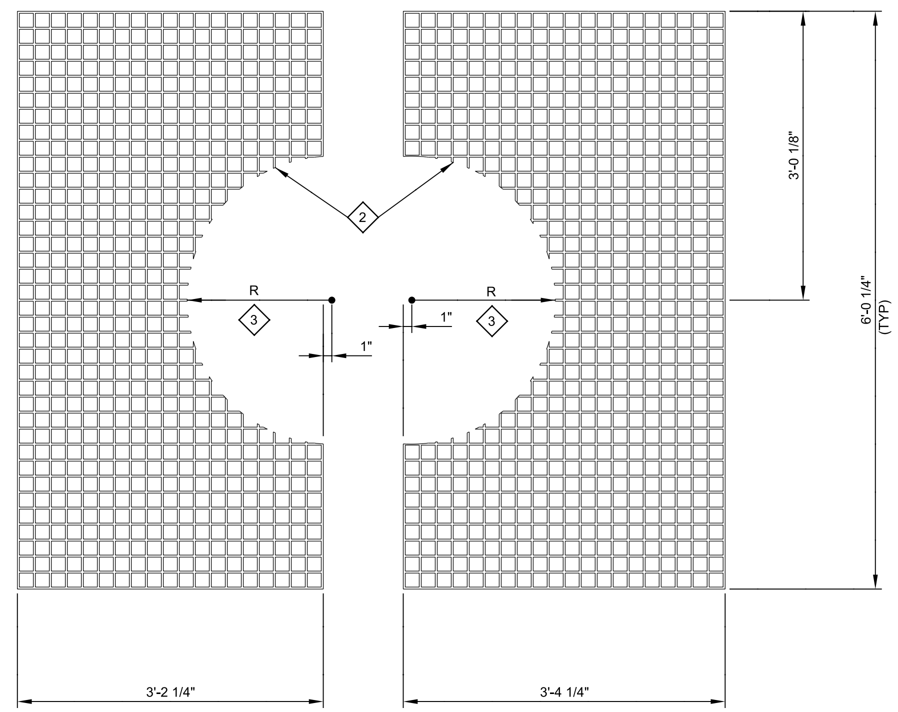

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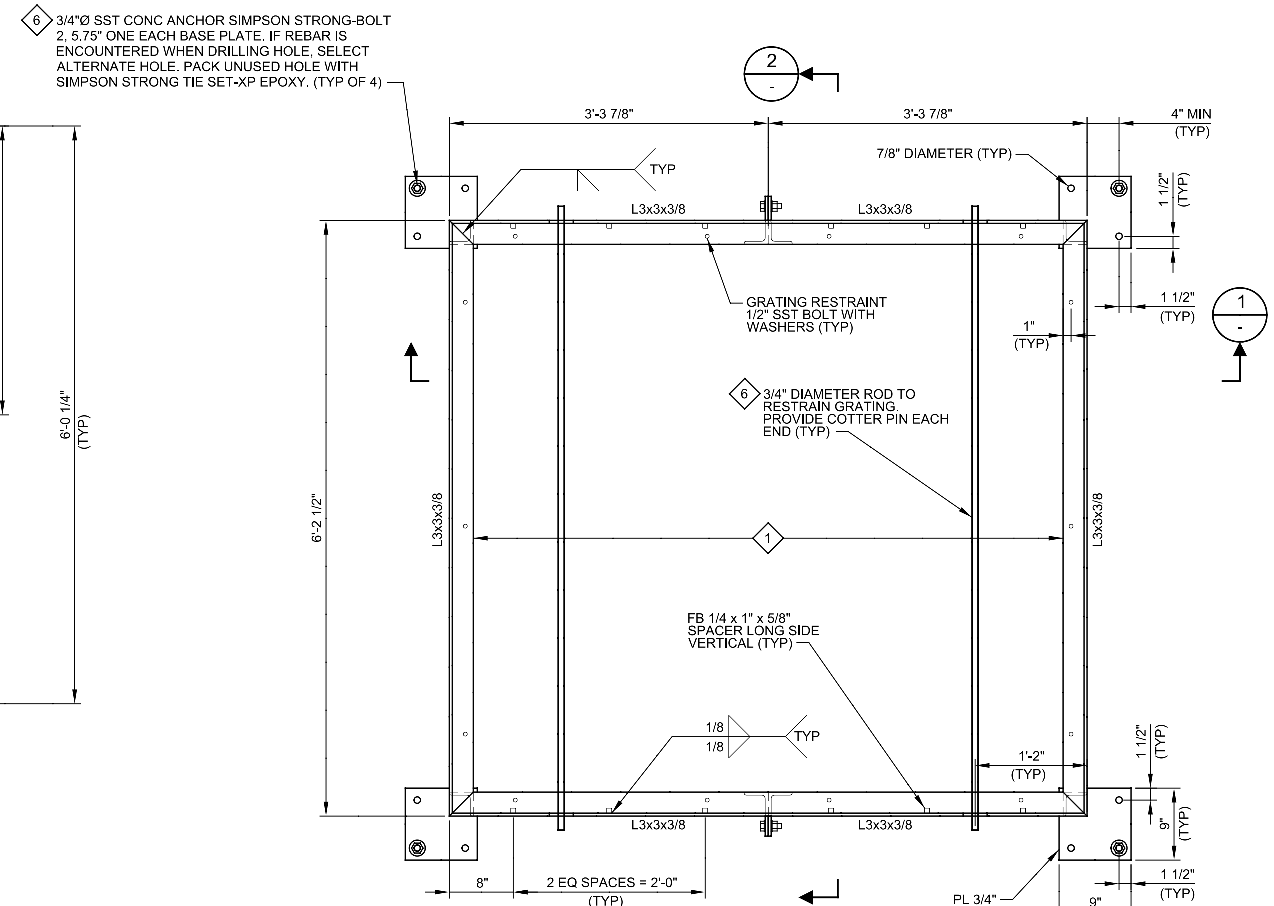

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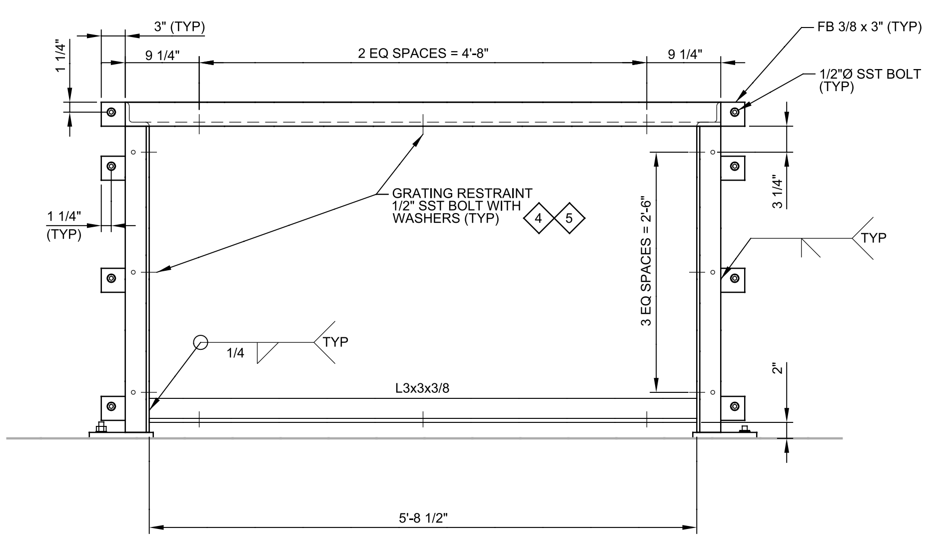

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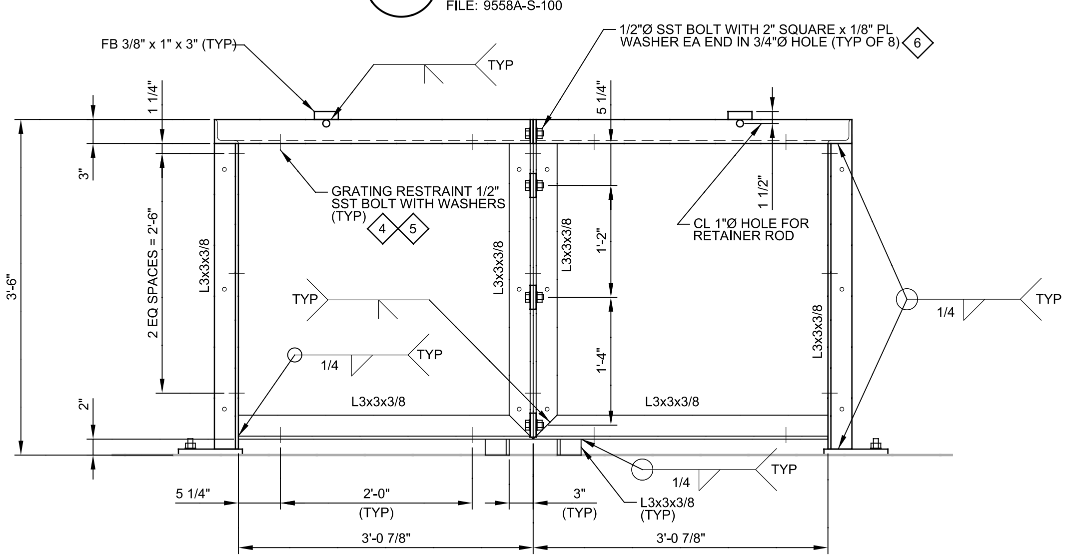

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GENERAL NOTES:

1. ALL METAL SHALL BE 304L STAINLESS STEEL
2. GRATING SHALL BE FIBERGRATE FGI-AM 2" DEEP x 2" SQUARE MESH. (COAT ALL CUT ENDS OF CUT PANELS WITH MANUFACTURER'S SEALING KIT)
3. FABRICATIONS WEIGH APPROXIMATELY 525 POUNDS EACH HALF WITH SIDE GRATING INSTALLED. TOP GRATINGS ADD AN ADDITIONAL 80 POUNDS EACH.
4. INSTALLATION SEQUENCE: LOCATE BOTH SECTIONS OF GRATING FRAME NEAR FINAL LOCATION. BOLT THE TWO HALVES TOGETHER AND INSTALL TOP GRATING SECTIONS. CENTER VORTEX BREAKER ASSEMBLY ON THE ON PUMP BARREL THEN INSTALL CONCRETE ANCHORS.

KEY NOTES:

1. FABRICATE FRAME IN TWO SECTIONS.
2. FABRICATE TOP GRATING IN TWO NON-SYMMETRIC SECTIONS.
3. PROVIDE 46" DIAMETER OPENING IN TOP GRATING FOR SOUTHSIDE PUMPS NO. 2, 3, 4, AND NORTHSIDE PUMPS NO. 5, 6, 7. PROVIDE 38" DIAMETER OPENING IN TOP GRATING FOR SOUTHSIDE PUMP NO. 1 AND NORTHSIDE PUMP NO. 8.
4. DRILL GRATING TO MATCH GRATING RESTRAINT BOLTS. INSTALL SIDE GRATING BEFORE SUBMERGING. INSTALL TOP GRATING AFTER BOLTING FRAME TO PUMP BAY.
5. LOCATE 1" FROM OUTSIDE EDGE.
6. DIVER TO INSTALL VORTEX BREAKER HALVES UNDERWATER. THIS INCLUDES (8) 1/2"Ø BOLTS, WASHERS, AND NUTS AND DRILLING (4) HOLES IN EXISTING CONCRETE FLOOR AND INSTALLING (4) 3/4"Ø SST EXPANSION BOLTS, WASHERS, AND NUTS. INSTALLATION OF TOP GRATING, GRATING RESTRAINT BARS AND COTTER PINS.
7. APPROXIMATE WEIGHT OF PANEL B LEFT IS 77 LB, PANEL B RIGHT IS 81 LB, PANEL C IS 69 LB EACH SIDE, PANEL D IS 37 LB EACH SIDE.
8. COAT ALL CUT ENDS OF CUT PANELS WITH MANUFACTURER'S SEALING KIT.

REV	DATE	BY	DESCRIPTION

DESIGNED: MED
DRAWN: MED
CHECKED: CTC
DATE: JUNE 2014

PROJECT ENGINEER — REGISTERED PROFESSIONAL ENGINEER MICHAEL E. DADIK No. S5368 STRUCTURAL STATE OF CALIFORNIA — 9 JUNE 2014

PROJECT MANAGER

PRINCIPAL

carollo®

CITY OF SACRAMENTO
INTAKE PUMP DROUGHT ALTERNATIVES EVALUATION
STRUCTURAL
SRWTP VORTEX BREAKER DETAIL

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

JOB NO. 9558A.00
DRAWING NO.
SHEET NO. 1 OF 1

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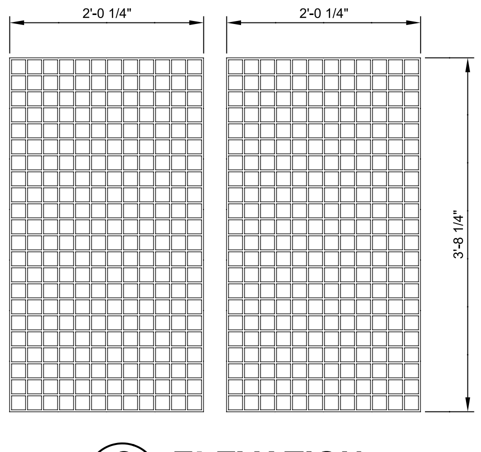

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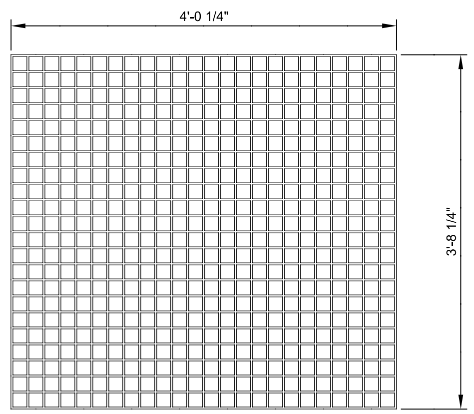

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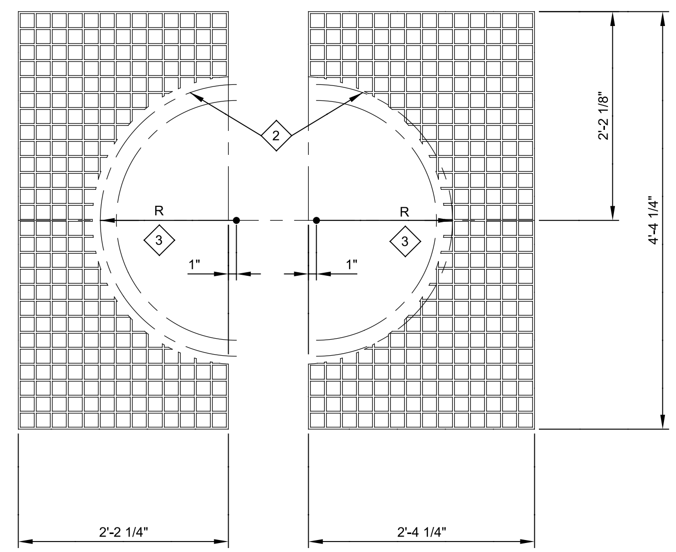

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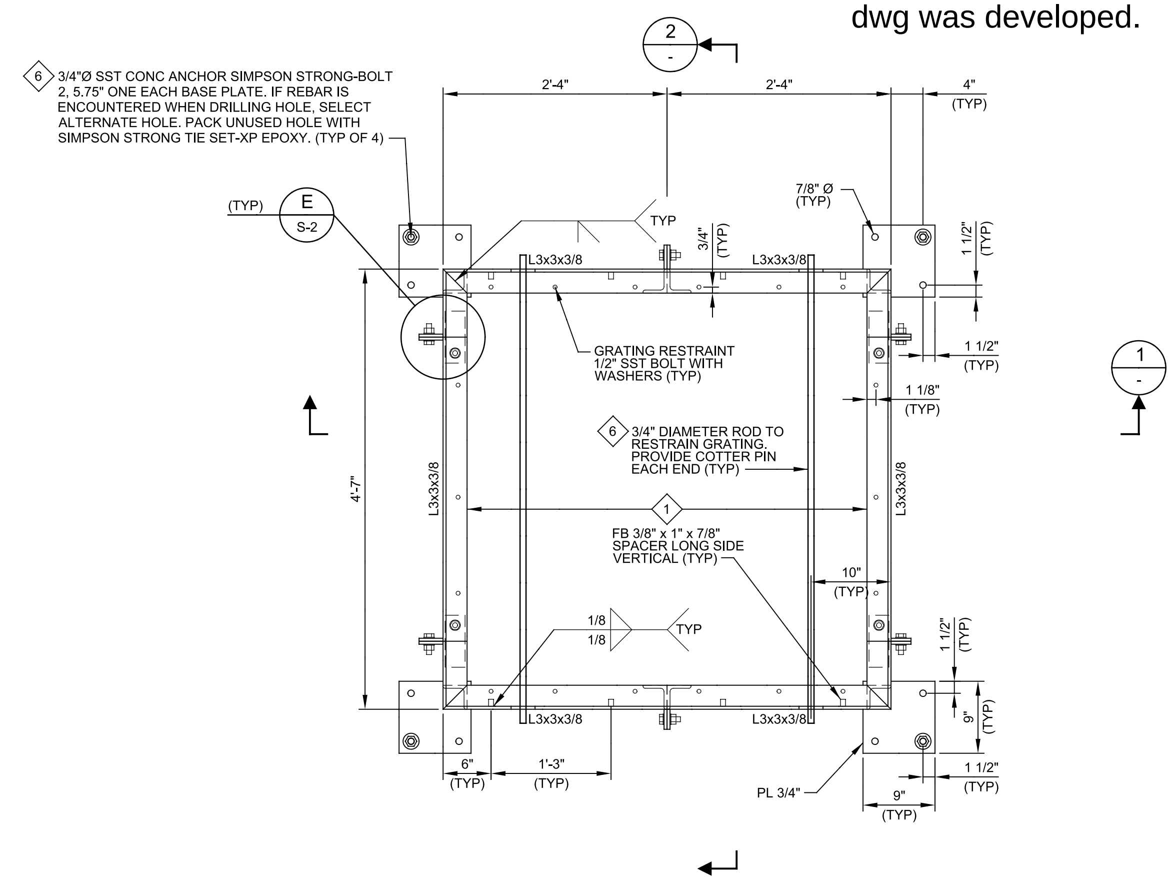


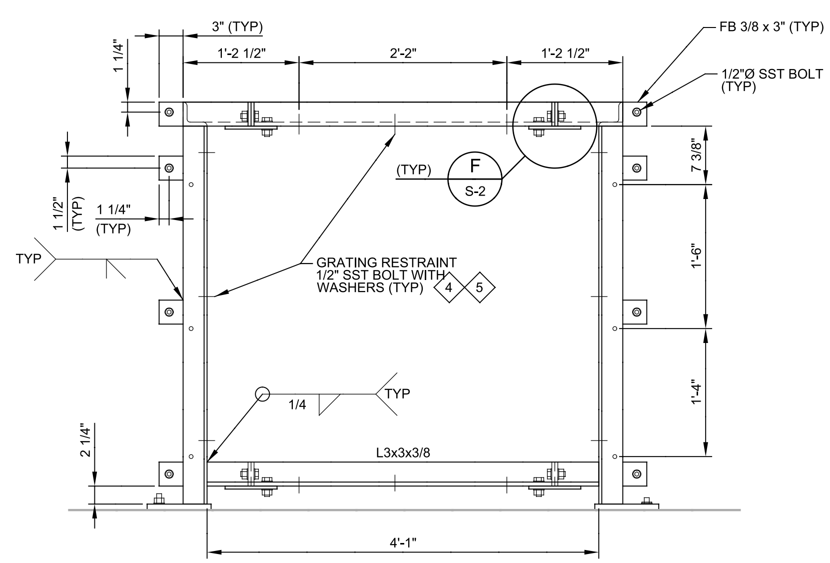
A FRAME PLAN
SCALE: 1" = 1'-0"
FILE: 9558A-S-100

GENERAL NOTES:

1. ALL METAL SHALL BE 304L STAINLESS STEEL
2. GRATING SHALL BE FIBERGRATE FGI-AM 2" DEEP x 2" SQUARE MESH. (COAT ALL CUT ENDS OF CUT PANELS WITH MANUFACTURER'S SEALING KIT)
3. FABRICATIONS WEIGH APPROXIMATELY 525 POUNDS EACH HALF WITH SIDE GRATING INSTALLED. TOP GRATINGS ADD AN ADDITIONAL 80 POUNDS EACH.
4. INSTALLATION SEQUENCE: LOCATE BOTH SECTIONS OF GRATING FRAME NEAR FINAL LOCATION. BOLT THE TWO HALVES TOGETHER AND INSTALL TOP GRATING SECTIONS. CENTER VORTEX BREAKER ASSEMBLY ON THE ON PUMP BARREL THEN INSTALL CONCRETE ANCHORS.

KEY NOTES:

1. FABRICATE FRAME IN SECTIONS. ASSEMBLE INTO 2 SECTIONS PRIOR TO SUBMERGING.
2. FABRICATE TOP GRATING IN TWO NON-SYMMETRIC SECTIONS.
3. PROVIDE 34" DIAMETER OPENING IN TOP GRATING FOR PUMPS NO. 1 AND 7. PROVIDE 30" DIAMETER OPENING IN TOP GRATING FOR PUMP NO. 6.
4. DRILL GRATING TO MATCH GRATING RESTRAINT BOLTS. INSTALL SIDE GRATING BEFORE SUBMERGING. INSTALL TOP GRATING AFTER BOLTING FRAME TO PUMP BAY.
5. LOCATE 1" FROM OUTSIDE EDGE.
6. DIVER TO INSTALL VORTEX BREAKER HALVES UNDERWATER. THIS INCLUDES (m) 1/2"Ø BOLTS, WASHERS, AND NUTS AND DRILLING (n) HOLES IN EXISTING CONCRETE FLOOR AND INSTALLING (n) 3/4"Ø SST EXPANSION BOLTS, WASHERS, AND NUTS. INSTALLATION OF TOP GRATING, GRATING RESTRAINT BARS AND COTTER PINS.
7. APPROXIMATE WEIGHT OF PANEL B LEFT IS xx LB, PANEL B RIGHT IS xx LB, PANEL C IS xx LB EACH SIDE, PANEL D IS xx LB EACH SIDE.
8. COAT ALL CUT ENDS OF CUT PANELS WITH MANUFACTURER'S SEALING KIT.



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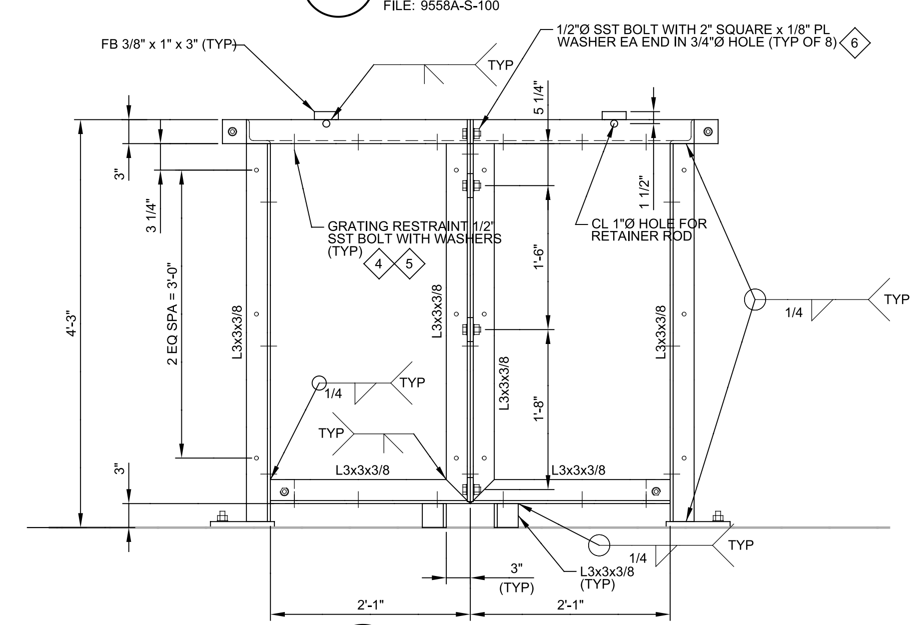

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REV	DATE	BY	DESCRIPTION

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CHECKED
DATE JUNE 2014

PROJECT ENGINEER — REGISTERED PROFESSIONAL ENGINEER MICHAEL E. DADIK No. S5368 STRUCTURAL STATE OF CALIFORNIA — 9 JUNE 2014
PROJECT MANAGER
PRINCIPAL

carollo®

CITY OF SACRAMENTO
INTAKE PUMP DROUGHT ALTERNATIVES EVALUATION
STRUCTURAL
EAFWTP VORTEX BREAKER

VERIFY SCALES
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DRAWING NO. S-1
SHEET NO. 1 OF 1

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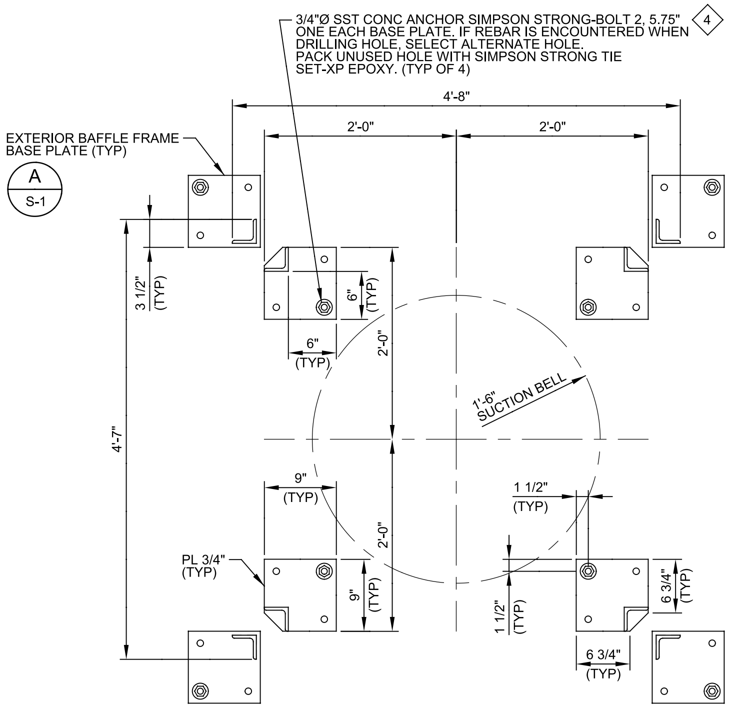

L BASE PLATE PLAN
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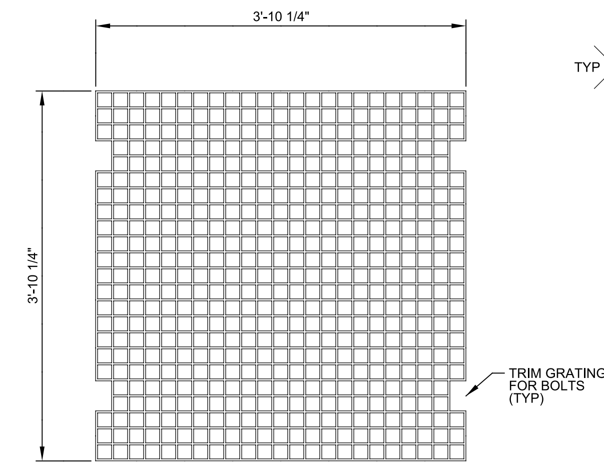
GENERAL NOTES:

1. ALL METAL SHALL BE 304L STAINLESS STEEL
2. GRATING SHALL BE FIBERGRATE FGI-AM 2" DEEP x 2" SQUARE MESH. (COAT ALL CUT ENDS OF CUT PANELS WITH MANUFACTURER'S SEALING KIT)
3. FLOOR VORTEX BREAKER FABRICATION WEIGHS APPROXIMATELY nnn POUNDS.
4. FLOOR VORTEX BREAKER INSTALLATION SEQUENCE: PRIOR TO INSTALLING EXTERIOR VORTEXT BREAKER FRAME, LOCATE BOTH SECTIONS AND SIDE RAILS OF GRATING FRAME NEAR FINAL LOCATION (LOWER CAT WALK). BOLT THE SIDE RAILS AND FRAMES TOGETHER. CENTER FLOOR VORTEX BREAKER ASSEMBLY ON THE ON PUMP BARREL THEN INSTALL CONCRETE ANCHORS.

KEY NOTES:

1. FABRICATE FLOOR VORTEX FRAME IN FOUR PIECES ASSEMBLE ON PUMP BAY LOWER CAT WALK.
2. FABRICATE TOP GRATING IN ONE SECTION.
3. DRILL GRATING TO MATCH GRATING RESTRAINT BOLTS. INSTALL TOP GRATING AFTER BOLTING FRAME TO PUMP BAY.
4. DIVER TO INSTALL FLOOR VORTEX BREAKER IN ONE PIECE UNDERWATER. THIS INCLUDES DRILLING (4) HOLES IN EXISTING CONCRETE FLOOR AND INSTALLING (4) 3/4"Ø SST EXPANSION BOLTS, WASHERS, AND NUTS. INSTALLATION OF TOP GRATING, GRATING RESTRAINT BARS AND COTTER PINS.
5. APPROXIMATE WEIGHT OF PANEL M xx LB.
6. COAT ALL CUT ENDS OF CUT PANELS WITH MANUFACTURER'S SEALING KIT.



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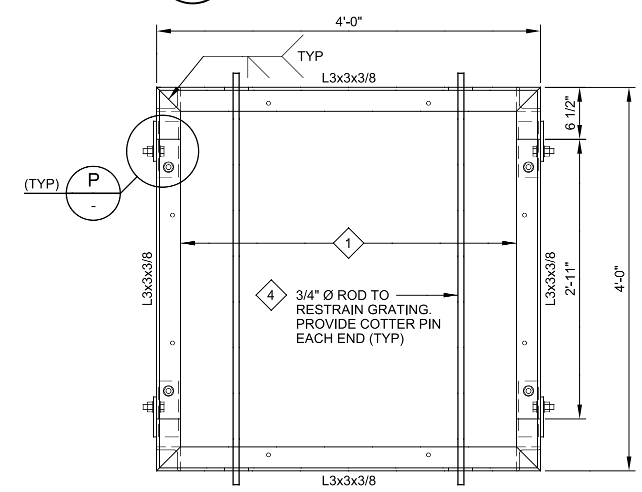

J FLOOR VORTEX BREAKER TOP PLAN
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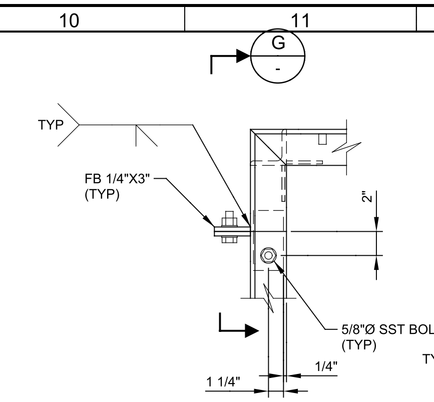

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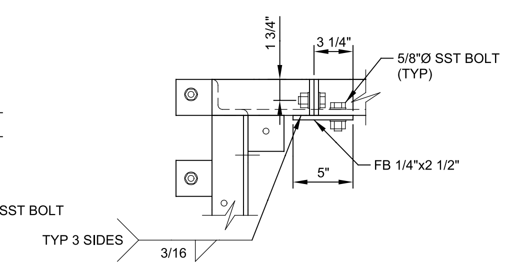

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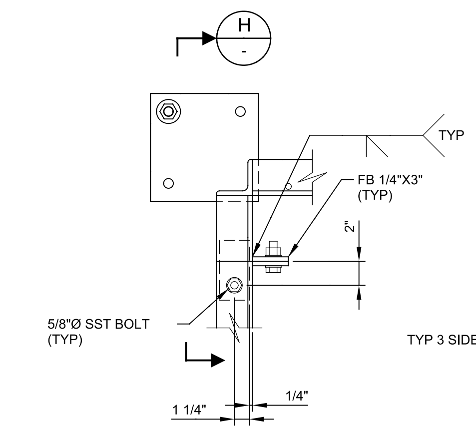

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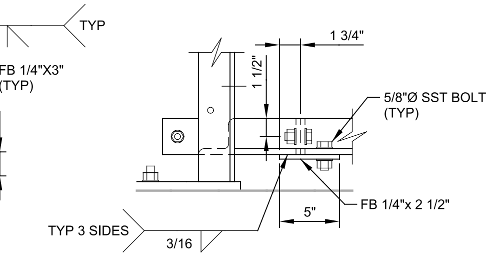

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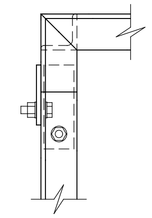

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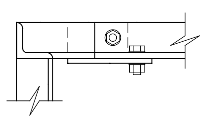

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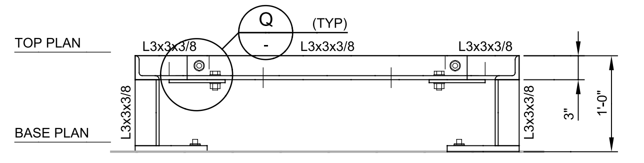

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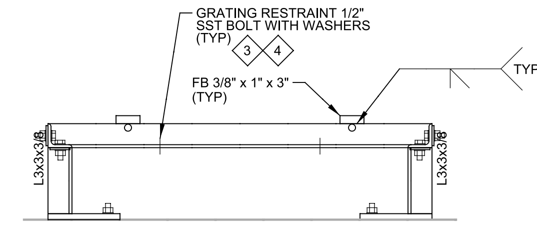

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REV	DATE	BY	DESCRIPTION

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DATE NOV 2014

PROJECT ENGINEER — REGISTERED PROFESSIONAL ENGINEER, MICHAEL E. DADIK, No. S5368, STRUCTURAL, STATE OF CALIFORNIA, 9 JUNE 2014

PROJECT MANAGER

PRINCIPAL

carollo®

CITY OF SACRAMENTO
INTAKE PUMP DROUGHT ALTERNATIVES EVALUATION
STRUCTURAL
EAFWTP VORTEX BREAKER DETAILS

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

JOB NO. 9558A.00
DRAWING NO. S-2
SHEET NO. 2 OF 1

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