Flow Rating Analysis for Pump Station G388
STA ¾ PSTA Outflow Pump Station

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Executive Summary

A rating analysis of G388 was carried out using the conventional case 8 model. The equation developed yields discharge rates that are within 1.82 percent of the discharges derived from the pump station rating curve under the expected range of static heads. Given the uncertainties inherent to the hydraulic head loss calculations, it is recommended that the rating equations be recalibrated with measured flows.

Acknowledgement

The authors wish to express appreciation to John Curley, Tim Carter, Kevin Snell, and Denise Darata for providing useful information regarding this station; and to Henry Newmon for providing the construction drawings of this station.

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Introduction

The structure G388 is the outflow pump station for the PSTA Demonstration Project located at Stormwater Treatment Area 3/4 (STA 3/4). There are two 42-inch, electric motor-driven, axial flow pumps at G388. Both were previously located in pump station G250. Each pump is rated at a capacity of 100 cfs at a total dynamic head of 9.0 ft.

Objectives and Scope

The primary purpose of the rating analyses conducted in this study is to enable flows through G388 to be estimated using measured head water elevations, tail water elevations and pump engine speeds. The hydraulic rating equations are based on pump performance characteristics, hydraulic properties of the pump station piping and appurtenances, and engineering principles. It is assumed that the performance curve from the pump manufacturer is still valid for these two pumps even though they were obtained from another station after many years in service and were subsequently reinstalled at the current station. Since G388 became operational only recently, the rating equations could not be calibrated to stream flow measurements since none were available at the time this rating analysis was conducted.

Station Design

The manufacturer's pump performance curve for both pumps is shown in Figure 1. Cross sectional and plan views of the pump station design are shown in figure 2. Table 1 contains the dimensions of the station piping while table 2 contains estimates of pipe roughness for STD steel pipes.

Rating Analysis

The model rating equation applied to G388 is the standard case 8 model (Imru and Wang, 2004):

$$Q = A\left(\frac{N}{N_O}\right) + BH^C\left(\frac{N_O}{N}\right)^{2C-1} \quad \text{.......................................} \quad (1)$$

Where Q is the discharge at N RPM, H is the TSH, N_O is the design engine or pump speed, and A, B and C are coefficients to be determined through regression. The form of this expression was determined through dimensional analysis and is based on the pump affinity laws. For pumps driven by electric motors, $N_O = N$ so the ratios involving these parameters are eliminated.

Figure 3 depicts the TSH vs. flow relationships obtained from the pump performance curve assuming minimum, average and maximum head losses. For comparative purposes, the manufacturer's pump performance curve is also shown in the same figure. The associated head loss computations are provided in appendix A. Equation (1) was fit to the average TSH vs. Q curve shown in figure 4. The resulting values of A, B and C are

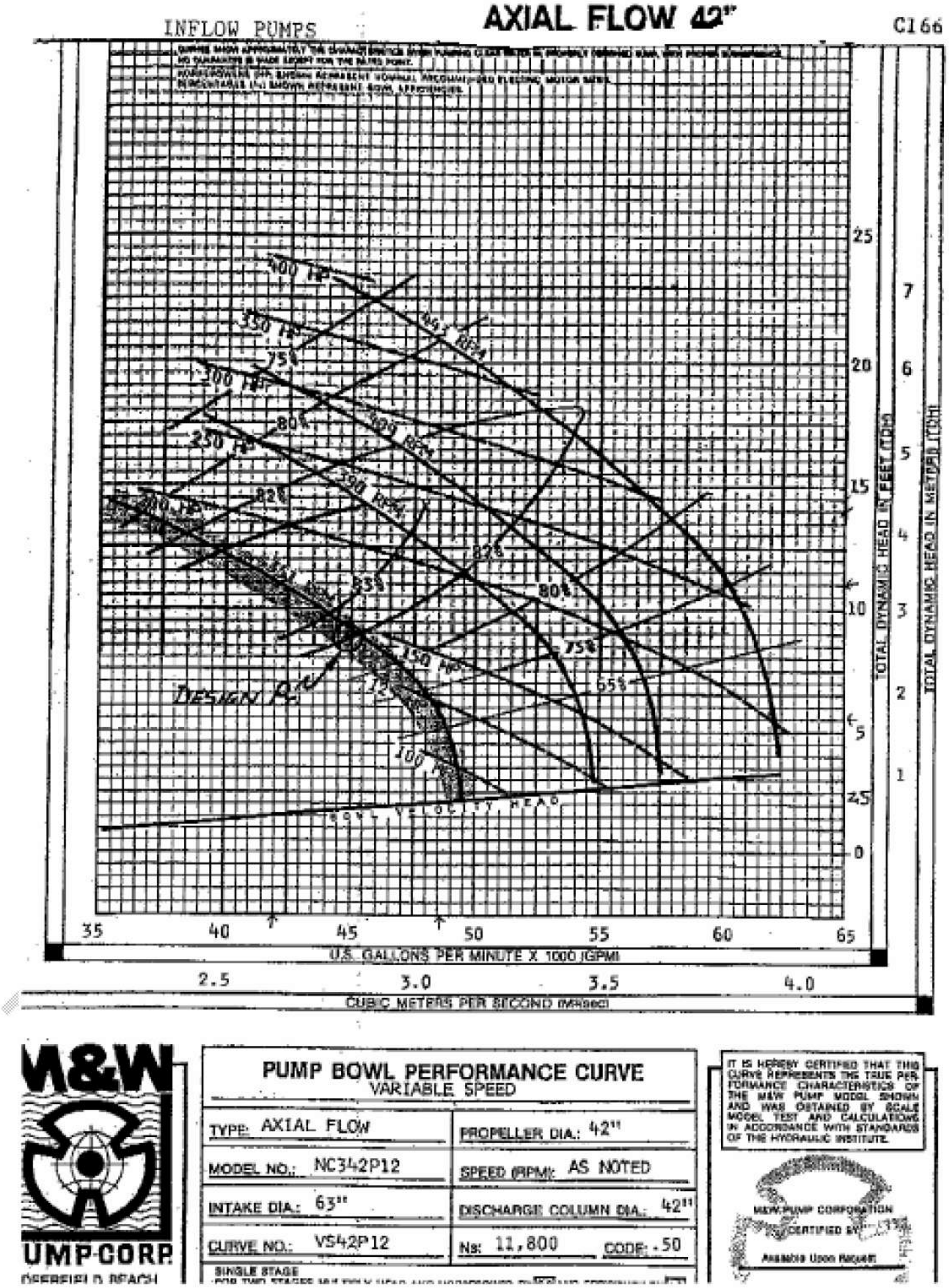

Figure 1. Pump performance curve for G388.

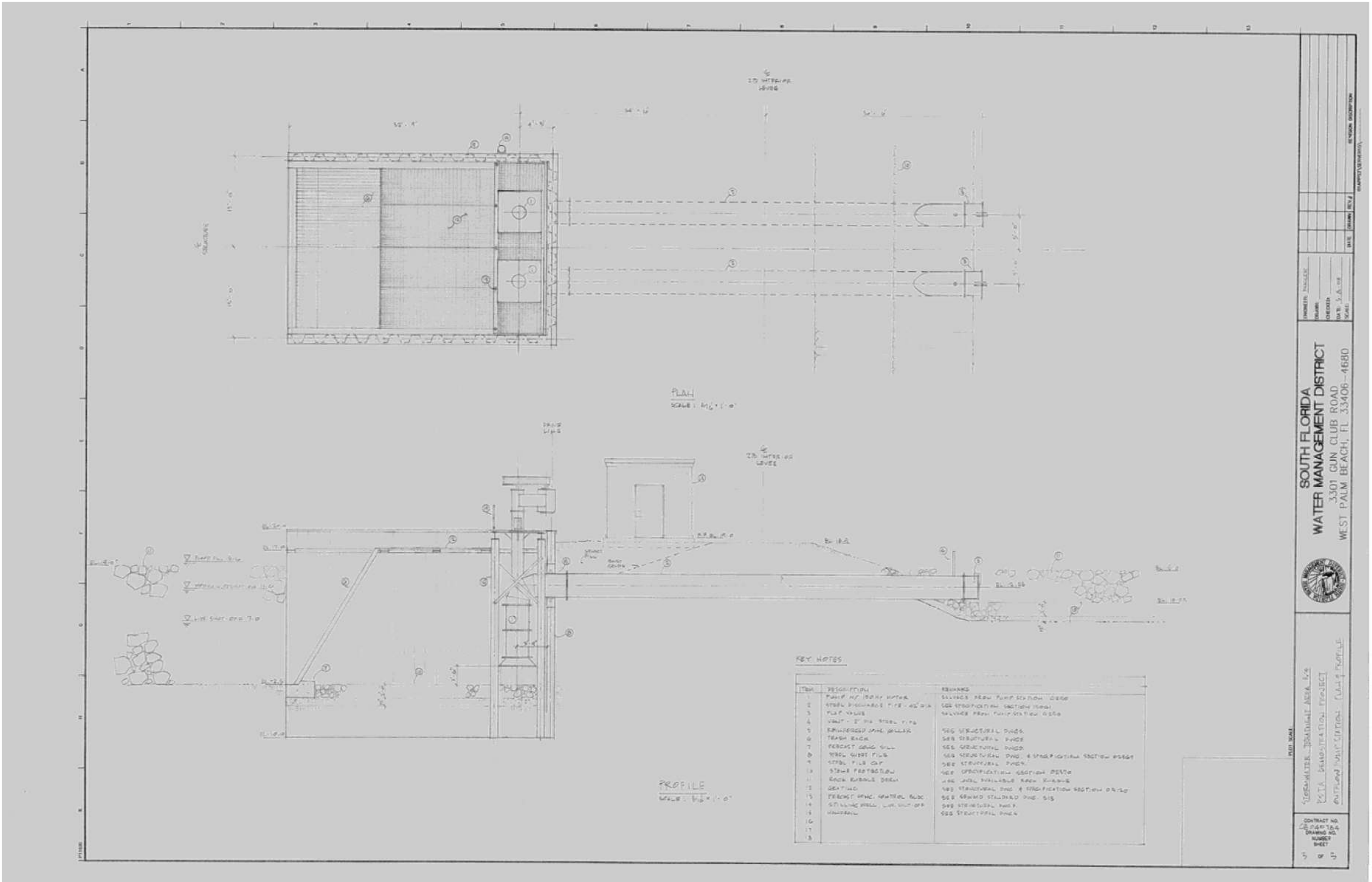

Figure 2. Plan and section views of pump station G388.

Table 1. Dimensions of station piping (steel, schedule STD 20).

Property	*Dimension*	*Source*
Pipe OD =	42 in	const plans
Wall Thickness =	0.375 in	proj specs
Pipe Length =	77.0 ft	const plans
Area =	9.28 ft^2	

Table 2. Estimates of steel pipe roughness.

Pipe Head Losses			
ε =	0.00015	ft	*Hydraulic Inst.*
ε =	0.00133	ft	*Sanks (1989)*

provided in table 3. Table 4 provides a comparison of the rating equation with the pump station performance curve.

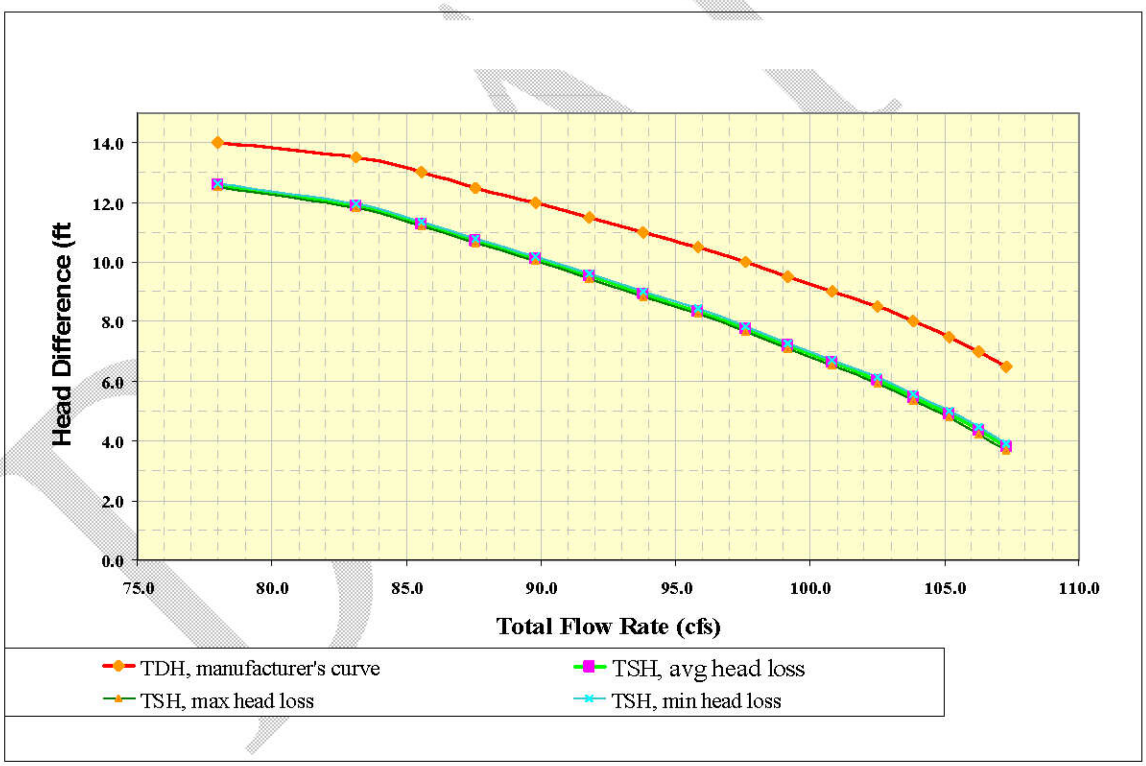

Figure 3. Performance curves for pump station G388.

Stream-Gauging Needs

The stream-gauging data needs for pump station G388 are summarized in Table 5. Indicated is the targeted number of flow measurements under each of the operating conditions.

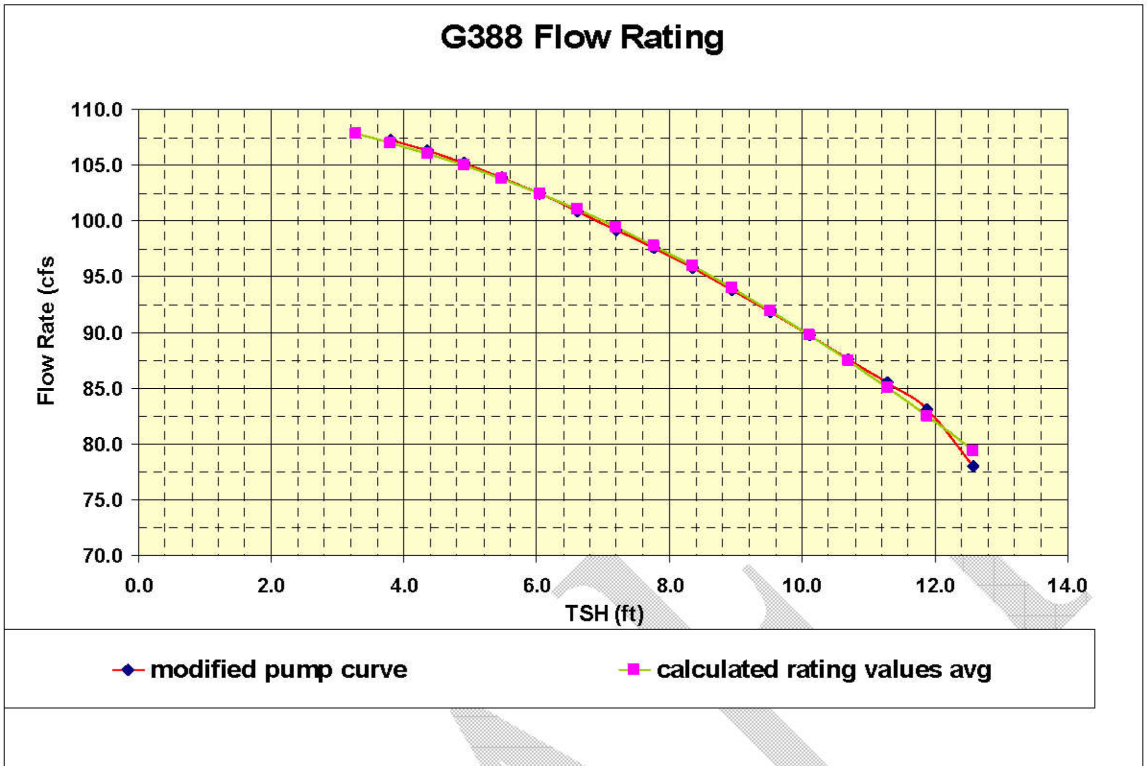

Figure 4. Flow rating for station G388.

Table 3. Regression parameters for the G388 rating equation.

Regression Parameter for Equation (1)	A	B	C
Approximate lower 95% C.I.	110.0	-0.3195	1.7957
Estimate	110.222	-0.2601	1.886
Approximate upper 95% C.I.	110.5	-0.2448	1.9028

Summary and Conclusions

A rating analysis of G388 pump station was carried out using the conventional case 8 model. A rating equation was developed for two identical pump units configured the same way. The equation yields discharge rates that are within 1.82% of the discharges derived from the pump station rating curve under the expected range of static heads. Given the uncertainties inherent to the modified pump station curves discussed above, it is recommended that the rating equation be recalibrated with measured flows of acceptable quality.

Table 4. A comparison of the regression equation with the pump station curve.

TSH (ft)	$Q_{p.s.\ perf.}$ (cfs)	Q_{rating} (cfs)	Error (%)
12.57	77.99	79.41	1.82
11.88	83.12	82.54	-0.70
11.28	85.57	85.10	-0.54
10.70	87.57	87.49	-0.10
10.11	89.80	89.80	0.00
9.52	91.81	91.97	0.18
8.94	93.81	94.04	0.24
8.35	95.82	95.99	0.18
7.77	97.60	97.80	0.20
7.20	99.16	99.47	0.31
6.62	100.83	101.04	0.20
6.04	102.50	102.50	-0.01
5.47	103.84	103.80	-0.04
4.91	105.18	104.99	-0.17
4.35	106.29	106.05	-0.22
3.80	107.29	106.99	-0.28
3.27	107.96	107.79	-0.16
2.74	108.52	108.48	-0.04
2.22	108.97	109.05	0.08
1.69	109.52	109.52	0.00
1.19	109.63	109.86	0.21
0.67	109.86	110.10	0.22
0.16	110.08	110.21	0.12

Table 5. Stream-gauging needs for G388.

Pump	TSH (ft)	Number of Measurements needed (@RPM =1780[1])
Unit 1 or 2	0~3.0	5
	3.0~6.0	5
	6.0~9.0	5

Note 1: The telemetry is reporting the pump rpm (350).

References

Hydraulic Institute (1990). Hydraulic Institute Engineering Data Book. Second Edition.

Imru, M. and Y. Wang. 2004. Flow Rating Development for New Pump Stations. Technical Publication EMA # 419, South Florida Water Management District, West Palm Beach, Florida, 44 pp.

Sanks, R., et al. (1989). Pumping Station Design, 828 pp.

Appendix A: Head Loss Calculations

Minimum Head Loss Calculation:

1780 RPM			Swamee & Jain(1976)							
TDH(ft)	**Q (GPM)**	**Q(cfs)**	**V(ft/s)**	**N_R**	**$V^2/2g$ (ft)**	**f**	**$h_l = f(L/D)V^2/2g$**	**$h_m = \Sigma KV^2/2g$**	**Total Head Loss (ft)**	**Static Head (ft)**
14.00	35000	77.99	8.40	2888788	1.10	0.01138	0.28	1.10	1.38	12.62
13.50	37300	83.12	8.96	3078622	1.25	0.01133	0.32	1.25	1.56	11.94
13.00	38400	85.57	9.22	3169413	1.32	0.01131	0.33	1.32	1.65	11.35
12.50	39300	87.57	9.44	3243696	1.38	0.01129	0.35	1.38	1.73	10.77
12.00	40300	89.80	9.68	3326233	1.45	0.01127	0.37	1.45	1.82	10.18
11.50	41200	91.81	9.89	3400516	1.52	0.01126	0.38	1.52	1.90	9.60
11.00	42100	93.81	10.11	3474799	1.59	0.01124	0.40	1.59	1.99	9.01
10.50	43000	95.82	10.32	3549082	1.66	0.01123	0.42	1.66	2.07	8.43
10.00	43800	97.60	10.52	3615111	1.72	0.01121	0.43	1.72	2.15	7.85
9.50	44500	99.16	10.68	3672887	1.77	0.01120	0.44	1.77	2.22	7.28
9.00	45250	100.83	10.86	3734790	1.83	0.01119	0.46	1.83	2.29	6.71
8.50	46000	102.50	11.04	3796692	1.89	0.01118	0.47	1.89	2.37	6.13
8.00	46600	103.84	11.19	3846214	1.94	0.01117	0.49	1.94	2.43	5.57
7.50	47200	105.18	11.33	3895736	1.99	0.01116	0.50	1.99	2.49	5.01
7.00	47700	106.29	11.45	3937005	2.04	0.01116	0.51	2.04	2.55	4.45
6.50	48150	107.29	11.56	3974146	2.08	0.01115	0.52	2.08	2.59	3.91
6	48450	107.96	11.63	3998907	2.10	0.01115	0.52	2.10	2.63	3.37
5.5	48700	108.52	11.69	4019542	2.12	0.01114	0.53	2.12	2.65	2.85
5	48900	108.97	11.74	4036049	2.14	0.01114	0.53	2.14	2.67	2.33
4.5	49150	109.52	11.80	4056683	2.16	0.01114	0.54	2.16	2.70	1.80
4	49200	109.63	11.81	4060810	2.17	0.01114	0.54	2.17	2.71	1.29
3.5	49300	109.86	11.84	4069064	2.18	0.01113	0.54	2.18	2.72	0.78
3	49400	110.08	11.86	4077317	2.18	0.01113	0.54	2.18	2.73	0.27
2.5	49480	110.26	11.88	4083920	2.19	0.01113	0.55	2.19	2.74	-0.24

Average Head Loss Calculation:

1780 RPM			$f_{av} = sqrt(f_{min} f_{max})$						
TDH(ft)	Q (GPM)	Q(cfs)	V(ft/s)	$V^2/2g$ (ft)	f	$h_l = f(L/D)V^2/2g$	$h_m = \Sigma KV^2/2g$	Total Head Loss (ft)	Static Head (ft)
14.00	35000	77.99	8.40	1.10	0.01352	0.33	1.10	1.43	12.57
13.50	37300	83.12	8.96	1.25	0.01348	0.38	1.25	1.62	11.88
13.00	38400	85.57	9.22	1.32	0.01347	0.40	1.32	1.72	11.28
12.50	39300	87.57	9.44	1.38	0.01346	0.42	1.38	1.80	10.70
12.00	40300	89.80	9.68	1.45	0.01344	0.44	1.45	1.89	10.11
11.50	41200	91.81	9.89	1.52	0.01343	0.46	1.52	1.98	9.52
11.00	42100	93.81	10.11	1.59	0.01342	0.48	1.59	2.06	8.94
10.50	43000	95.82	10.32	1.66	0.01341	0.50	1.66	2.15	8.35
10.00	43800	97.60	10.52	1.72	0.01340	0.52	1.72	2.23	7.77
9.50	44500	99.16	10.68	1.77	0.01339	0.53	1.77	2.30	7.20
9.00	45250	100.83	10.86	1.83	0.01338	0.55	1.83	2.38	6.62
8.50	46000	102.50	11.04	1.89	0.01337	0.57	1.89	2.46	6.04
8.00	46600	103.84	11.19	1.94	0.01337	0.58	1.94	2.53	5.47
7.50	47200	105.18	11.33	1.99	0.01336	0.60	1.99	2.59	4.91
7.00	47700	106.29	11.45	2.04	0.01336	0.61	2.04	2.65	4.35
6.50	48150	107.29	11.56	2.08	0.01335	0.62	2.08	2.70	3.80
6	48450	107.96	11.63	2.10	0.01335	0.63	2.10	2.73	3.27
5.5	48700	108.52	11.69	2.12	0.01335	0.63	2.12	2.76	2.74
5	48900	108.97	11.74	2.14	0.01334	0.64	2.14	2.78	2.22
4.5	49150	109.52	11.80	2.16	0.01334	0.65	2.16	2.81	1.69
4	49200	109.63	11.81	2.17	0.01334	0.65	2.17	2.81	1.19
3.5	49300	109.86	11.84	2.18	0.01334	0.65	2.18	2.83	0.67
3	49400	110.08	11.86	2.18	0.01334	0.65	2.18	2.84	0.16
2.5	49480	110.26	11.88	2.19	0.01334	0.65	2.19	2.85	-0.35

Maximum Head Loss Calculation:

1780 RPM			Swamee & Jain(1976)							
TDH(ft)	Q (GPM)	Q(cfs)	V(ft/s)	N_R	$V^2/2g$ (ft)	f	$h_l = f(L/D)V^2/2g$	$h_m = \Sigma KV^2/2g$	Total Head Loss (ft)	Static Head (ft)
14.00	35000	77.99	8.40	2888788	1.10	0.01606	0.39	1.10	1.49	12.51
13.50	37300	83.12	8.96	3078622	1.25	0.01604	0.45	1.25	1.69	11.81
13.00	38400	85.57	9.22	3169413	1.32	0.01604	0.47	1.32	1.79	11.21
12.50	39300	87.57	9.44	3243696	1.38	0.01603	0.50	1.38	1.88	10.62
12.00	40300	89.80	9.68	3326233	1.45	0.01603	0.52	1.45	1.98	10.02
11.50	41200	91.81	9.89	3400516	1.52	0.01602	0.55	1.52	2.06	9.44
11.00	42100	93.81	10.11	3474799	1.59	0.01602	0.57	1.59	2.16	8.84
10.50	43000	95.82	10.32	3549082	1.66	0.01601	0.59	1.66	2.25	8.25
10.00	43800	97.60	10.52	3615111	1.72	0.01601	0.62	1.72	2.33	7.67
9.50	44500	99.16	10.68	3672887	1.77	0.01601	0.64	1.77	2.41	7.09
9.00	45250	100.83	10.86	3734790	1.83	0.01600	0.66	1.83	2.49	6.51
8.50	46000	102.50	11.04	3796692	1.89	0.01600	0.68	1.89	2.57	5.93
8.00	46600	103.84	11.19	3846214	1.94	0.01600	0.70	1.94	2.64	5.36
7.50	47200	105.18	11.33	3895736	1.99	0.01599	0.71	1.99	2.71	4.79
7.00	47700	106.29	11.45	3937005	2.04	0.01599	0.73	2.04	2.77	4.23
6.50	48150	107.29	11.56	3974146	2.08	0.01599	0.74	2.08	2.82	3.68
6	48450	107.96	11.63	3998907	2.10	0.01599	0.75	2.10	2.85	3.15
5.5	48700	108.52	11.69	4019542	2.12	0.01599	0.76	2.12	2.88	2.62
5	48900	108.97	11.74	4036049	2.14	0.01599	0.77	2.14	2.91	2.09
4.5	49150	109.52	11.80	4056683	2.16	0.01599	0.77	2.16	2.94	1.56
4	49200	109.63	11.81	4060810	2.17	0.01599	0.78	2.17	2.94	1.06
3.5	49300	109.86	11.84	4069064	2.18	0.01599	0.78	2.18	2.95	0.55
3	49400	110.08	11.86	4077317	2.18	0.01599	0.78	2.18	2.97	0.03
2.5	49480	110.26	11.88	4083920	2.19	0.01599	0.78	2.19	2.98	-0.48