

# **FLOW RATING ANALYSIS FOR PUMP STATION G434 & G436**



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## ACKNOWLEDGEMENT

The authors wish to express their appreciation to Larry Vicars for collecting the pump performance curve and pump design information for this rating analysis.



## DEFINITIONS

### Acronyms

TDH	Total dynamic head
TSH	Total static head
SFWMD	South Florida Water Management District
STA	Stormwater treatment area



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## **EXECUTIVE SUMMARY**

This report summarizes a preliminary flow rating analysis for each type of pump at Pump Station G434 and Pump Station G436, based on the pump performance curve. The developed rating equation will be used to compute flows through these pump stations.



## 1.0 INTRODUCTION

### 1.1 Background

Pump Station G434 is the Compartment B North Build-out inflow pump station. The station discharges into the northwest corner of the North Build-out (NBO) Area of the Compartment B Stormwater Treatment Area (STA). The station is located on the east side of U.S. Highway 27, south of Belle Glade, approximately 2800 feet north of the Woerner Bridge. The station's intake canal connects directly to the North New River Canal. Pump Station G434 consists of three electric seepage pumps each with capacity of 100 cfs, two electric stormwater pumps each with capacity of 100 cfs, and two diesel stormwater pump each with capacity of 460 cfs.

Pump Station G436 is the Compartment B outflow pump station. The station is located on the east side of the Compartment B STA South Build-out (SBO) area, approximately 3.5 miles east of U.S. Highway 27 and just south of the District's existing G335 pump station. Pump Station G336 discharges into L-6 Canal. The location of Compartment B is shown in **Figure 1**. Pump Station G436 consists of two electric stormwater pumps each with capacity of 100 cfs, and three diesel stormwater pumps each with capacity of 533 cfs.

### 1.2 Objectives and Scope

We will conduct a preliminary rating analysis to develop flow rating equations for Pump Station G434 and G436 to compute flows through the pump stations. We will develop a rating equation for each type of pumps at these two pump stations.

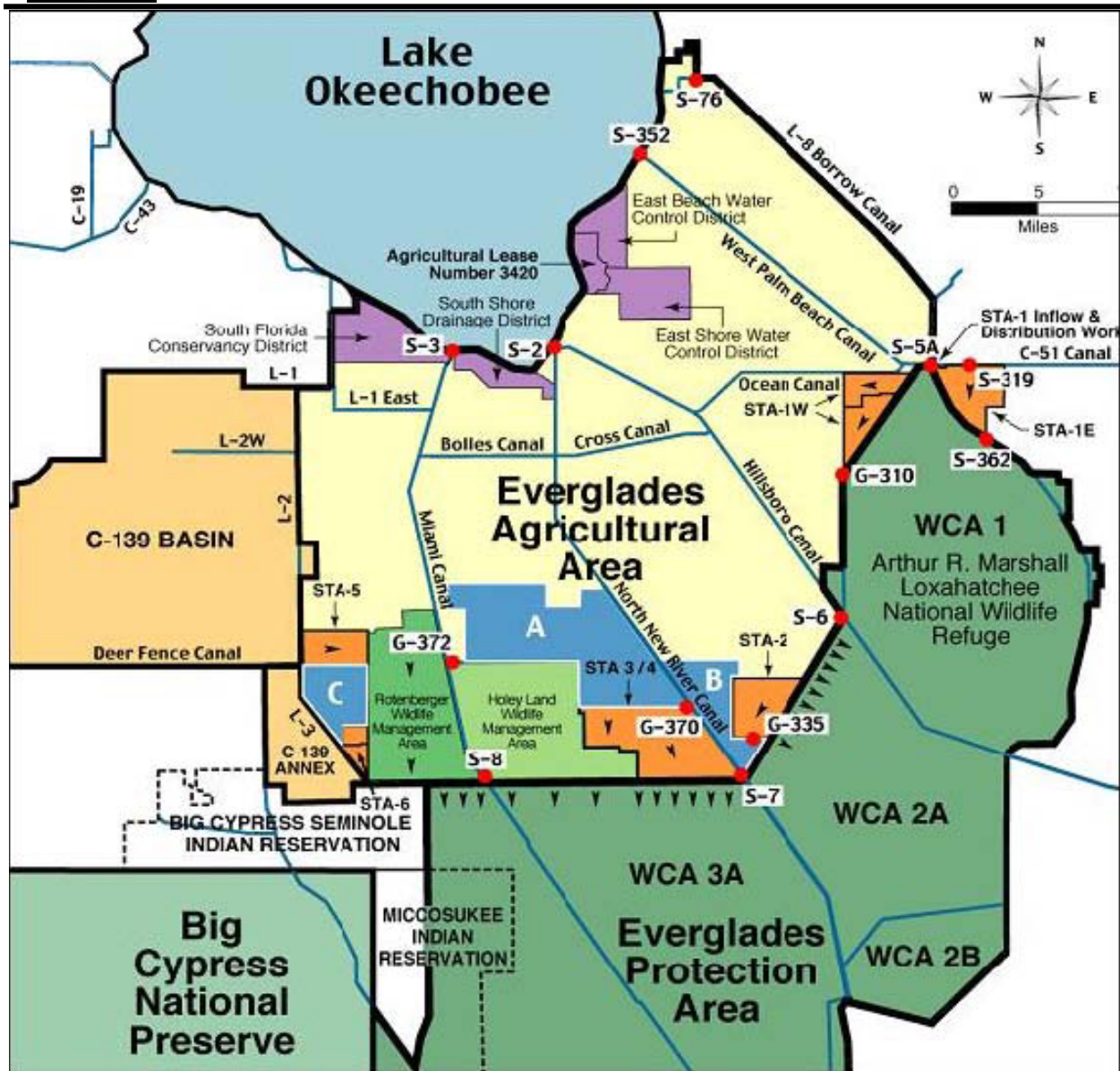


Figure 1. Location Map for Compartment B

## 2.0 STATION DESIGN

Pump Station G434 consists of three electric seepage pumps each with capacity of 100 cfs, two electric stormwater pumps each with capacity of 100 cfs, and two diesel stormwater pump each with capacity of 460 cfs. **Table 1** presents more detailed description for G434. Pump Station G436 consists of two electric stormwater pumps each with capacity of 100 cfs and three diesel stormwater pumps each with capacity of 533 cfs. **Table 2** presents more detailed description for G436.





**Table 1. Description for Pump Station G434**

<b>Pump Type</b>	<b>ITEM</b>	<b>Description</b>
Electric seepage pump	Number of pumps	3
	Design pump capacity	100 cfs
	Engine motor horsepower	150 Hp
	Design engine speed	440 rpm
	Pump impeller speed	440 rpm
	Propeller Diameter	34 in
	Discharge pump diameter	42 in
Electric stormwater pump	Number of pumps	2
	Design pump capacity	100 cfs
	Engine motor horsepower	150 Hp
	Design engine speed	440 rpm
	Pump impeller speed	440 rpm
	Propeller Diameter	34 in
	Discharge pump diameter	42 in
Diesel Stormwater pump	Number of pumps	2
	Design pump capacity	460 cfs
	Engine motor horsepower	575 Hp
	Design engine speed	1750 rpm
	Pump impeller speed	146 rpm
	Propeller Diameter	80.7 in
	Discharge pump diameter	96 in
Elevation	Maximum upstream water surface elev.	12.5 ft, NAVD
	Maximum downstream water surface elev.	12.5 ft, NAVD
	Minimum upstream water surface elev.	5.2 ft, NAVD
	Minimum downstream water surface elev.	9.0 ft, NAVD



**Table 2. Description for Pump Station G436**

Pump Type	ITEM	Description
Electric stormwater pump	Number of pumps	2
	Design pump capacity	100 cfs
	Engine motor horsepower	200 Hp
	Design engine speed	440 rpm
	Pump impeller speed	440 rpm
	Propeller Diameter	34 in
	Discharge pump diameter	42 in
Diesel stormwater pump	Number of pumps	3
	Design pump capacity	533 cfs
	Engine motor horsepower	986 Hp
	Design engine speed	1150 rpm
	Pump impeller speed	186 rpm
	Propeller Diameter	80.7 in
	Discharge pump diameter	96 in
Elevation	Maximum upstream water surface elev.	11.0 ft, NAVD
	Maximum downstream water surface elev.	15.4 ft, NAVD
	Minimum upstream water surface elev.	4.2 ft, NAVD
	Minimum downstream water surface elev.	8.1 ft, NAVD

**2.1. Pump Performance Curves for G434**

The factory provides the pump performance curves for these three types of pumps at Pump Station G434, as shown in **Figure 2 through 4**.

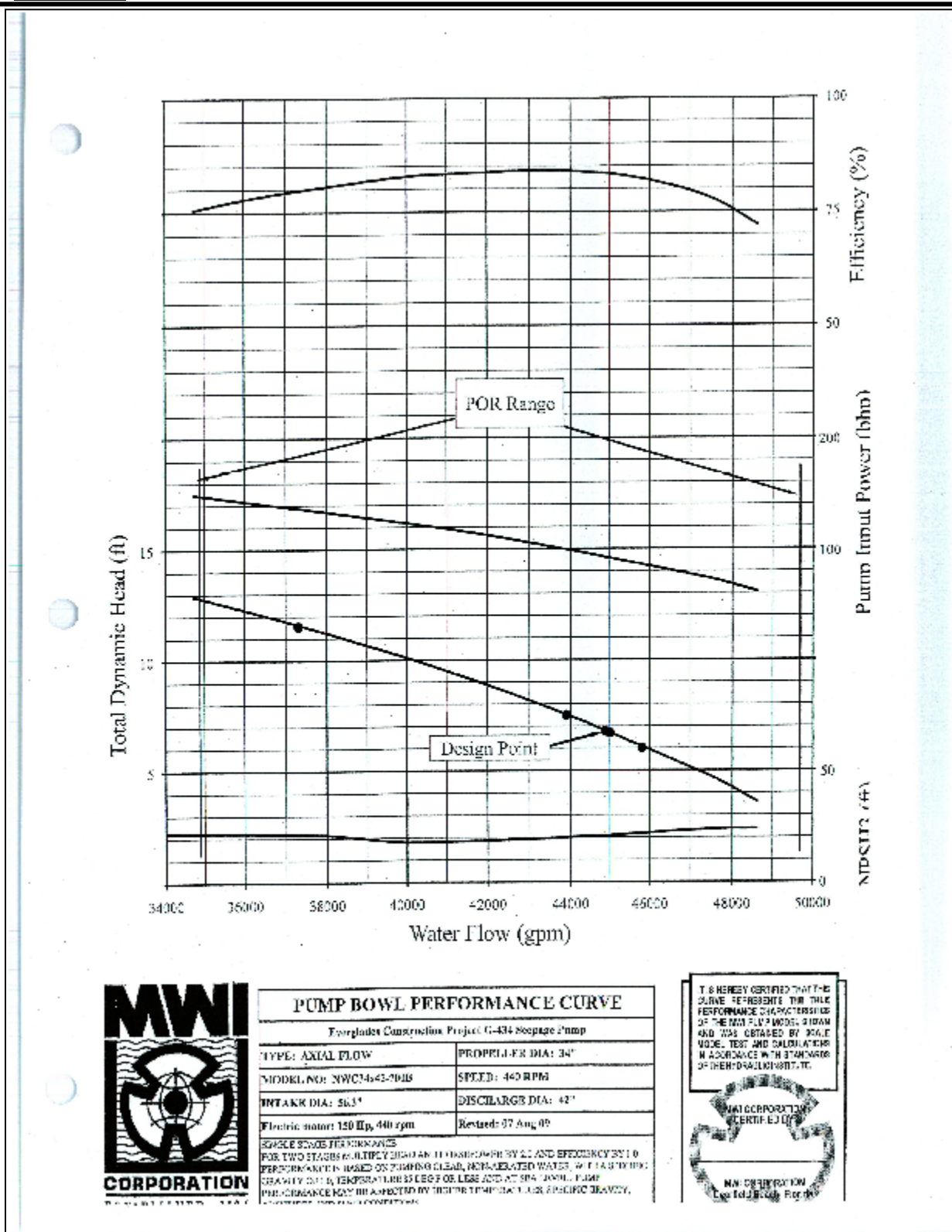


Figure 2 Performance Curve for Seepage Pump at G434.

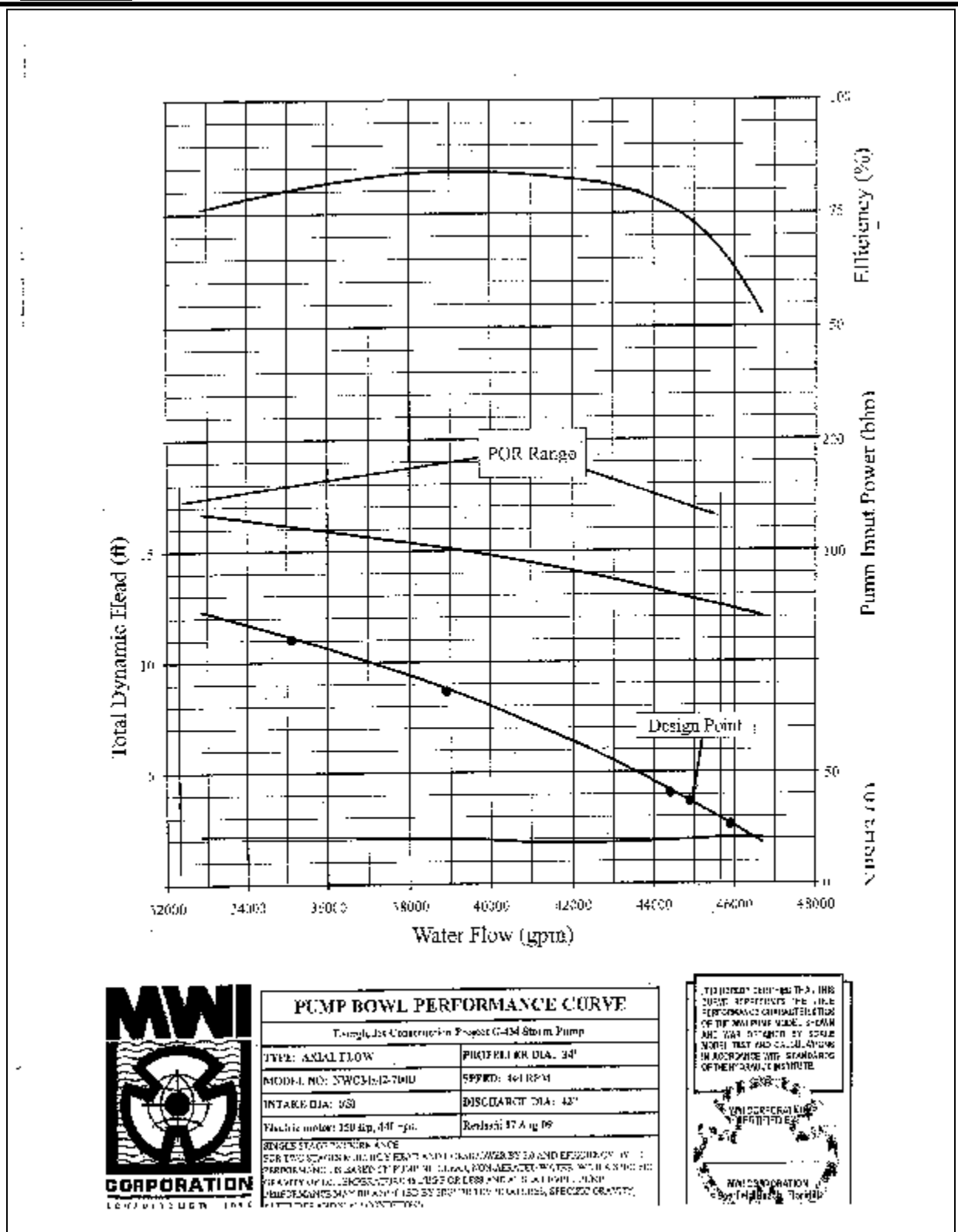


Figure 3. Pump Performance Curve for Electric Stormwater Pump at G434

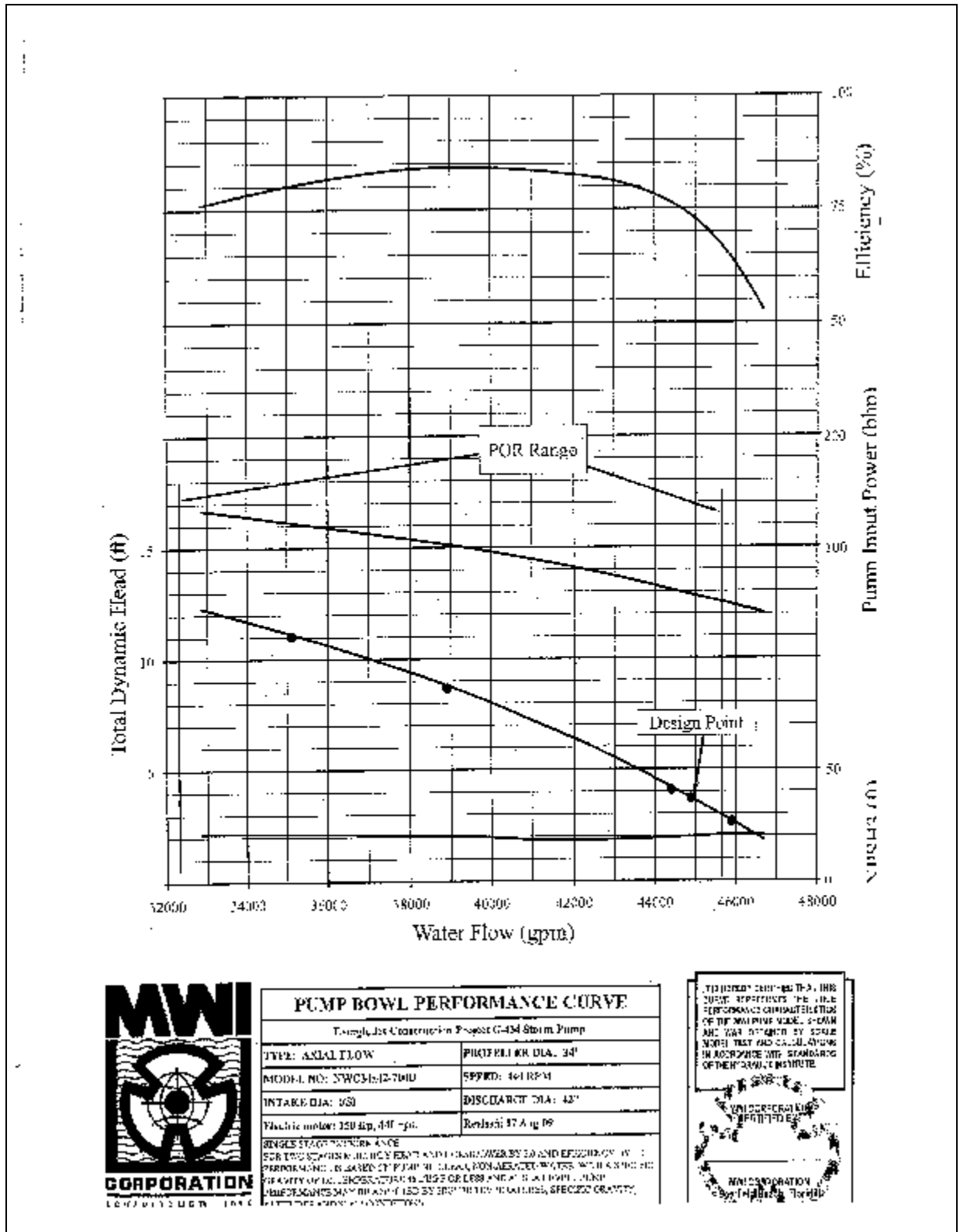


Figure 4. Pump Performance Curve for Diesel Stormwater Pump at G434



2.2. Pump Performance Curves for G436

Figures 5 and 6 show the pump station performance curve for electric and diesel stormwater pumps, respectively.

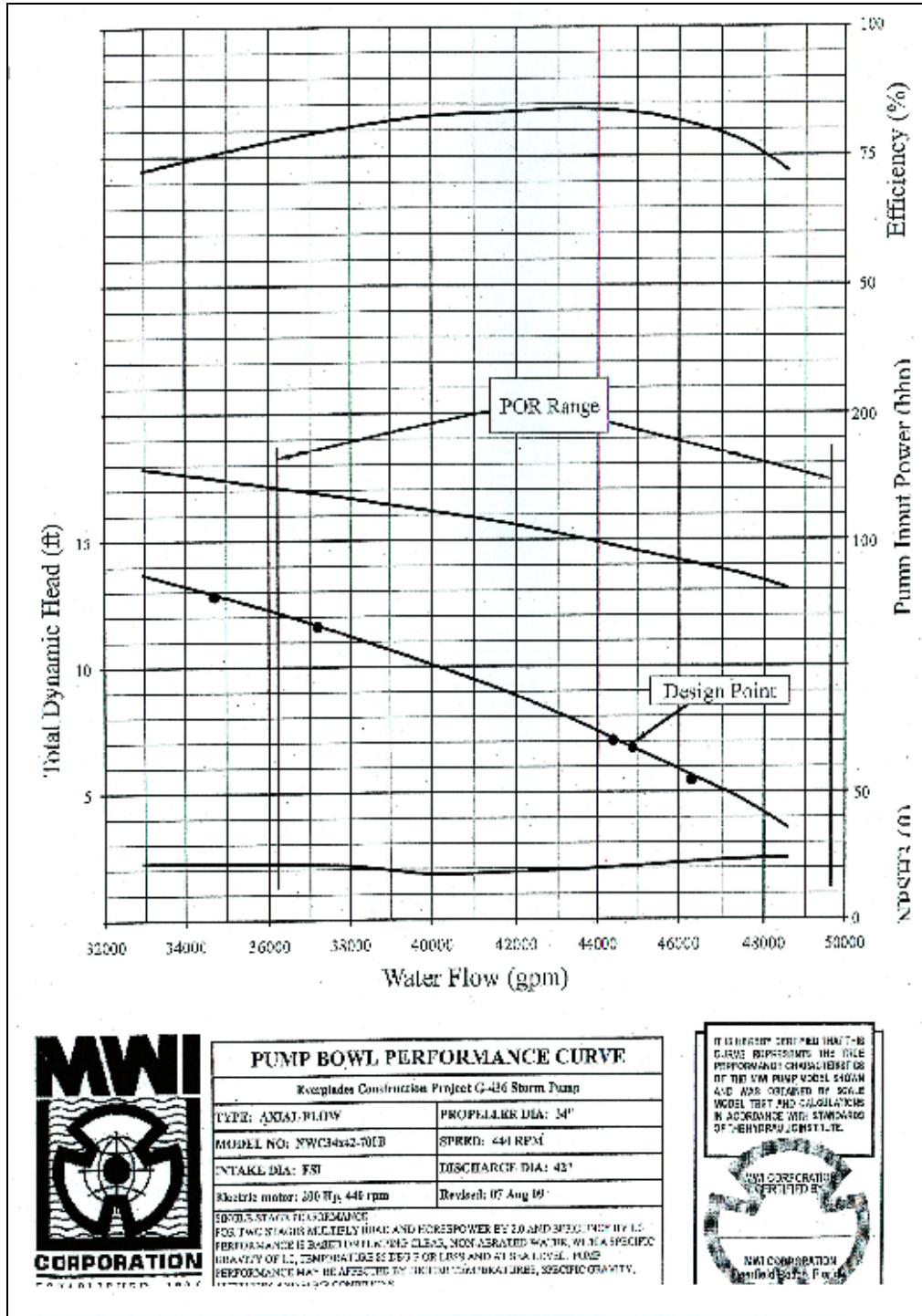
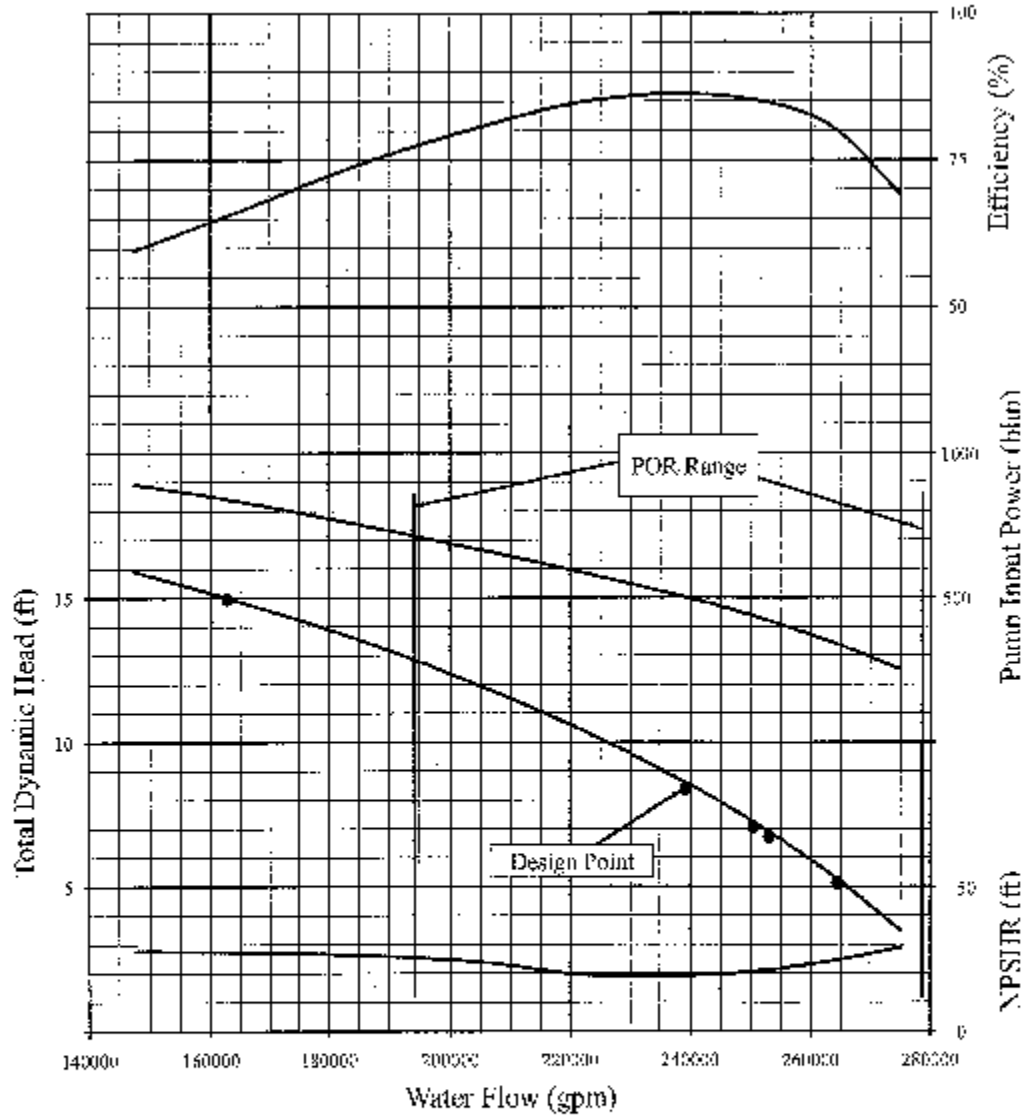


Figure 5. Pump Performance Curve for Electric Stormwater Pump at G436



PUMP BOWL PERFORMANCE CURVE	
Everglades Construction Project G 436 2306 Pump	
TYPE: AXIAL FLOW	PROPELLER DIA: 80.0"
MODEL NO: NWC06	SPEED: 146 RPM
INTAKE TYPE: SST	DISCHARGE DIA: 36"
Rated Output: 386 Hp @ 1150 gpm	Date: 18 Aug 09
<small>NOTES: 1. PERFORMANCE IS FOR CLEAN WATER AND HORSEPOWER BY 1.49 AND HEAD BY 1.47. 2. PUMP DISCHARGE BASED ON PUMPING CLEAN 30-40°F AND WATER WITH A SPECIFIC GRAVITY OF 1.0. 3. PUMP AT 1150 GPM IS 11.5 IN. ABOVE WATER. 4. PUMP PERFORMANCE MAY BE AFFECTED BY LIQUID TEMPERATURES, SPECIFIC GRAVITY, ALTITUDE AND SUMP CONDITIONS.</small>	



Figure 6. Pump Performance Curve for Diesel Stormwater Pump at G436





### 3.0 RATING ANALYSIS

We will develop a Case 8 rating equation for each type of pump at the two pump stations based on the factory pump performance curve. Case 8 rating equation is developed by dimensional analysis and the pump affinity laws, which is the conventional rating equation representing all the possible cases, as documented in Damisse (2001) and Imru and Wang (2003). Equation below shows the Case 8 rating equation.

$$Q = A \left( \frac{N}{No} \right) + BH^C \left( \frac{No}{N} \right)^{2C-1} \quad (1)$$

$$H = \max\{CL, TW\} - HW \quad (2)$$

Where

- $Q$ : Discharge in cfs;
- $N$ : Pump engine speed in rpm;
- $No$ : Design pump engine speed in rpm;
- $H$ : Total static head (TSH);
- $A, B$  and  $C$ : Regression coefficients determined through regression analysis ( $A > 0$ ,  $B < 0$ , and  $C > 1.0$ ).
- $CL$ : Discharge pipe outlet centerline elevation;
- $TW$ : Tailwater elevation;
- $HW$ : Headwater elevation.

The  $H$  versus  $Q$  relationship can be estimated by subtracting the total head losses through the intake and discharge works from total dynamic head (TDH) on the pump performance curve. We will then conduct a non-linear regression analysis using SAS NLIN function to determine the coefficient in the above equation.

#### 3.1 Pump Station G434

Pump Station G434 consists of three types of pumps: Electric seepage pump, electric stormwater pump, and diesel stormwater pump. Each pump has its own performance curve. Hence, we need to develop a flow rating equation for each type of the pump. As stated above, we computed TSH by subtracting total head loss from TDH. The total head loss includes friction loss and minor losses, which were computed based on the loss coefficients provided by the pump manufactory. **Table 3** through **Table 5** present TSH vs.  $Q$  values corresponding to the electric seepage pump of 100 cfs, electric stormwater pump of 100 cfs, and diesel stormwater pump of 460 cfs, respectively. **Table 6** presents the flow rating equation coefficients of Eq. (1) corresponding to each type of the pump, which were derived based on SAS Nonlinear regression analysis. **Figure 7** illustrates the developed rating curve for G434 electric seepage pump of 100 cfs, **Figure 8** for G434 electric stormwater pump of 100 cfs, and **Figure 9** for G434 diesel stormwater pump of 460 cfs. These diagrams illustrate that the rating equation from the developed rating equation fits the TSH well.





**Table 3. TDH, Head Loss, TSH and Discharge Relations for G434 Electric Seepage Pump -100 cfs**

Flow Rate (gpm)	Flow Rate (cfs)	TDH (ft)	Head Loss (ft)	TSH (ft)
35000	77.983	12.76	1.45	11.313
36000	80.211	12.30	1.53	10.770
37000	82.439	11.80	1.62	10.183
38000	84.667	11.22	1.71	9.515
39000	86.895	10.70	1.80	8.904
40000	89.123	10.10	1.89	8.211
41000	91.351	9.50	1.99	7.515
42000	93.579	8.84	2.08	6.757
43000	95.807	8.20	2.18	6.017
44000	98.036	7.46	2.29	5.174
45000	100.264	6.70	2.39	4.309
46000	102.492	5.94	2.50	3.441
47000	104.720	5.14	2.61	2.532
48000	106.948	4.26	2.72	1.539

**Table 4. TDH, Head Loss, TSH and Discharge Relations for G434 Electric Stormwater Pump - 100 cfs**

Flow Rate (gpm)	Flow Rate (cfs)	TDH (ft)	Head Loss (ft)	TSH (ft)
33000	73.527	12.20	1.25	10.953
34000	75.755	11.70	1.32	10.376
35000	77.983	11.20	1.40	9.797
36000	80.211	10.62	1.48	9.136
37000	82.439	10.04	1.57	8.472
38000	84.667	9.40	1.65	7.747
39000	86.895	8.70	1.74	6.958
40000	89.123	8.00	1.83	6.168
41000	91.351	7.20	1.92	5.275
42000	93.579	6.40	2.02	4.380
43000	95.807	5.52	2.12	3.403
44000	98.036	4.60	2.22	2.383
45000	100.264	3.60	2.32	1.281
46000	102.492	2.60	2.42	0.177



**Table 5. TDH, Head Loss, TSH and Discharge Relations for G343 Diesel Stormwater Pump - 460 cfs**

Flow Rate (gpm)	Flow Rate (cfs)	TDH (ft)	Head Loss (ft)	TSH (ft)
120000	267.370	9.60	0.614	8.986
125000	278.510	9.38	0.666	8.714
130000	289.650	9.14	0.720	8.420
135000	300.791	8.90	0.777	8.123
140000	311.931	8.62	0.835	7.785
145000	323.072	8.36	0.896	7.464
150000	334.212	8.06	0.959	7.101
155000	345.352	7.74	1.024	6.716
160000	356.493	7.40	1.091	6.309
165000	367.633	7.06	1.160	5.900
170000	378.774	6.70	1.231	5.469
175000	389.914	6.34	1.305	5.035
180000	401.054	5.96	1.381	4.579
185000	412.195	5.50	1.458	4.042
190000	423.335	5.06	1.538	3.522
195000	434.476	4.60	1.620	2.980
200000	445.616	4.10	1.704	2.396
205000	456.756	3.54	1.791	1.749
210000	467.897	2.92	1.879	1.041
215000	479.037	2.30	1.970	0.330

**Table 6. Flow Rating Coefficients for G434**

Pump Type	N0 (rpm)	Rating Coefficient	Estimate	Approximate Lower 95% Confidence Limit	Approximate Upper 95% Confidence Limit
Electric Seepage Pump - 100 cfs	440	A	108.8	108.3	109.3
		B	-1.1447	-1.3051	-0.9844
		C	1.353	1.2996	1.4063
Electric Stormwater Pump - 100 cfs	440	A	102.1	101.5	102.7
		B	-1.1704	-1.3952	-0.9455
		C	1.3278	1.251	1.4045
Diesel Stormwater Pump - 460 cfs	1750	A	476.3	473.0	479.6
		B	-7.8039	-8.9795	-6.6284
		C	1.4886	1.4231	1.554

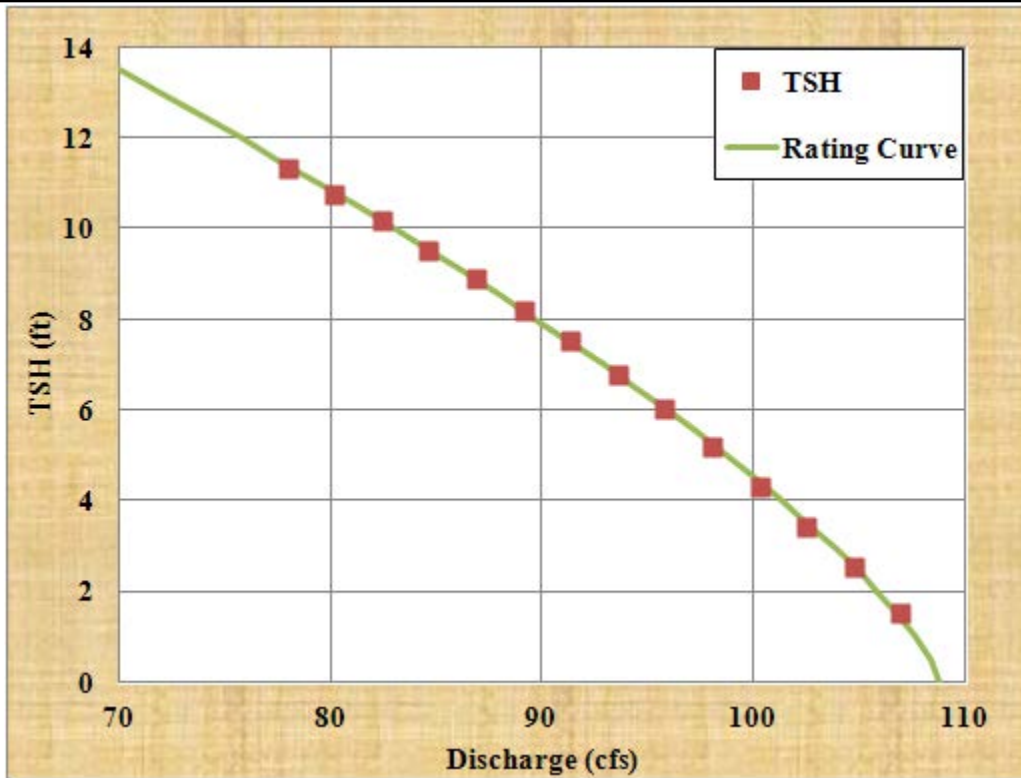


Figure 7. Rating Curve for G434 Electric Seepage Pump – 100 cfs

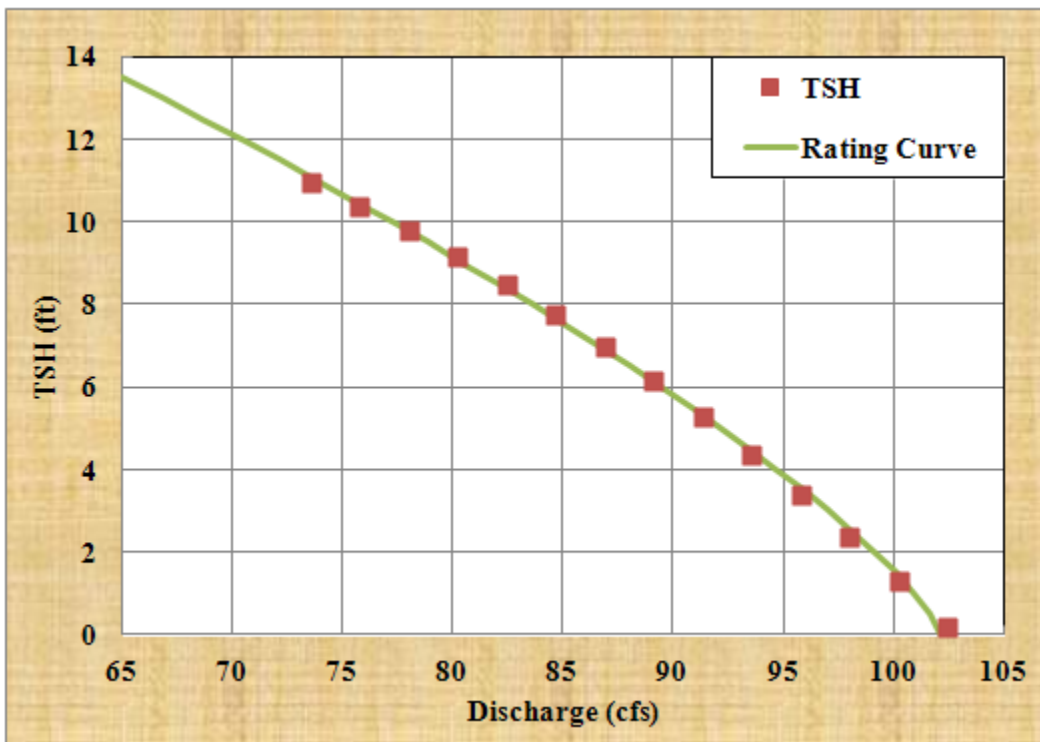


Figure 8. Rating Curve for G434 Electric Stormwater Pump – 100 cfs

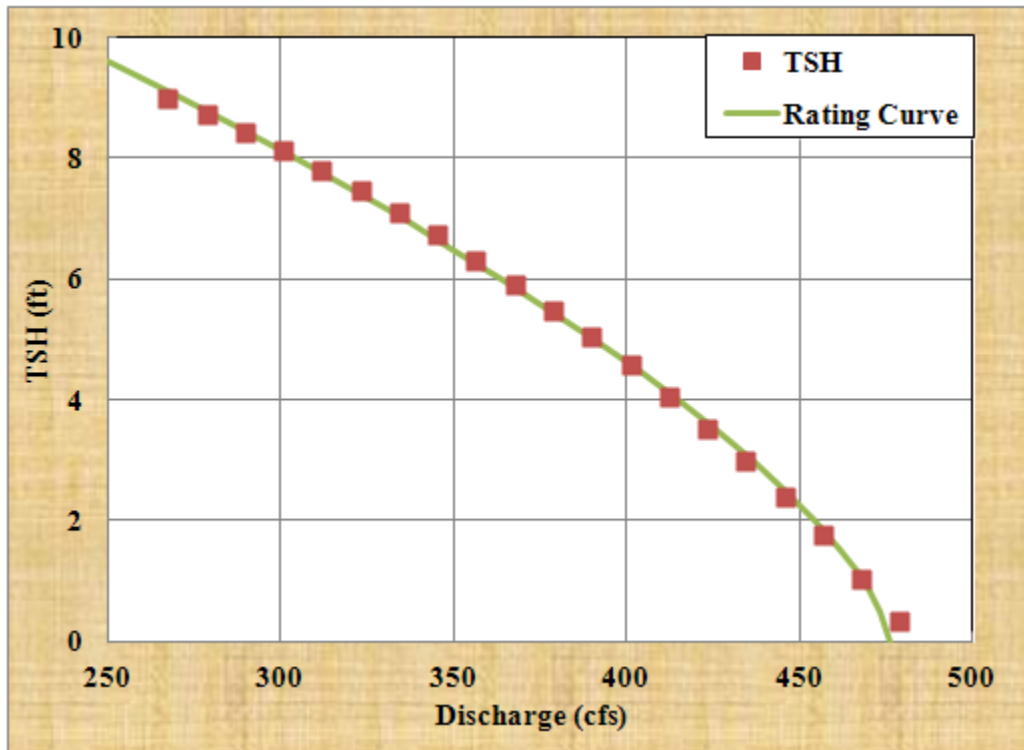


Figure 9. Rating Curve for G434 Diesel Stormwater Pump – 460 cfs

### 3.2 Pump Station G436

Pump Station G436 consists of two types of pumps: Electric stormwater pump and diesel stormwater pump. Each pump has its own performance curve. Similar to Pump Station G434, we developed a flow rating equation for each type of pump. **Table 7** and **Table 8** present TSH vs. Q values corresponding to the electric stormwater pump of 100 cfs and the diesel stormwater pump of 553 cfs, respectively. The TSH was computed by subtracting total head loss from TDH. **Table 9** presents the flow rating equation coefficients of Eq. (1) corresponding to each type of pump, which were derived based on SAS Nonlinear regression analysis. **Figure 10** illustrates the developed rating curve for G436 electric stormwater pump of 100 cfs and **Figure 11** for G436 electric stormwater pump of 533 cfs. These diagrams illustrate that the rating curve from the developed rating equation well fit the TSH.



**Table 7. TDH, Head Loss, TSH and Discharge Relations for G436 Electric Stormwater Pump - 100 cfs**

Flow Rate (gpm)	Flow Rate (cfs)	TDH (ft)	Head Loss (ft)	TSH (ft)
33000	73.527	13.66	1.33	12.330
34000	75.755	13.2	1.41	11.788
35000	77.983	12.8	1.50	11.304
36000	80.211	12.3	1.58	10.718
37000	82.439	11.72	1.67	10.048
38000	84.667	11.2	1.76	9.437
39000	86.895	10.7	1.86	8.843
40000	89.123	10.1	1.95	8.146
41000	91.351	9.5	2.05	7.447
42000	93.579	8.84	2.15	6.686
43000	95.807	8.14	2.26	5.882
44000	98.036	7.5	2.36	5.136
45000	100.264	6.76	2.47	4.287
46000	102.492	5.87	2.58	3.286
47000	104.720	5.1	2.70	2.403
48000	106.948	4.2	2.81	1.387

**Table 8. TDH, Head Loss, TSH and Discharge Relations for G436 Diesel Stormwater Pump - 533 cfs**

Flow Rate (gpm)	Flow Rate (cfs)	TDH (ft)	Head Loss (ft)	TSH (ft)
150000	334.212	15.70	0.917	14.783
155000	345.352	15.50	0.979	14.521
160000	356.493	15.20	1.043	14.157
165000	367.633	14.86	1.109	13.751
170000	378.774	14.50	1.177	13.323
175000	389.914	14.24	1.248	12.992
180000	401.054	13.90	1.320	12.580
185000	412.195	13.54	1.394	12.146
190000	423.335	13.18	1.471	11.709
195000	434.476	12.72	1.549	11.171
200000	445.616	12.34	1.630	10.710
205000	456.756	11.92	1.712	10.208
210000	467.897	11.50	1.797	9.703
215000	479.037	11.10	1.883	9.217
220000	490.178	10.60	1.972	8.628



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225000	501.318	10.10	2.063	8.037
230000	512.458	9.60	2.155	7.445
235000	523.599	9.06	2.250	6.810
240000	534.739	8.50	2.347	6.153
245000	545.880	7.90	2.446	5.454
250000	557.020	7.30	2.546	4.754
255000	568.160	6.60	2.649	3.951
260000	579.301	5.90	2.754	3.146
265000	590.441	5.20	2.861	2.339
270000	601.581	4.30	2.970	1.330
275000	612.722	3.50	3.081	0.419

**Table 9. Flow Rating Coefficients for G436**

Pump Type	N0 (rpm)	Rating Coefficient	Estimate	Approximate Lower 95% Confidence Limit	Approximate Upper 95% Confidence Limit
Electric Stormwater Pump - 100 cfs	440	A	108.2	107.7	108.7
		B	-1.0183	-1.1644	-0.8722
		C	1.4006	1.3471	1.4542
Diesel Stormwater Pump - 460 cfs	1150	A	607.4	603.7	611.0
		B	-4.4525	-5.1636	-3.7414
		C	1.520	1.4628	1.5772

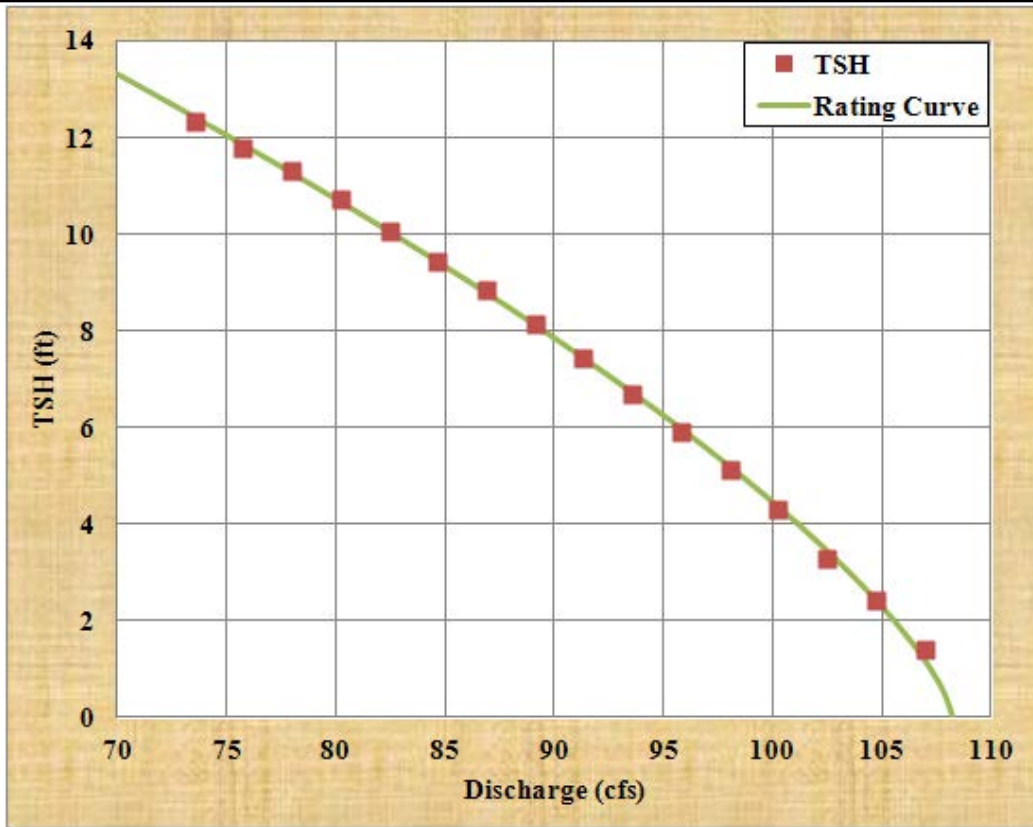


Figure 10. Rating Curve for G436 Electric Stormwater Pump – 100 cfs

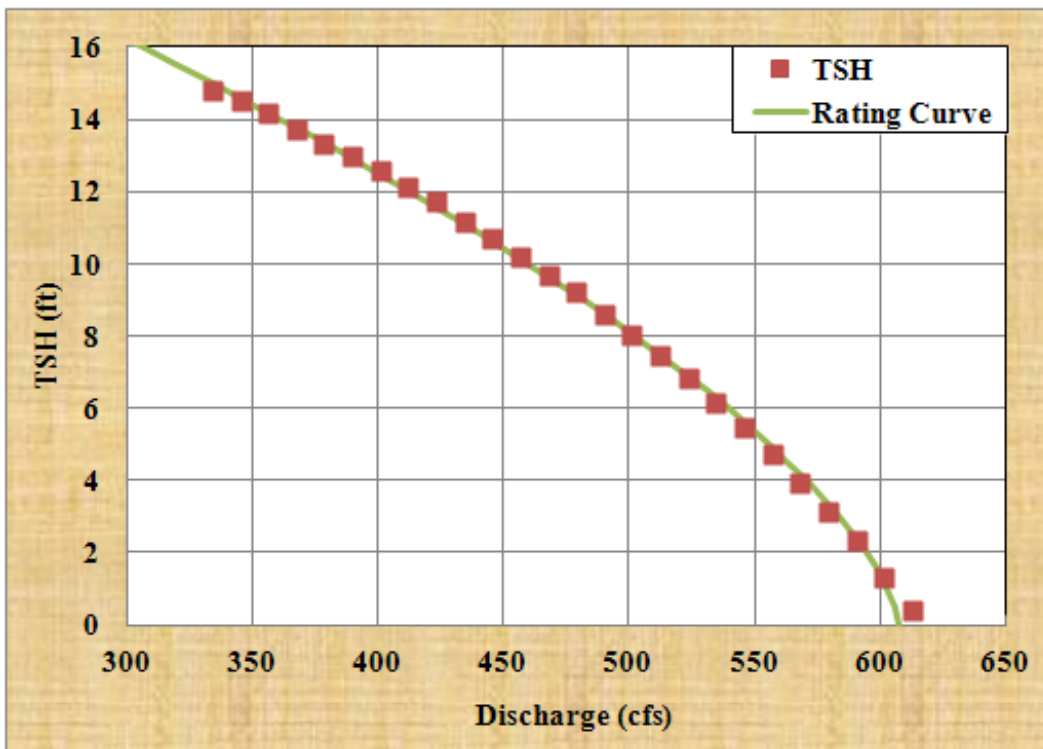


Figure 11. Rating Curve for G436 Diesel Stormwater Pump – 533 cfs



## 4.0 CONCLUDING REMARKS

We conducted preliminary rating analysis for each type of pump at Pump Station G434 and G436 based on the pump performance curve. **Table 6** presents the flow rating parameters for Pump Station G434, and **Table 9** the flow rating parameters for Pump Station G436. The preliminary flow rating equations need to be calibrated, and to be potentially improved based on future flow measurements after the pump stations are constructed and operated.





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Imru, M. and Y. Wang. 2003. Flow Rating Analysis Procedures for Pumps. Technical Publication EMA # 413, South Florida Water Management District, West Palm Beach, Florida.