FLOW RATING ANALYSIS FOR PUMP STATION G445

By
Sheng Yue & Emile Damisse
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Hydro Data Management Section
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South Florida Water Management District

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ACKNOWLEDGEMENT

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DEFINITIONS

Acronyms

SFWMD	South Florida Water Management District
STA	Stormwater treatment area
TDH	Total dynamic head
TSH	Total static head
ARE	Absolute relative error
AARE	Average absolute relative error

EXECUTIVE SUMMARY

Pump Station G445 houses two identical electric pump units each with design capacity of 13 cfs. This report summarizes a flow rating analysis for Pump Station G445 based on the corresponding pump performance curve. The developed rating equation will be used to compute flow through the pump station.

1.0 INTRODUCTION

1.1 Background

Pump Station G445 houses two identical electric pumps each with design capacity of 13 cfs. The station is a seepage return pump station that provides seepage control for the 45 acre triangle at the southern tip of Cell 8 of STA-2, as shown in **Figure 1**. The pump station G445 discharges back into Cell 8.

A generator is located on-site to supply power in case the commercial electric service is disrupted. The two pumps operate automatically in response to headwater elevation. Local and remote operation of G445 is possible as required to maintain average water elevation within the east west farm canal upstream of the intake pumps at 8.00 ft NAVD 88 (9.46 ft NGVD 29) during normal operations. Remote operation via telemetry is from the District's West Palm Beach Operations Control Center. Headwater, tailwater stage and pump information are available to the remote operators, while headwater and tailwater staff gauges and pump information are available for local operation.

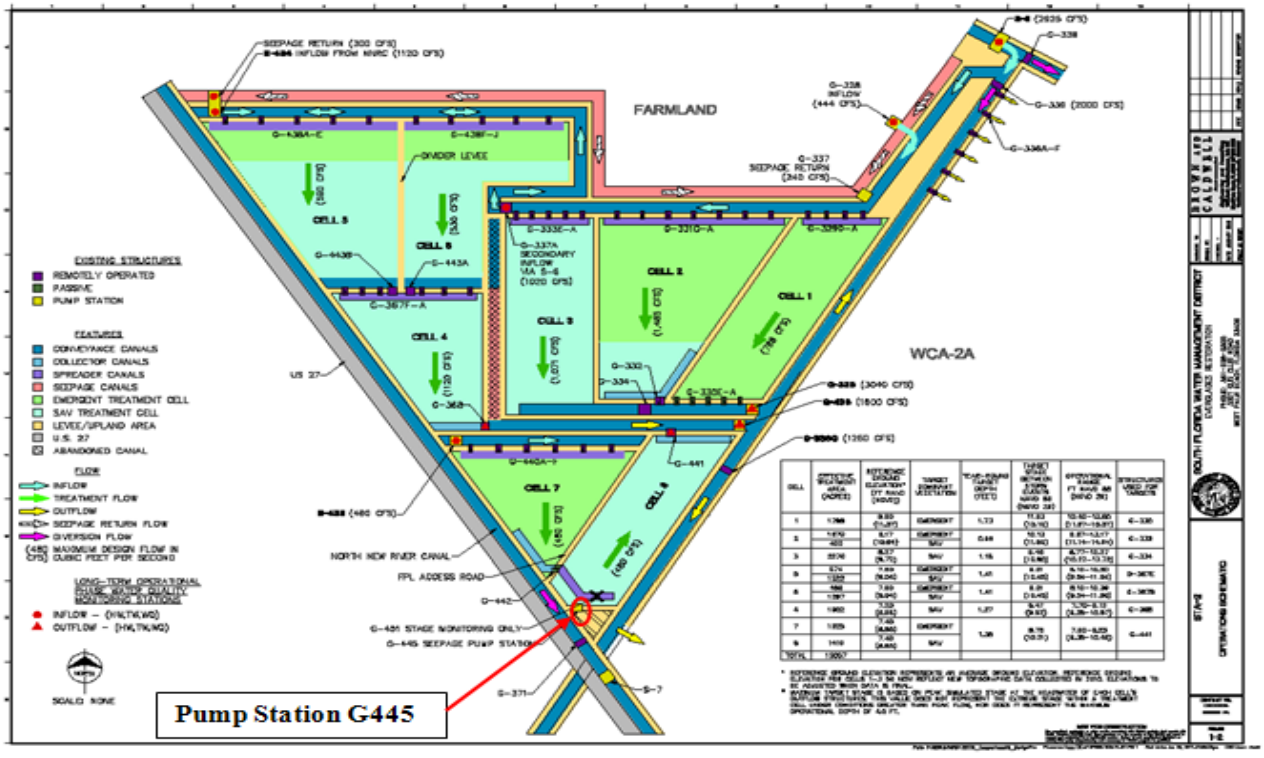

Figure 1. Location map for Pump Station G445

1.2 Objectives and Scope

We will conduct a rating analysis to develop a flow rating equation for Pump Station G445 to compute flow through the station.

2.0 STATION DESIGN

Pump Station G445 consists of two identical electric pump units each with design capacity of 13 cfs. **Table 1** presents more detailed description for the station. **Figure 2** illustrates the plan view of the station and **Figure 3** the profile view of the station.

Table 1. Description for Pump Station G445

Item	Description
Number of pumps	2
Design pump capacity (cfs)	13.0
Engine motor horsepower (HP)	25
Design pump speed (rpm)	890
Pump Diameter (Discharge/Suction Bell) (in)	16/24
Design Headwater Elevation, ft NAVD 88 (NGVD 29)	8.00 (9.46)
Headwater Start Up Condition, ft NAVD 88 (NGVD 29)	8.00 (9.46)
Design Minimum Headwater Pool Elevation, ft NAVD 88	6.00 (7.46)
Design Maximum Headwater Pool Elevation, ft NAVD 88 (NGVD	9.10 (10.56)
Discharge Weir Elevation, ft NAVD 88 (NGVD 29)	12.50 (13.96)
Design Maximum Tailwater Pool Elevation, ft NAVD 88 (NGVD 29)	11.00 (12.46)
Maximum Pool-to-pool Head Differential, ft	5.0
Nominal “On / Off Elevation”	As needed to maintain headwater an average elevation of 8.00 NAVD 88 (9.46 NGVD 29)
Centerline Discharge Connection, ft NAVD 88 (NGVD 29)	3.25 (4.71)
Pump Station Floor Elevation, ft NAVD 88 (NGVD 29)	16.00 (17.46)
Intake Floor Elevation, ft NAVD 88 (NGVD 29)	0.50 (1.96)
Discharge Floor Elevation, ft NAVD 88 (NGVD 29)	0.50 (1.96)

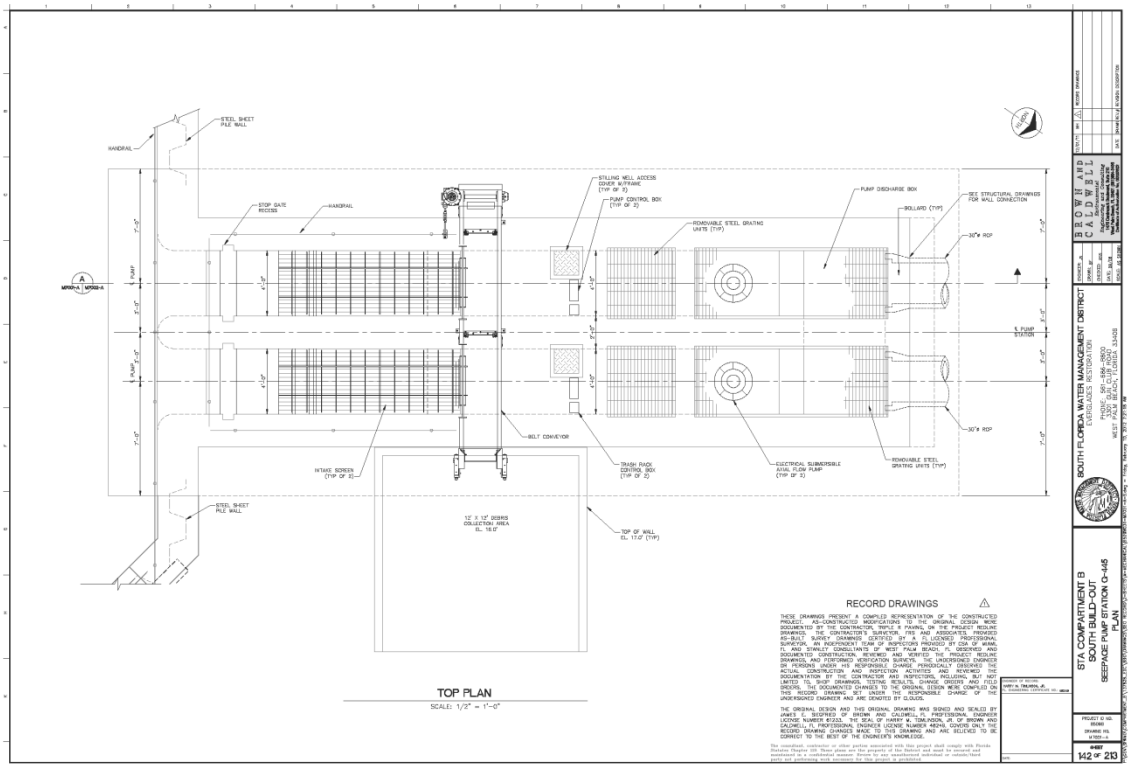

Figure 2. Plan view of Pump Station G445

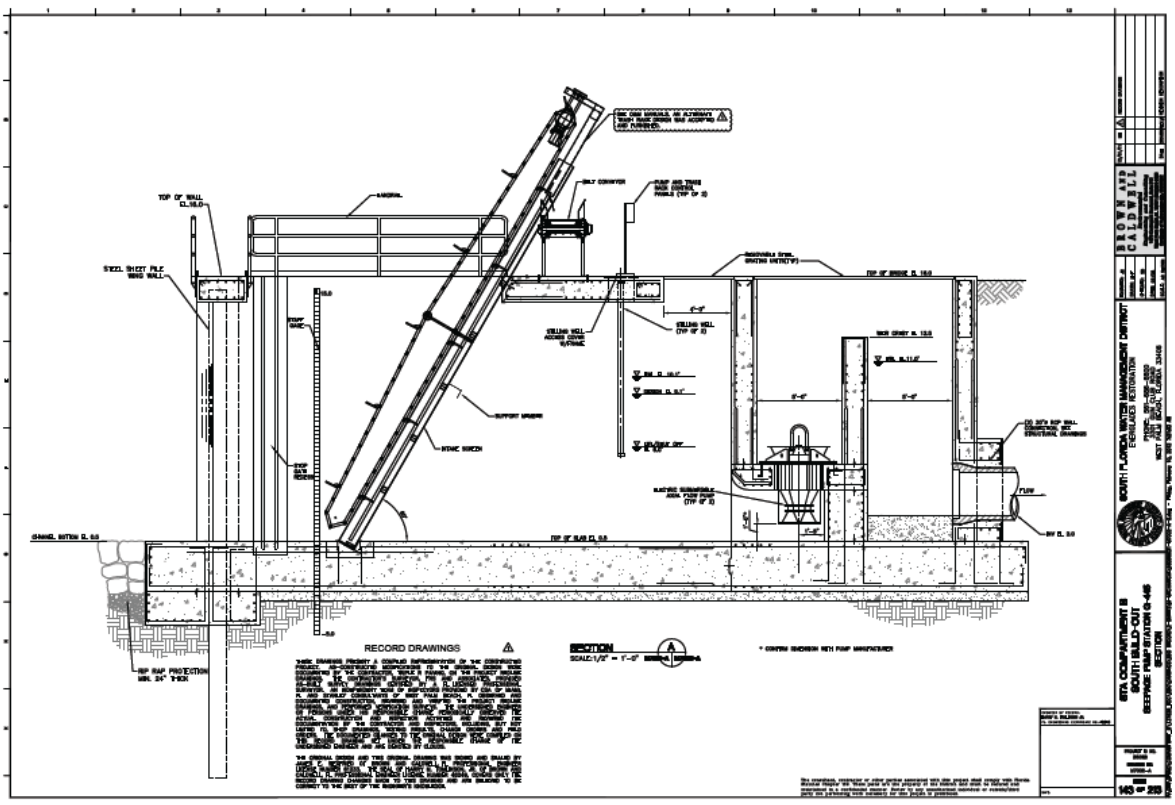

Figure 3. Profile view of Pump Station G445

2.1. Pump Performance Curve for G445

The manufacturer provides the pump performance curve for Pump Station G445 based on the pump tests, as shown in **Figure 4**.

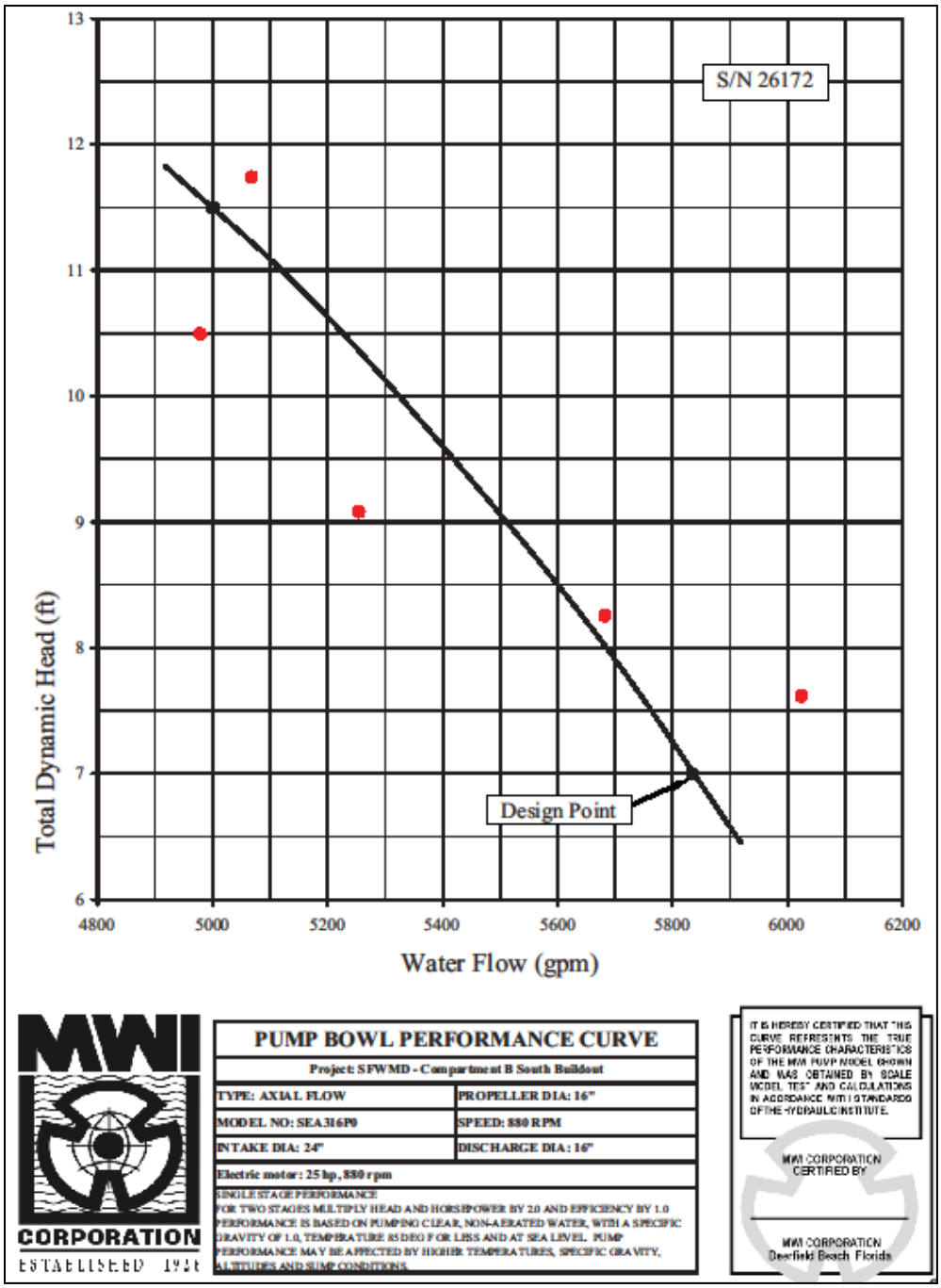

Figure 4. Pump performance curve for Pump Station G445

3.0 RATING ANALYSIS

We will develop a Case 8 flow rating equation for Pump Station G445 based on the factory pump performance curve that was obtained from the pump tests. Case 8 rating equation is developed using dimensional analysis and the pump affinity laws. This conventional rating equation represents all the possible cases, as documented in Damisse (2001) and Imru and Wang (2003). Rating equation below shows the Case 8 flow 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;
H:	Total static head (TSH);
N:	Pump engine speed in rpm;
No:	Design pump engine speed in rpm;
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.

For an electric pump with constant speed, $N = N_o$, and Equation (1) becomes

$$Q = A + BH^{C} \quad (3)$$

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 coefficients in the above equation.

We computed TSH by subtracting total head loss from TDH. The total head loss through a pump includes friction loss and minor losses. Friction head loss was ignored here since the discharge pipe is short. **Table 2** presents the minor loss coefficients for pump inlet, motor region and outlet, provided by the pump manufacture.

Table 2. Minor Loss Coefficients

Minor Loss Coefficient	Value
Intake Bell & Bar Strainer	0.35
Motor Region Loss (sudden enlargement)	1.90
Pipe Exit - Projecting Exit	1.00

Table 3 presents TDH, total head loss, and TSH vs. *Q* values for the pumps at Pump Station G445. **Table 4** provides the flow rating equation coefficients of Eq. (3), which were estimated by conducting nonlinear regression analysis.

Table 3. TDH, Head Loss, TSH and Discharge Relations for the Pumps at Pump Station G445

Discharge (gpm)	Discharge (cfs)	TDH (ft)	Velocity head (ft)	Total head loss (ft)	TSH (ft)
5000	11.14	11.500	0.195	2.421	8.884
5100	11.36	11.083	0.203	2.518	8.362
5200	11.59	10.625	0.211	2.618	7.795
5300	11.81	10.121	0.220	2.720	7.181
5400	12.03	9.583	0.228	2.823	6.532
5500	12.25	9.054	0.237	2.929	5.889
5600	12.48	8.500	0.245	3.036	5.218
5700	12.70	7.888	0.254	3.146	4.488
5800	12.92	7.238	0.263	3.257	3.717
5900	13.15	6.554	0.272	3.371	2.911

Table 4. Flow Rating Coefficients for the Pumps at G445

Rating Coefficient	Estimate	Approximate Lower 95% Confidence Limit	Approximate Upper 95% Confidence Limit
A	13.656	13.598	13.714
B	-0.114	-0.131	-0.096
C	1.417	1.354	1.479

Figure 5 illustrates the developed rating curve for the pumps at Pump Station G445. The diagram illustrate that the rating curve from the developed rating equation well fits the tested data from the pump tests. **Table 5** presents the relative errors between tested and calculated flows, and the AARE between tested and calculated flows is 0.07%. These results indicate that the developed rating well represents the relationship between total static head and discharge obtained from the manufactory pump tests.

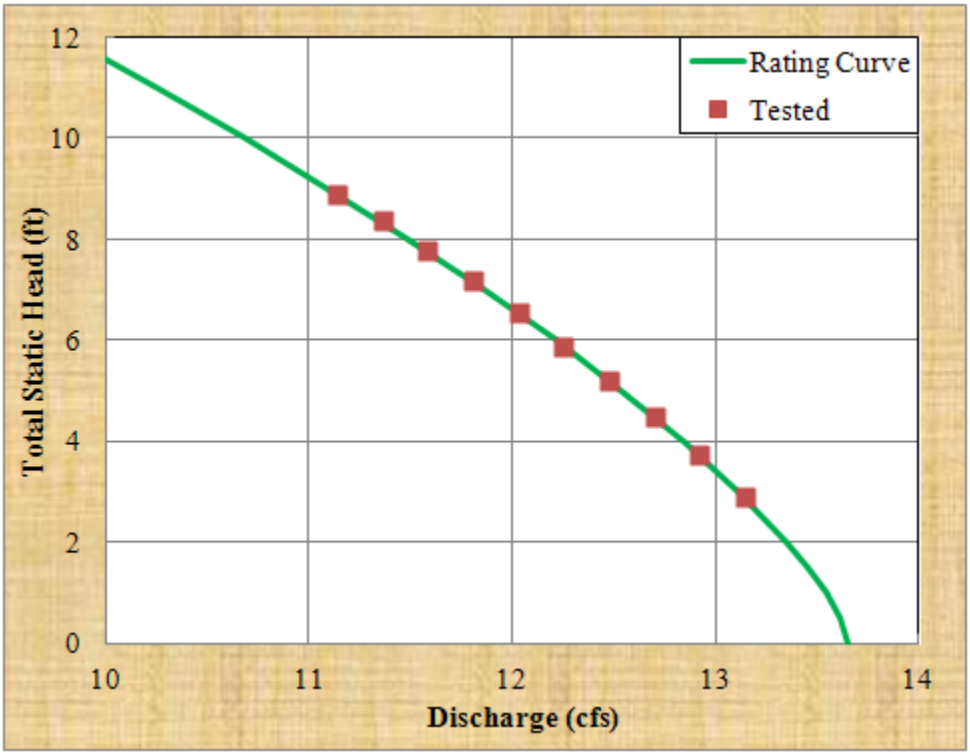

Figure 5. Flow Rating Curve for Pump Station G445

Table 5. Comparison between Tested and Calculated Flows

TSH (ft)	Pump speed at test (rpm)	Discharge from Rating Equation (cfs)	Discharge from pump test (cfs)	Absolute Relative Error (%)
8.884	890	11.140	11.138	0.022
8.362	890	11.363	11.345	0.160
7.795	890	11.586	11.564	0.194
7.181	890	11.809	11.793	0.132
6.532	890	12.032	12.027	0.035
5.889	890	12.254	12.250	0.037
5.218	890	12.477	12.471	0.048
4.488	890	12.700	12.699	0.006
3.717	890	12.923	12.923	0.004
2.911	890	13.146	13.138	0.060
Average Absolute Relative Error (AARE)				**0.07**

4.0 CONCLUDING REMARKS

We conducted rating analysis for Pump Station G445 based on the pump performance curve derived from the pump tests. **Table 5** presents the coefficients of the flow rating equation for Pump Station G445. The flow rating equation needs to be calibrated, and to be potentially improved based on future flow measurements after the pump stations are constructed and operated.

REFERENCES

Damisse, E. 2001. Flow rating development for G335 Pump Station in STA-2. Hydrologic Data Management Division, South Florida Water Management District, West Palm Beach, Florida.

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.