FLOW RATING ANALYSIS FOR PUMP STATION G507

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ACKNOWLEDGEMENT

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DEFINITIONS

Acronyms

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

EXECUTIVE SUMMARY

Pump Station G507 houses one pump unit with flow capacity of 51.3 cfs. This report summarizes a flow rating analysis for Pump Station G507 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 G507 has a single 36-inch diameter pump with a 125-Hp diesel powered engine, has a flow capacity of 51.3 cfs. The purpose of the pump station is to provide water supply to the STA by moving water from the STA-5 discharge canal into Cell 1B during periods of drought. Supplemental water entering STA-5 Cell 1B may be passed into Cell 2B via the G-345 Structure. The structure is located at the north east corner of STA-5, in Hendry County, as shown in **Figure 1**.

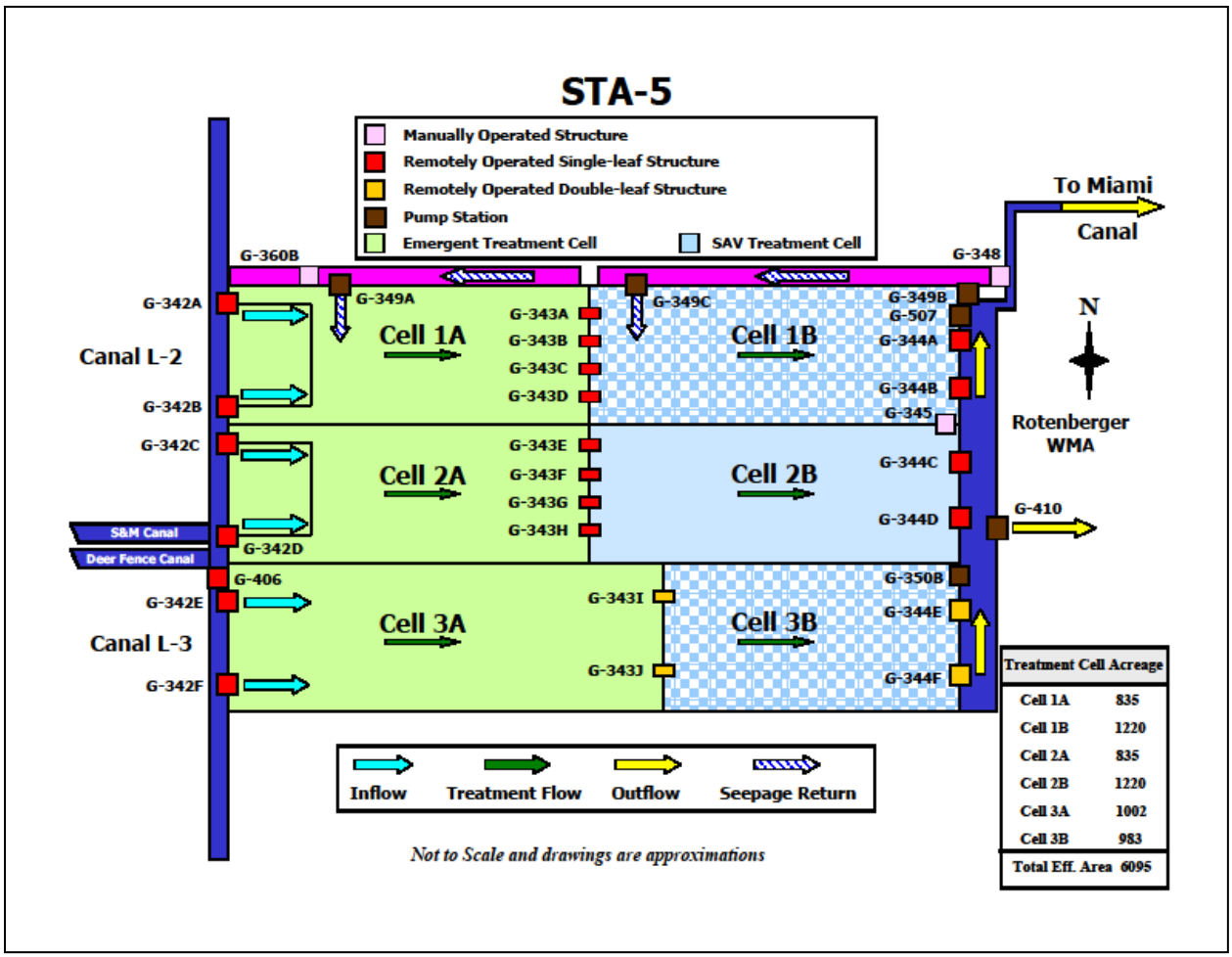

Figure 1. Location Map of Pump Station G507

The pump at Pump Station G507 is a manually-operated pump, with an access platform and a metal roof. Clewiston Field Station serves to operate the pump. Headwater and tailwater data are obtained from station G-344A approximately 100 yards south of G507.

1.2 Objectives and Scope

We will conduct a rating analysis to develop a flow rating equation for Pump Station G507 to compute flow through the station.

2.0 STATION DESIGN

Table 1 presents more detailed description for the station. **Figure 2** shows the pump inlet and **Figure 3** the pump outlet.

Table 1. Description for Pump Station G507

Item	Description
Number of pumps	1
Design pump capacity (cfs)	51.3
Engine motor horsepower (HP)	125
Design motor speed (rpm)	1800
Pump Diameter (in)	36
Design Pipe invert Elevation (ft, NGVD)	14.3
Pump total length from inlet to out let (ft)	106
Gearbox Type & Model	Belt Driven
Gearbox ratio	3.27 : 1.0
Shut off HW Elevation (ft, NGVD)	10.0

Figure 2. Pump Station Inlet

Figure 3. Pump Station Outlet

2.1. Pump Performance Curve for G507

The manufacturer provides the pump performance curve for Pump Station G507, as shown in **Figure 4**.

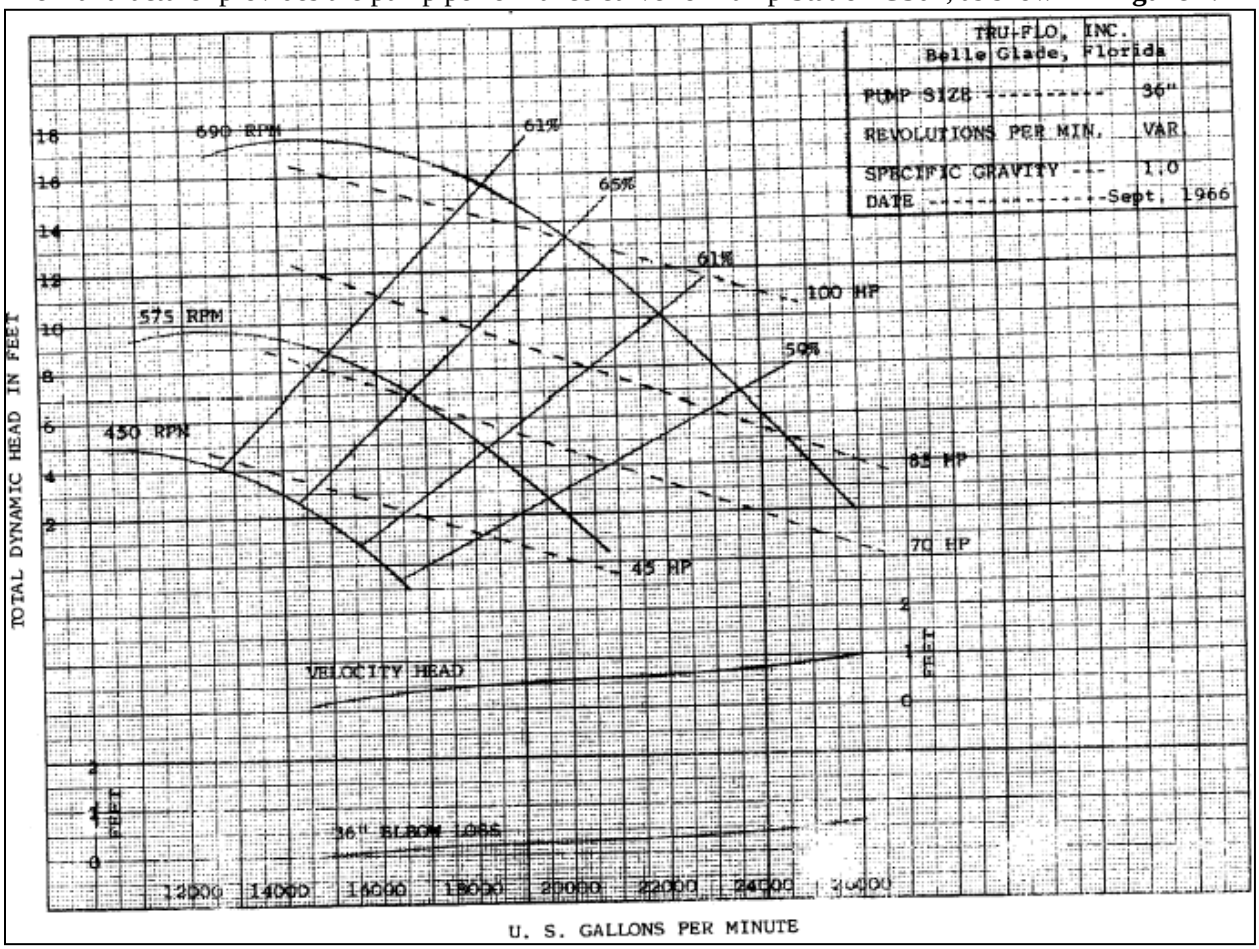

Figure 4. Pump Performance Curve for Pump Station G507

3.0 RATING ANALYSIS

We will develop a Case 8 flow rating equation for Pump Station G507 based on the factory pump performance curve. 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 (=1800 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.

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 the pump includes friction loss (h_f), minor loss ((h_m), and head loss through the flap gate (h_G) at the outlet of the pipe. We estimate friction and minor head losses using the following equations.

$$h_f = \frac{fLv^2}{2Dg} \quad (3)$$

$$h_m = K\frac{v^2}{2g} \quad (4)$$

Where

f – Friction coefficient;
K – Total minor loss coefficient;
D – Pipe diameter (ft);
L – Pipe total length (ft);
v – Flow velocity (ft/s);
g – Acceleration of gravity, 32.2 ft/s^2

The head loss through the flap gate is estimated by the following equation (See www.hydrogate.com)

$$h_G = \left(\frac{4v^2}{g}\right) e^{\left(\frac{-1.15v}{\sqrt{D}}\right)} \quad (5)$$

The total head loss through the pump is the sum of friction loss, minor loss, and flap gate loss. **Table 2** presents the minor loss coefficients associated with pump intake, bend, and outlet, and friction coefficient for computing friction loss through the pump.

Table 2. Flow Loss Coefficients

Loss Coefficient		Value
Minor Loss Coefficient	Intake Bell	0.050
	Bend	0.236
	Pipe Exit - Projecting Exit	1.000
	Total	1.286
Friction coefficient		0.015

Table 3 presents TDH from the pump performance curve, total head loss, TSH, and pump speed vs. *Q* values for Pump Station G507. **Table 4** provides the flow rating equation coefficients of Eq. (1), which were estimated by conducting nonlinear regression analysis using SAS NLIN function with *No* = 1800 rpm.

Table 3. TDH, Head Loss, TSH, Pump Speed and Discharge Relations for the Pumps at Pump Station G507

Flow		TDH (ft)	Pump speed (rpm)	Engine speed (rpm)	Total head loss (ft)	TSH (ft)
GPM	CFS					
15000	33.421	8.8	575	1880	0.751	8.049
15500	34.535	8.3	575	1880	0.789	7.511
16000	35.649	7.8	575	1880	0.829	6.971
16500	36.763	7.2	575	1880	0.870	6.330
17000	37.877	6.6	575	1880	0.912	5.688
17500	38.991	6.0	575	1880	0.959	5.041
18000	40.105	5.2	575	1880	1.009	4.191
18500	41.219	4.4	575	1880	1.060	3.340
19000	42.334	3.6	575	1880	1.112	2.488
19500	43.448	2.7	575	1880	1.166	1.534
20000	44.562	1.8	575	1880	1.222	0.578

Table 4. Flow Rating Coefficients for Pump Station G507

Rating Coefficient	Estimate	Approximate Lower 95% Confidence Limit	Approximate Upper 95% Confidence Limit
A	42.785	42.406	43.165
B	-0.689	-0.881	-0.497
C	1.371	1.240	1.501

Figure 5 illustrates the developed rating curve for the pumps at Pump Station G507. The rating curve with N = 1880 rpm illustrates that the rating curve from the developed rating equation well fits the discharges from the pump performance curve. **Table 5** presents the absolute relative errors between calculated flows and the flows from the pump performance curve, and the AARE between them is 0.3%. These results indicate that the developed rating well represents the relationship between total static head and discharge obtained from the manufactory pump performance curve. The rating curve corresponding to the design pump engine speed of 1800 rpm is also presented in **Figure 5**.

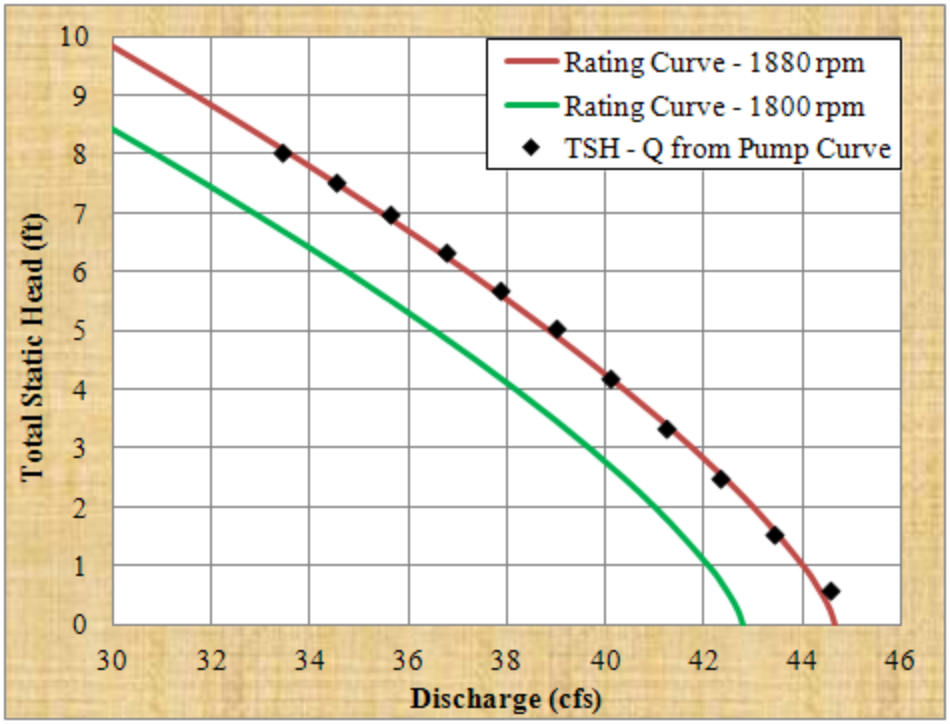

Figure 5. Flow Rating Curve for Pump Station G507

Table 5. Comparison between Computed Flows and Those from the Pump Curve

TSH (ft)	Pump engine speed (rpm)	Discharge from Rating Equation (cfs)	Discharge from pump curve (cfs)	Absolute Relative Error (%)
8.0	1880	33.5	33.4	0.4
7.5	1880	34.6	34.5	0.0
7.0	1880	35.5	35.6	0.3
6.3	1880	36.7	36.8	0.3
5.7	1880	37.8	37.9	0.3
5.0	1880	38.8	39.0	0.4
4.2	1880	40.1	40.1	0.1
3.3	1880	41.3	41.2	0.3
2.5	1880	42.5	42.3	0.3
1.5	1880	43.5	43.4	0.2
0.6	1880	44.4	44.6	0.4
Average Absolute Relative Error (AARE)				**0.3**

4.0 CONCLUDING REMARKS

We conducted rating analysis for Pump Station G507 based on the pump performance curve. **Table 4** presents the coefficients of the flow rating equation for Pump Station G507. The flow rating equation needs to be calibrated, and to be potentially improved based on future flow measurements.

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.