
Task C: Year 2000 Energy Optimization Analysis

**Comprehensive Water Master Plan
DWSD Contract No. CS-1278**

Final Report

For Submittal to

**Detroit Water and Sewerage
Department**

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SECTION 1

Introduction

In accordance with Task C2 in the scope of work, the project team has analyzed the existing DWSD water transmission system using the pump optimization program. The pump optimization program is a hydraulic model that identifies energy-efficient pump combinations to meet specified demands.

The pump optimization program was originally developed for a portion of the system under CS-1178, Energy Optimization of Water Distribution Systems. The program was subsequently expanded to include the entire transmission system under a separate task of CS-1272, Study and Evaluation of DWSD Electric Utility Rates. This report summarizes the findings of the energy optimization analysis done for the CWMP.

Pumping water comprises a significant fraction of the operating budgets of many water utilities. The Detroit Water and Sewerage Department (DWSD), for example, spent over \$29 million to pump finished water to its customers. Annual pumping costs are certain to increase as system-wide water usage increases and as more pumping facilities are placed on line.

Today there are many water utilities exploring the possibilities of lowering their pumping costs. There are several ways that these costs can be reduced. One way is to install energy efficient pumps and motors. Another approach is to examine and possibly modify system-wide operations. Energy savings realized by addressing system-wide operations is attractive since it requires no capital investment on the part of the water utility.

The purpose of the study documented in this memorandum is to quantify the potential savings in energy costs associated with pumping operations for the DWSD transmission system. This system includes the high service pumping facilities located at each of the five water treatment plants and booster facilities directly connected to the transmission system (excluding Farmington, St. Clair Shores, and Roseville Stations).

Potential annual savings were quantified by examining three demand conditions. The demand conditions are: 1) average day, 2) maximum day and 3) minimum day demands. The average day condition was assumed to be in effect for 10 months of the year with the maximum and minimum day conditions lasting for one month each. A review of actual operating records confirmed that the amount of time proportioned to each demand condition is reasonable.

Baseline Costs

A baseline operating cost for each demand condition was developed using the Energy Optimization of Water Supply Systems (EOWSS) computer program. This cost was found by analyzing a calibrated model of the DWSD transmission system representing the demand condition. The geometry of the system was generally the same for each of the demand days. The major difference between each model was, of course, the magnitude and spatial allocation of system-wide demands and the pumps that were in service for the day.

The demands for each of the three days reflect Year 2000 demands. The magnitude of the Year 2000 demands were computed based on per capita usage and population estimates. This information was compiled under Task B of the Comprehensive Water Master Plan project.

As shown in Table 1, the actual pumping operations were selected from days that occurred in 1999. The reason that days occurring in 1999 were selected – instead of days occurring in 2000 – is that 1999 demands represented more typical maximum day conditions than 2000. The estimated Year 2000 demand in the computer model was scaled up or down to match the actual amount of water pumped during the demand day.

The baseline and annual cost for each of the demand conditions is presented in Table 1. Note that the baseline cost represents the daily cost of pumping water. A comparison was made in an effort to gauge how closely pumping costs computed from EOWSS agreed with actual pumping costs. Based on electrical billing records for the month of May, the mean daily pumping cost in 1999 associated with the average day condition was \$77,041. This agrees within 3.3% of the daily cost computed by EOWSS thus suggesting a good agreement between actual and simulated system behavior.

Table 1
Baseline Operating Cost

Demand Condition	Demand Day	Daily Baseline Cost	Annual Cost
Average Day	May 6, 1999	\$74,602	\$22,691,442
Maximum Day	June 8, 1999	\$126,083	\$3,835,025
Minimum Day	April 4, 1999	\$63,911	\$1,943,960
	Total		\$28,470,427

SECTION 3

Cost Reduction Approach

After the baseline cost for each demand condition was established, the EOWSS program was used to help develop a lower-cost pumping policy. The EOWSS program determines pumping strategies designed to maintain pressures at selected locations in the DWSD system at specified values. These locations generally represent the monitoring sites for each of the individual pumping facilities.

The pressures at sites used to monitor the performance of the DWSD system are allowed to fluctuate within some prescribed bounds. The upper and lower bounds vary between the different monitoring sites. For example the pressure at the suction side of the Adams Station booster, which serves as the monitoring site for North Service Center, is allowed to vary between 45 and 60 psi. The allowable pressure range for the Franklin Station discharge site is 130 - 156 psi.

The EOWSS program was used to generate a cost-effective pumping policy that generally kept pressures at the monitoring sites within their prescribed bounds. This was accomplished by specifying target pressures at the monitoring sites, generating an optimal pumping policy, and viewing monitoring site pressures to insure that they were within reasonable ranges. The findings of the analyses for each of the demand conditions are presented below.

3.1 Average Day Condition

Using the results from EOWSS as the basis for an average day pumping scheme, a pumping policy for the average day demand condition was developed where the daily cost was \$71,031. This represents a daily savings of \$3,571, a percent savings of 4.79%, and an annual savings of \$1,086,179. Figures 1-4 in Appendix A shows the pressures at selected sites for the average day condition.

3.2 Maximum Day Condition

For the maximum day demand condition, a pumping policy costing \$115,771 was developed. This translates into a daily savings of \$10,312, a percent savings of 8.2% and an annual savings of \$313,657. Figures 5-8 in Appendix A shows the pressures at selected sites for the maximum day condition.

There are a few lower pressure boundary violations during the maximum day condition. However, as shown in Figure 8 (Appendix A), there were some pressure violations due to the actual pumping policy for the maximum day. The optimized maximum day for this location, Tyler and Belleville west of Wick Road Station, does represent an improvement over the actual day, though some pressure violations still occur. Pressure violations during

the maximum day would not be unexpected since higher flows through system lines would generate higher head losses and consequently lower pressures.

3.3 Minimum Day Condition

Under the minimum day demand condition a daily savings of \$909 or 1.4% was realized using the results of the EOWSS program. Annual savings equate to \$27,649. System-wide pressures generally remained within the specified upper and lower boundaries. Figures 9-12 (Appendix A) shows the pressures at selected sites for the minimum day condition.

SECTION 4

Summary

An examination of the energy use characteristics of the DWSD transmission system was undertaken to determine if cost savings resulting from operational modifications could be obtained. The Energy Optimization of Water Supply Systems (EOWSS) computer program developed for DWSD was used in the study.

Based on the results of the analysis, an annual savings of \$1,427,485, or approximately 5.0% was computed. Potential cost savings may be realized for each demand day examined. Though the largest single percent savings occurs during the maximum day demand condition, the greatest amount of savings can be realized under average day conditions. Marginal savings are possible under the minimum day case. Table 2 summarizes the findings of the study.

Table 2

Estimated Cost Saving

Demand Condition	Daily Baseline Cost	Optimized Cost	Daily Savings (\$)	Annual Savings
Average Day	\$74,602	\$71,031	\$3,571	\$1,086,179
Maximum Day	\$126,083	\$115,771	\$10,312	\$313,657
Minimum Day	\$63,911	\$63,002	\$909	\$27,649
Total				1,427,485

SECTION 5

General Observations

Inspection of the actual versus optimized cost of the individual pumping facilities for the average day case reveals that some facilities have substantially lower optimized costs while some have higher costs.

Table 3 provides a summary of the actual and optimized costs for the average day condition. The savings obtained in this study are primarily due to three factors:

1. Shifting the load from higher cost plants to lower cost plants
2. Use of more efficient pumping combinations at individual facilities
3. Maintaining pressures near the lower range at the monitoring locations

Note that for the average day case, a significant fraction of the savings originates at the Lake Huron Pumping Plant. For the average day case, a savings of over \$4,000 was found at Lake Huron while over \$5,800 of savings occurred at Lake Huron during the maximum day condition. In essence, the optimized pumping policy is shifting the load from Lake Huron to other water treatment plants in the DWSD system. This helps to explain why other facilities, namely Springwells WTP, have higher operating costs under the optimized policy.

In an effort to verify that in fact it is more expensive to pump from Lake Huron than the other plants, the unit cost of pumping at each treatment plant was computed for the average day condition. The results of the analysis are presented in Table 4. In some cases the unit cost of pumping at Lake Huron is over twice as much as the unit cost at other DWSD treatment plants.

Table 3
Cost Comparison – Average Day Condition

Pumping Facility	Actual Cost	Optimized Cost	Savings
Lake Huron WTP *	\$18,661.80	\$14,632.35	\$4,029.45
Northeast WTP	\$10,316.29	\$10,783.90	(\$467.61)
Springwells WTP	\$10,203.11	\$11,278.19	(\$1,075.08)
Southwest WTP	\$3,940.81	\$3,254.24	\$686.57
Water Works Park WTP	\$6,683.67	\$6,248.73	\$434.94
North Service Center	\$6,474.94	\$6,644.22	(\$169.28)
Imlay Station *	\$3,184.28	\$2,935.72	\$248.56
West Service Center	\$2,127.78	\$2,696.55	(\$568.77)
Adams Station	\$2,517.13	\$2,448.50	\$68.63
Franklin Station	\$1,614.01	\$1,963.66	(\$349.65)
Eastside Station	\$184.57	\$0.36	\$184.21
Rochester Station	\$411.86	\$957.20	(\$545.34)
Northwest Station	\$7.50	\$7.50	\$0.00
Electric Avenue Station	\$68.08	\$77.21	(\$9.13)
Newburgh Station	\$994.48	\$1,111.63	(\$117.15)
Orion Station	\$264.28	\$134.79	\$129.49
Ypsilanti Station *	\$1,032.60	\$737.64	\$294.96
Ford Road Station	\$722.55	\$969.71	(\$247.16)
West Chicago Station	\$148.20	\$169.49	(\$21.29)
Michigan Station *	\$233.31	\$234.82	(\$1.51)
Schoolcraft Station	\$1,396.03	\$1,167.98	\$228.05
Wick Road Station	\$1,862.00	\$1,221.37	\$640.63
Joy Road Station	\$1,557.78	\$1,355.13	\$202.65
Total	\$74,607.06	\$71,030.89	\$3,576.17

Table 4**Unit Cost of Pumping for Treatment Plants**

Pumping Plant	Cost/1000 Gallons Pumped
Lake Huron	\$7.16
Northeast	\$4.68
Springwells	\$3.70
Southwest	\$3.03
Water Works Park	\$4.58

One of the primary functions of the EOWSS program is to identify efficient groups of pumps by evaluating a large number of pump combinations. The operating characteristics of each group are found using a hydraulic simulation model whose demands reflect the demand day of interest, e.g. average day, maximum day or minimum day. The groups are then ranked in order of increasing power (and hence cost) consumption. Thus additional savings are most likely due to running different pump combinations than were run during the actual demand days.

As the figures in Appendix A illustrate, the pressures at selected sites within the DWSD system are generally lower during the optimized condition than during the actual condition. For the most part, however, the pressures under the optimized case were kept within allowable pressure boundaries. Pump combinations consisting of smaller horsepower pumps, which in turn, have lower power consumption characteristics than larger pumps, may generate lower pressures.

SECTION 6

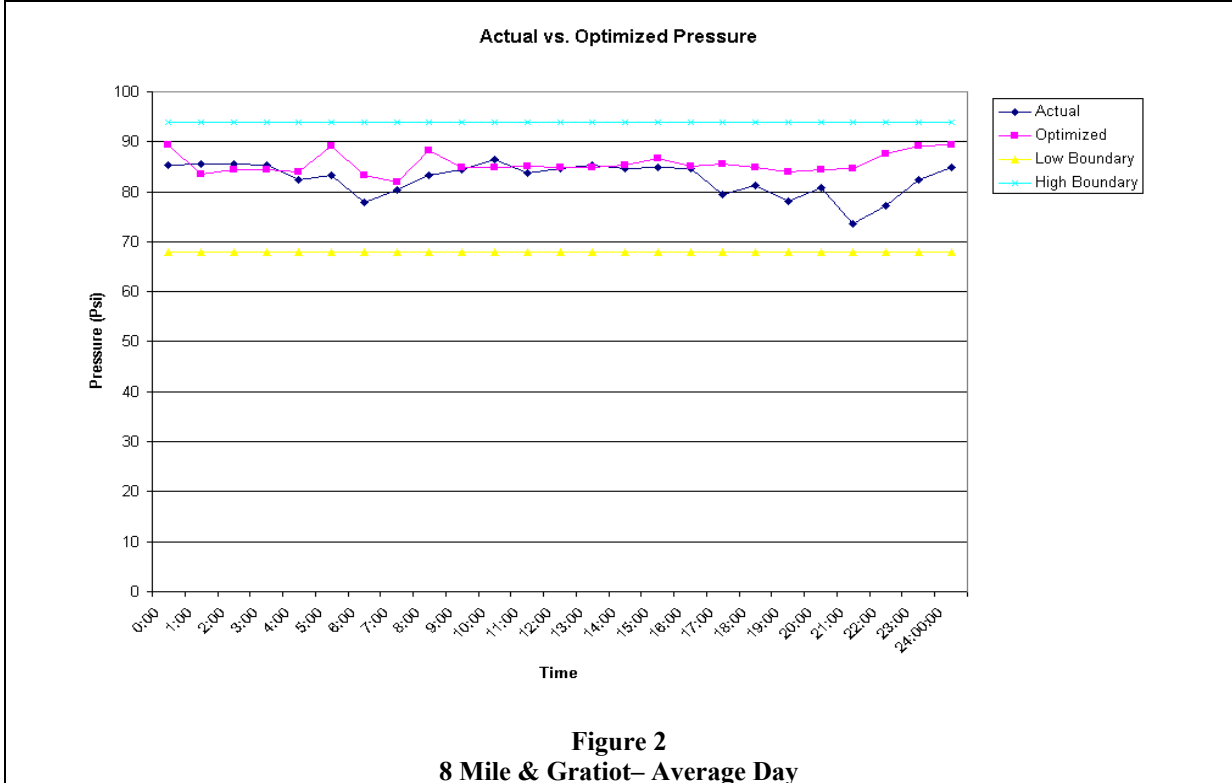
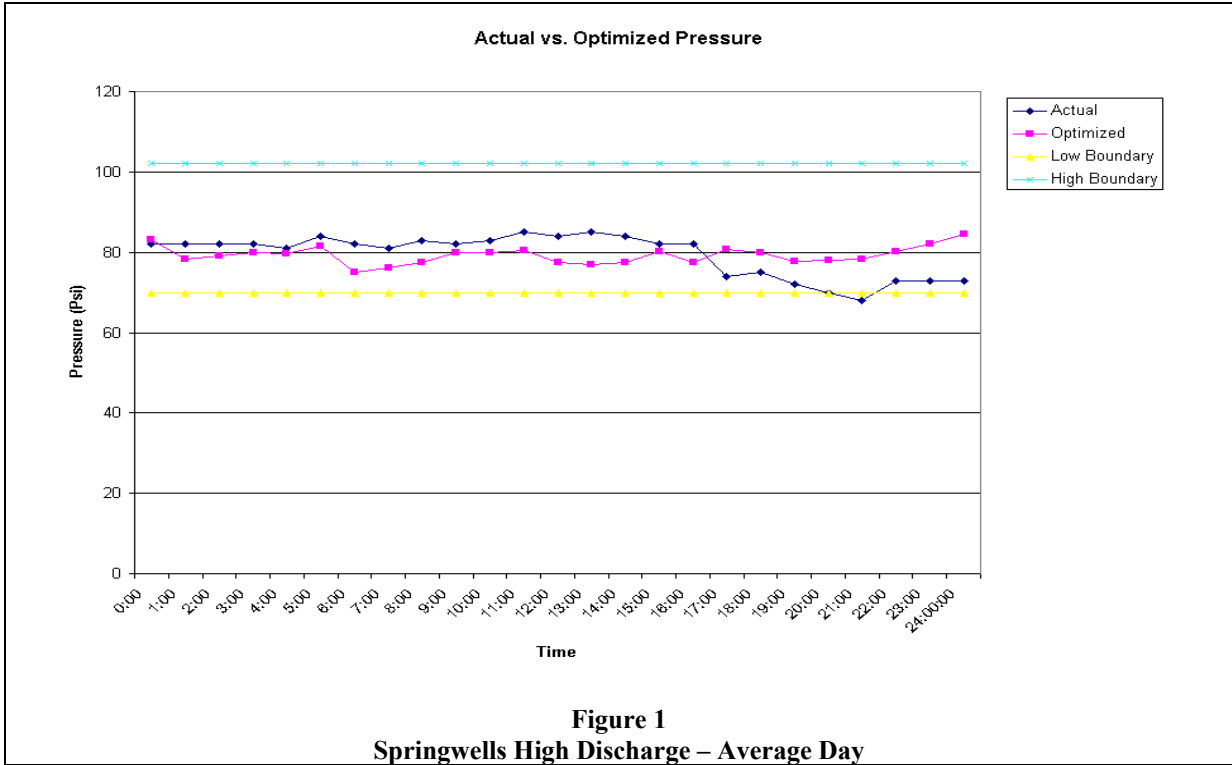
Recommendations

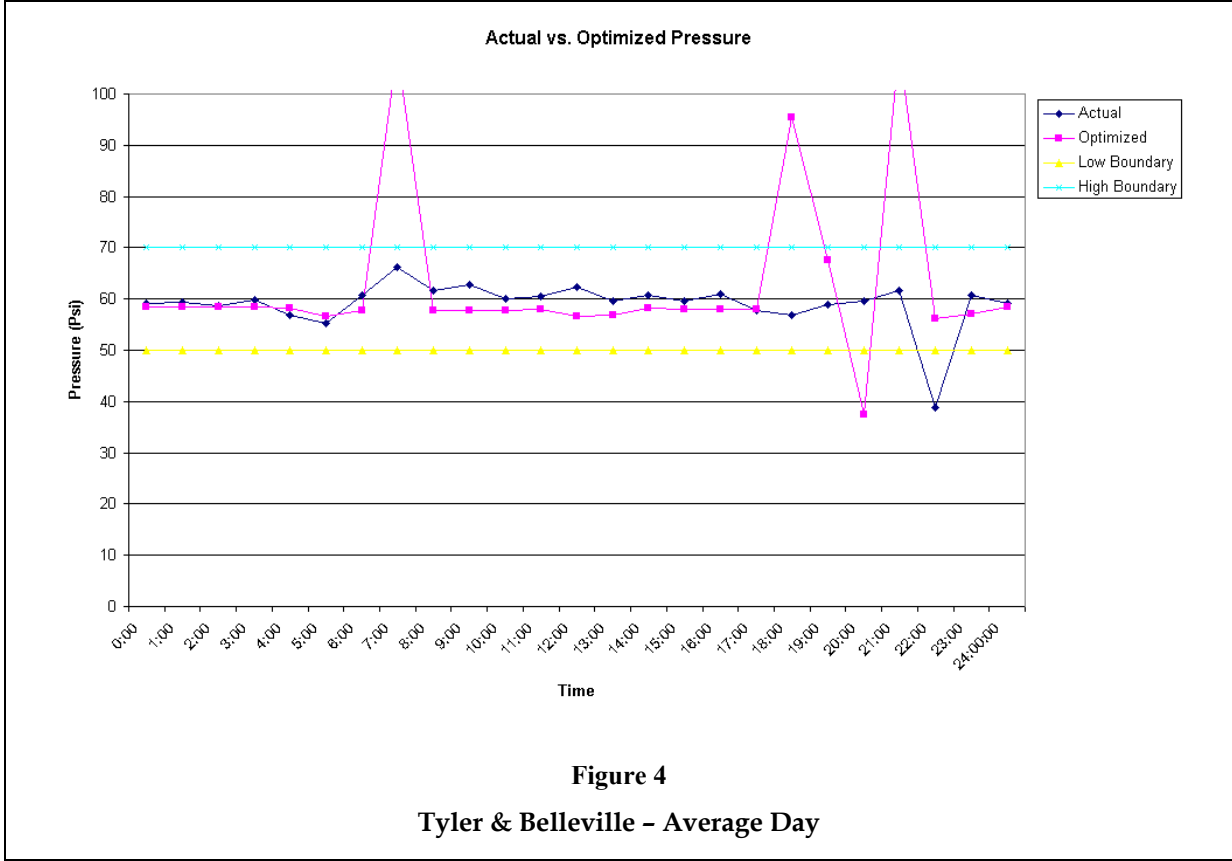
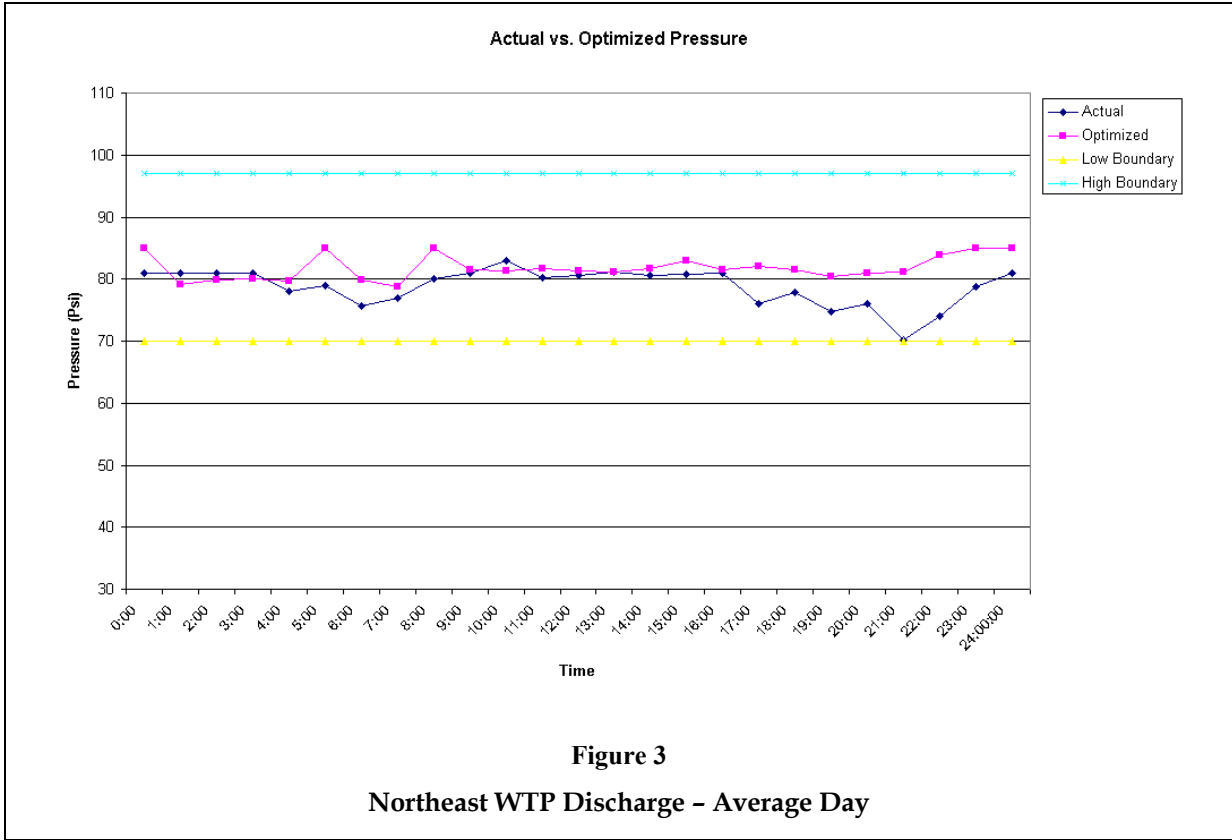
Potential cost savings are possible by modifying the operational characteristics at DWSD pumping facilities. These savings can be significant amounting to over \$1M annually. The savings were found from the results of calibrated hydraulic models of the DWSD transmission system. The accuracy of the hydraulic simulation models can be improved through the use of real-time data.

A natural evolution of the EOWSS computer program is to interface it with a real-time data collection or Supervisory Control and Data Acquisition (SCADA) system. Real-time data would be used to update demands and any boundary conditions in the model. Again this would be used to improve the accuracy of the hydraulic models.

Actual vs. Optimized Pressure at Selected Sites

Average Day Pressure Comparison at Selected Sites





Maximum Day Pressure Comparison at Selected Sites

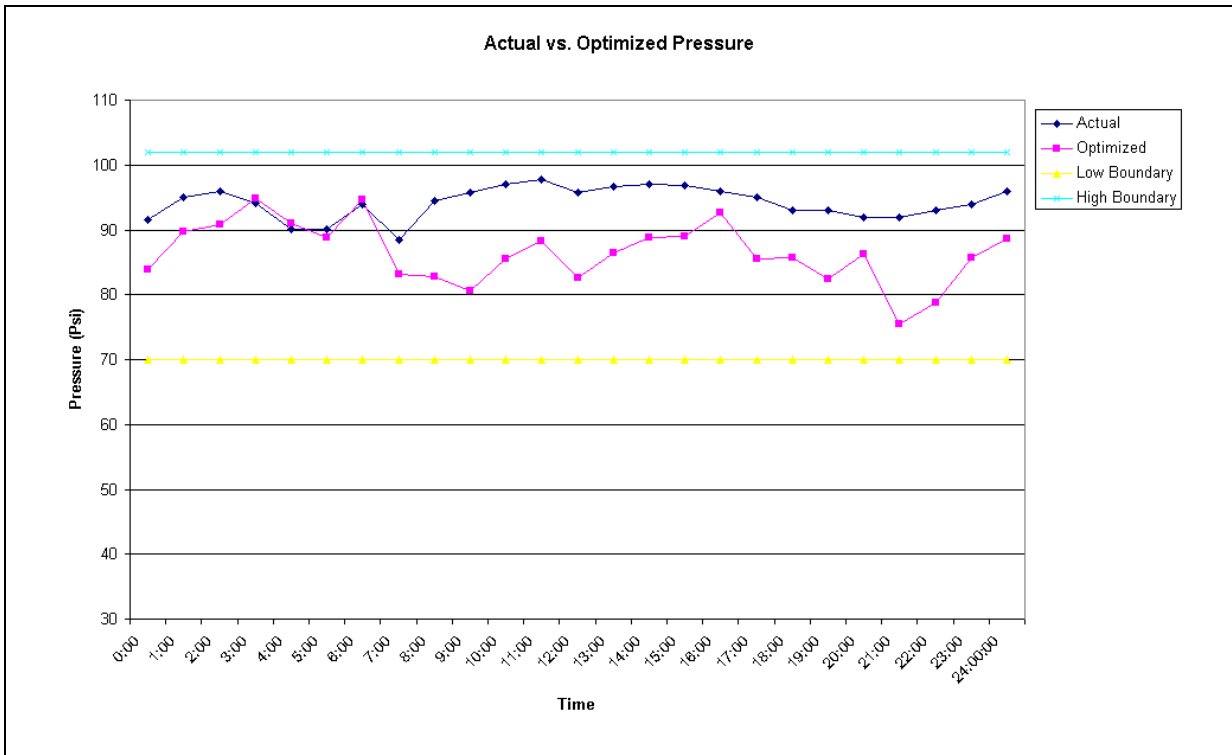


Figure 5
Springwells High Discharge - Maximum Day

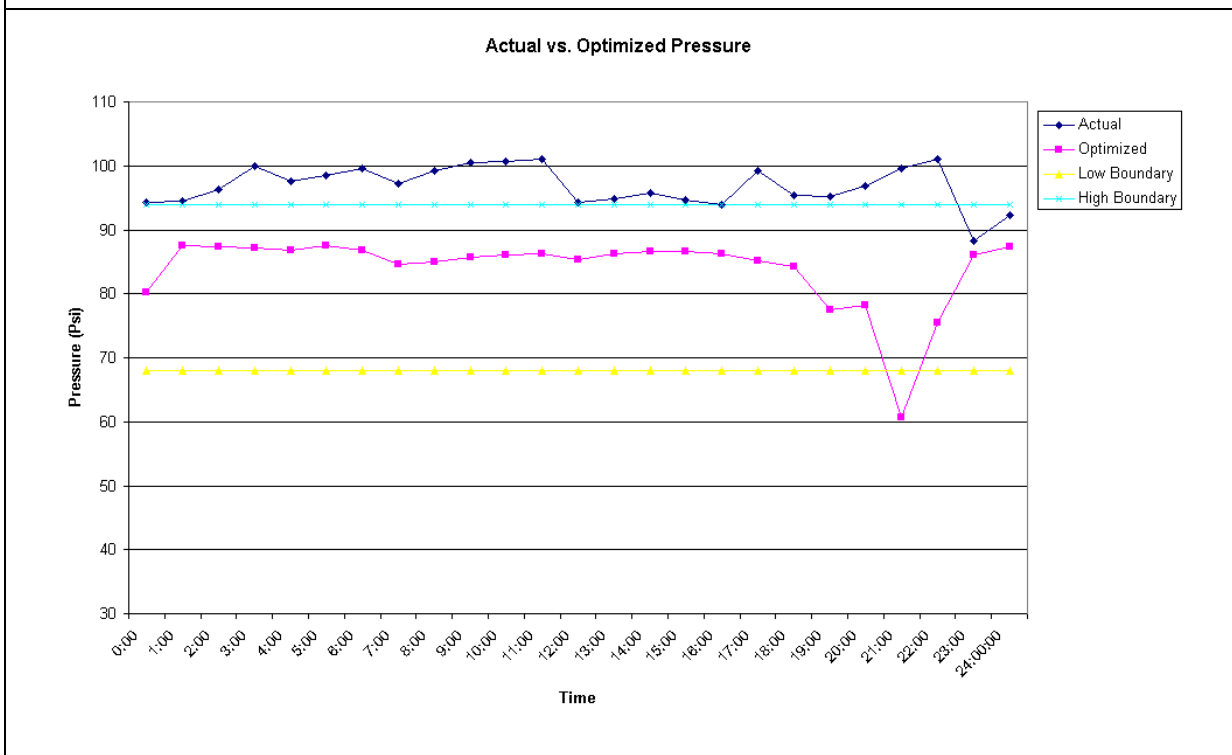
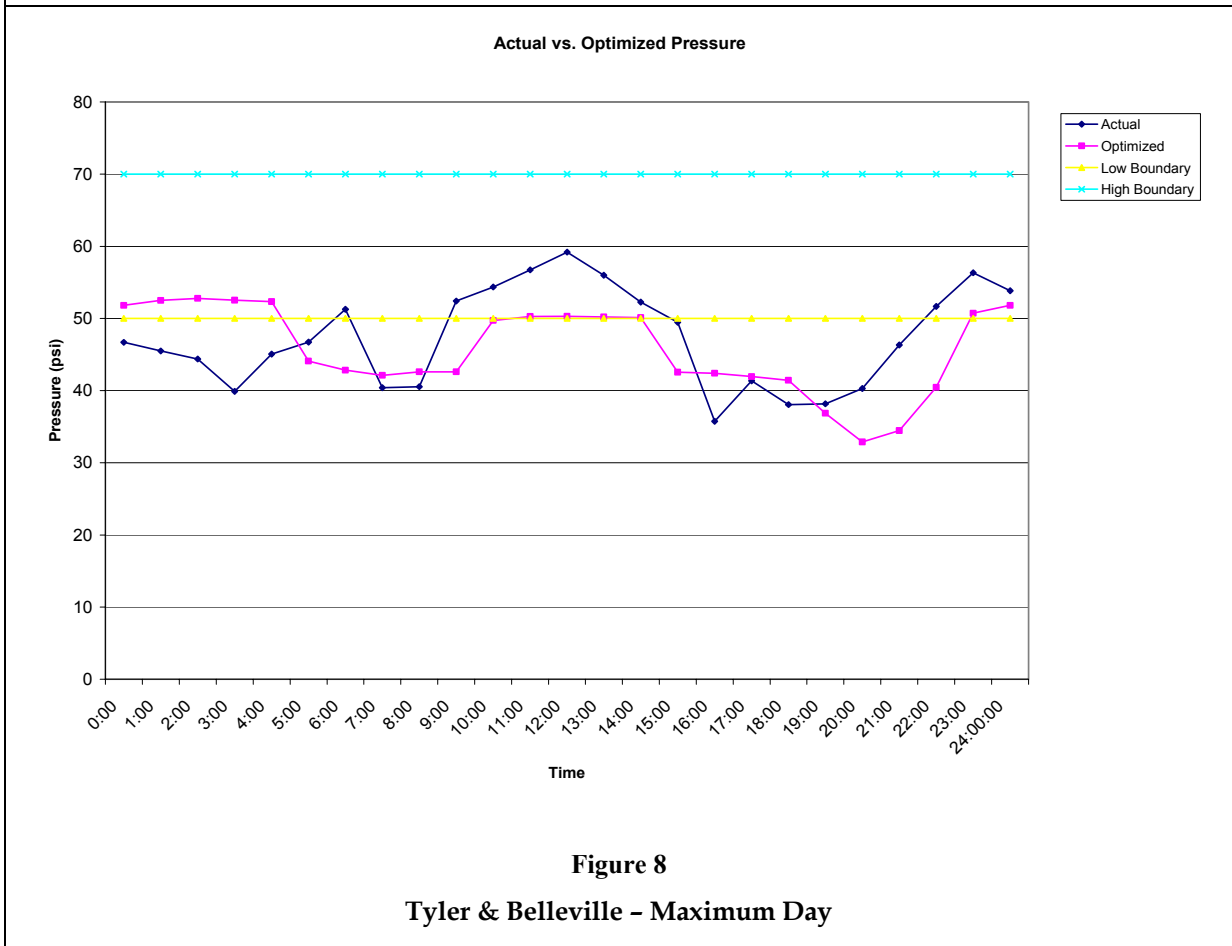
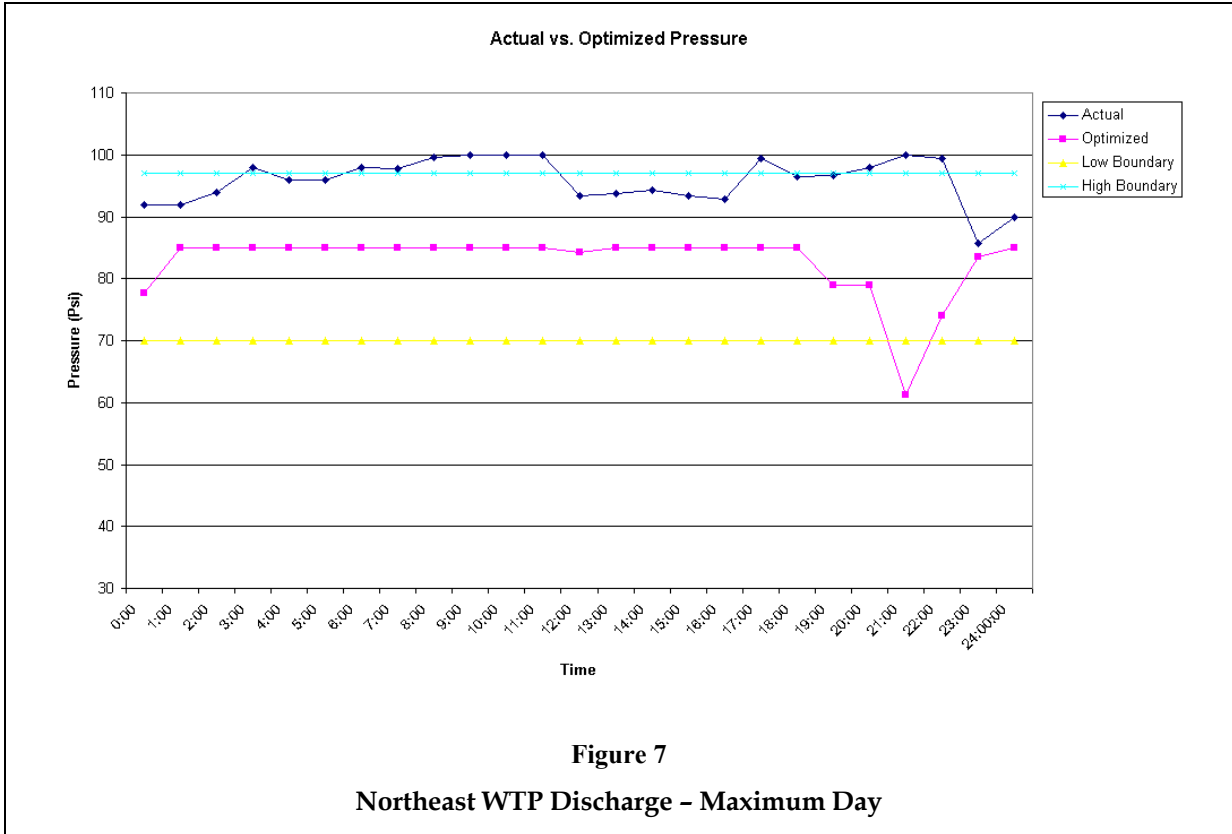


Figure 6
8 Mile & Gratiot- Maximum Day



Minimum Day Pressure Comparison at Selected Sites

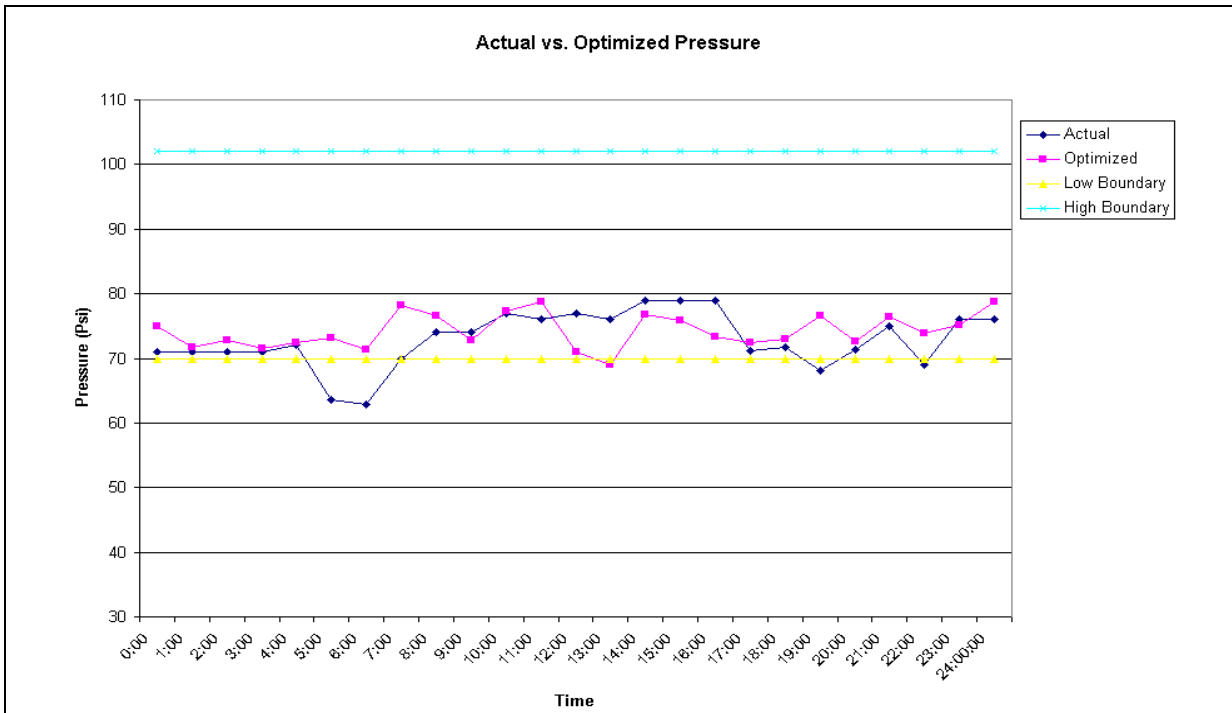


Figure 9
Springwells High Discharge - Minimum Day

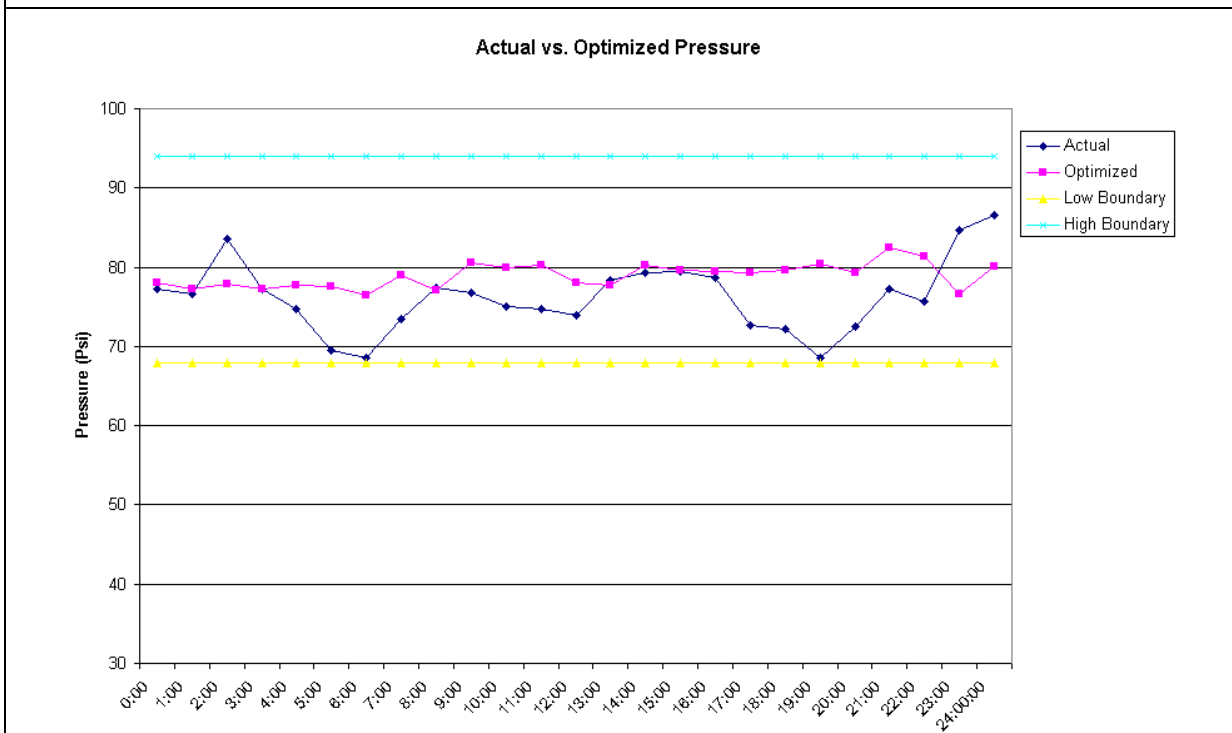


Figure 10
8 Mile & Gratiot- Minimum Day

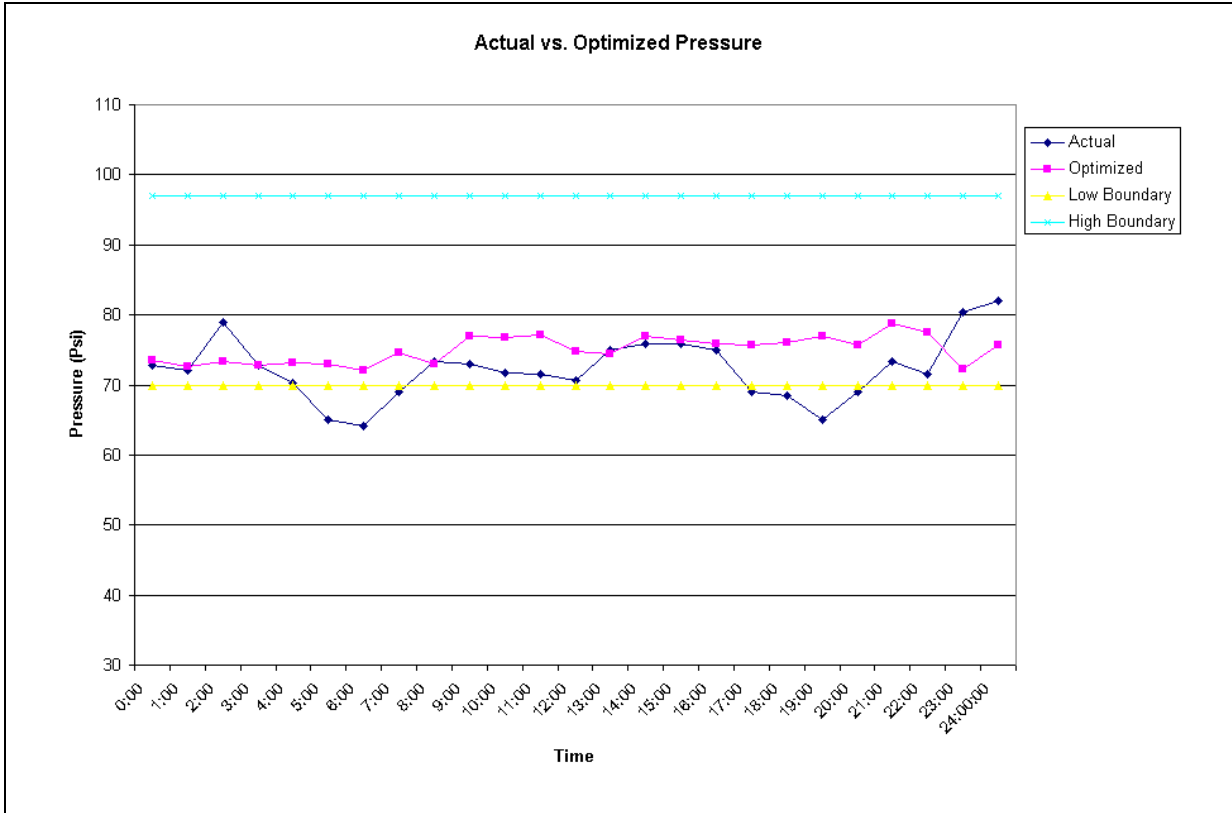


Figure 11
Northeast WTP Discharge - Minimum Day

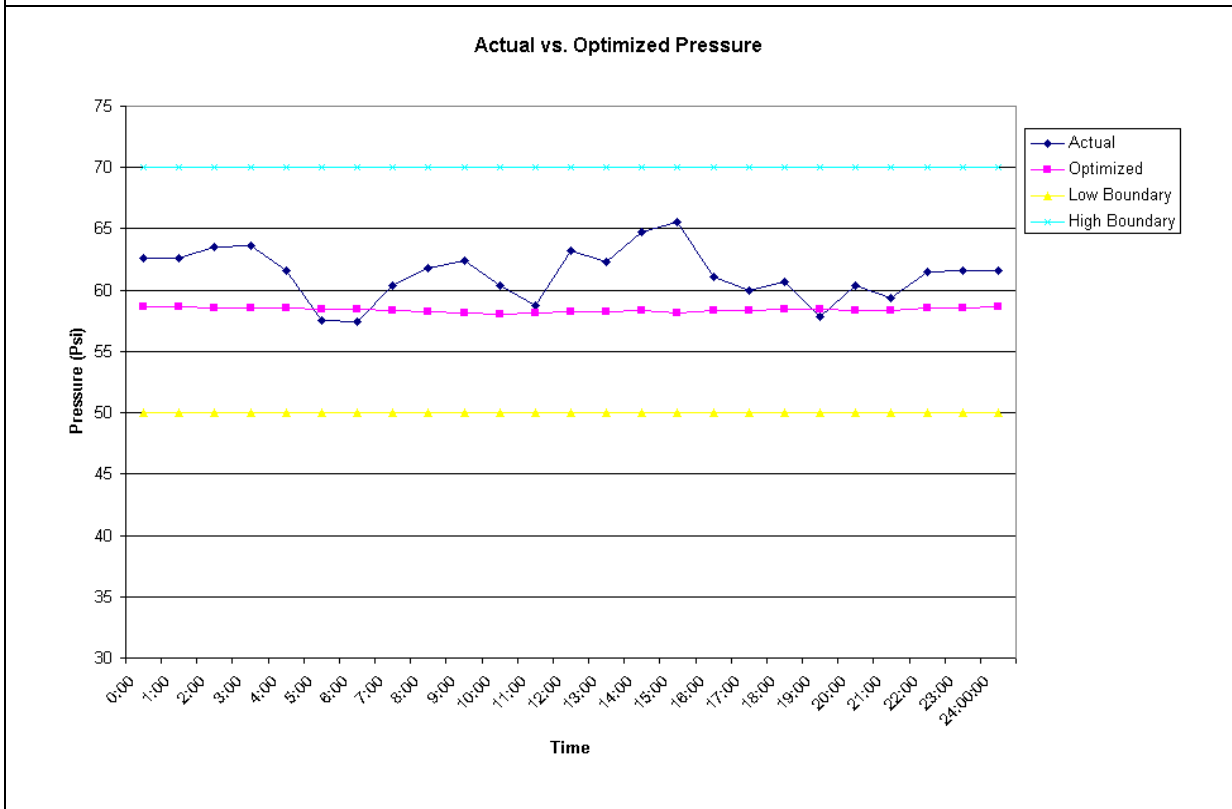


Figure 12
Tyler & Belleville - Minimum Day

Appendix B

Actual vs. Optimized Pump Logs

Year 2000 Avg. Day Optimization Pump Logs (May 6, 1999)

* Actual times are those used to balance the model, which are based on System Control pump logs.

Northeast WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
11	Hi	Midnight 7:00	1:00 11:00	Midnight	-
12	Hi	Midnight	-	1:00 3:00 6:00 8:00	2:00 5:00 7:00 23:00
14	Hi	-	-	Midnight 2:00 5:00	1:00 3:00 -
17	Hi	Midnight	-	-	-
18	Hi	-	-	Midnight 5:00 7:00 23:00	1:00 6:00 9:00 -

Schoolcraft Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	8:00	13:00	8:00	13:00
R-2	Res	6:00	8:00	-	-

Imlay Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
R-1	Res	-	-	Midnight	-
R-3	Res	Midnight	-	-	-

Springwells WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
11	Hi	-	-	Midnight	2:00
				5:00	6:00
				12:00	15:00
				22:00	-
12	Int	-	-	Midnight	-
13	Hi	Midnight	-	Midnight	1:00
				2:00	5:00
				6:00	-
14	Int	-	-	12:00	15:00
15	Hi	-	-	5:00	6:00
16	Int	-	-	7:00	8:00
19	Hi	-	-	7:00	12:00
				17:00	22:00
20	Int	Midnight	-	-	-
21	Hi	14:00	17:00	-	-
22	Int	-	-	Midnight	7:00
				8:00	12:00
				15:00	-
24	Hi	23:00	-	-	-
25	Hi	-	-	1:00	2:00
				6:00	7:00
				15:00	17:00
26	Hi	Midnight	14:00	-	-

Orion Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	6:00	11:00	Midnight	4:00
				6:00	11:00
2	Line	6:00	11:00	4:00	-
		19:00	21:00		
3	Line	Midnight	-	-	-
4	Line	1:00	-	-	-

Adams Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	-	-	3:00	23:00
3	Line	9:00	12:00	6:00	7:00
		21:00	23:00		
4	Line	Midnight	1:00	-	-
		4:00	-		
R-1	Res	7:00	9:00	7:00	9:00

Southwest WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Int	Midnight	7:00	-	-
		17:00	-		
3	Int	7:00	17:00	-	-
4	Int	7:00	17:00	Midnight	-

West Chicago Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	-	-	-	-
2	Line	-	-	-	-
3	Line	7:00	17:00	Midnight	-
		19:00	22:00		

Wick Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	18:00
				22:00	23:00
2	Line	4:00	8:00	22:00	23:00
		16:00	18:00		
		22:00	-		
R-1	Res	18:00	22:00	18:00	22:00
R-3	Res	-	-	7:00	8:00

Michigan Ave. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	9:00	Midnight	1:00
		23:00	-	5:00	8:00
				16:00	23:00
2	Line	-	-	7:00	8:00
				16:00	23:00
3	Line	8:00	16:00	7:00	-
R-4	Res	16:00	23:00	1:00	5:00
R-5	Res	7:00	8:00	2:00	3:00

Ford Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	3:00
				5:00	6:00
				7:00	10:00
				13:00	15:00
				16:00	23:00
2	Line	6:00	10:00	Midnight	3:00
				5:00	6:00
				8:00	9:00
				11:00	14:00
				18:00	23:00
3	Line	-	-	Midnight	1:00
				2:00	18:00
				22:00	-
4	Line	16:00	17:00	Midnight	1:00
				2:00	5:00
				6:00	8:00
				10:00	17:00
				23:00	-
5	Line	21:00	-	Midnight	1:00
				3:00	5:00
				10:00	11:00
				12:00	13:00
				14:00	16:00
R-6	Res	-	-	6:00	10:00
				17:00	23:00
R-8	Res	17:00	23:00	-	-
R-9	Res	6:00	10:00	-	-

Joy Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	6:00	10:00	6:00	10:00
		21:00	22:00	21:00	22:00
3	Line	-	-	-	-
R-2	Res	7:00	9:00	-	-
R-3	Res	12:00	15:00	-	-

Franklin Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	6:00	10:00	Midnight	1:00
3	Line	-	-	Midnight	12:00
				15:00	-
R-1	Res	-	-	6:00	12:00
				17:00	23:00
R-2	Res	6:00	12:00	-	-
		17:00	23:00		

Water Works Park WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
3	Int	-	-	16:00	17:00
5	Int	6:00	17:00	-	-
9	Int	Midnight	6:00	Midnight	16:00
				17:00	-
10	Int	Midnight	15:00	6:00	16:00
		17:00	-	17:00	22:00
11	Int	15:00	-	-	-

Ypsilanti Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	5:00	9:00	Midnight	-
		21:00	-		
2	Line	Midnight	-	-	-

West Service Center Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line (int)	18:00	21:00	Midnight	-
2	Line (int)	-	-	6:00	-
3	Line (int)	Midnight	-	7:00	9:00
4	Line (hi)	Midnight	-	Midnight	-
5	Line (hi)	Midnight	2:00	Midnight	3:00
		6:00	9:00	5:00	-
6	Line (hi)	-	-	Midnight	2:00
				7:00	9:00
R-1	Res	6:00	9:00	Midnight	6:00
R-2	Res	16:00	23:00	2:00	5:00

Lake Huron WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
3	Hi	-	-	Midnight	-
4	Hi	-	-	Midnight	-
5	Hi	Midnight	-	-	-
6	Hi	Midnight	-	-	-
7	Hi	Midnight	-	-	-

Rochester Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	6:00	11:00	Midnight	-
2	Line	6:00	11:00	-	-
3	Line	-	-	Midnight	1:00
				3:00	4:00
				5:00	7:00
				8:00	23:00

Newburgh Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	9:00
				10:00	19:00
				22:00	-
2	Line	-	-	Midnight	6:00
				7:00	9:00
				14:00	19:00
				23:00	-
3	Line	Midnight	-	6:00	14:00
				19:00	23:00
4	Line	-	-	9:00	10:00
				19:00	22:00

North Service Center Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2-L	Line	-	-	Midnight	-
3-L	Line	-	-	Midnight	2:00
				3:00	23:00
4-L	Line	-	-	Midnight	-
5-H	Line	Midnight	22:00	12:00	-

North Service Center Booster Station (cont.)

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
5-L	Line	-	-	1:00	2:00
				4:00	5:00
				6:00	10:00
				11:00	12:00
				15:00	17:00
				18:00	22:00
6-L	Line	21:00	-	8:00	10:00
				11:00	12:00
				18:00	20:00
7	Line	4:00	-	Midnight	1:00
				2:00	8:00
				9:00	11:00
				12:00	18:00
				20:00	-
8	Line	Midnight	-	2:00	4:00
				5:00	7:00
				10:00	11:00
				12:00	15:00
				17:00	18:00
				22:00	-
9	Line	-	-	2:00	4:00
				5:00	7:00
				10:00	11:00
				12:00	15:00
				17:00	18:00
10	Line	-	-	2:00	3:00
				5:00	6:00
				10:00	11:00
				23:00	-
R-1	Res	6:00	10:00	-	-
		17:00	22:00		
R-3	Res	7:00	8:00	6:00	10:00
				17:00	22:00

Electric Ave. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	-	-	17:00	20:00
2	Line	-	-	20:00	22:00
R-3	Res	17:00	22:00	1:00	2:00
				22:00	-
R-4	Res	-	-	Midnight	1:00
				23:00	-

Eastside Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Res	-	-	-	-
3	Res	7:00	10:00	-	-
		17:00	22:00		

Year 2000 Max. Day Optimization Pump Logs (June 8, 1999)

* Actual times are those used to balance the model, which are based on System Control pump logs.

Northeast WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
9	Hi	Midnight	-	-	-
10	Hi	Midnight	-	-	-
11	Hi	21:00	23:00	Midnight	-
12	Hi	Midnight	23:00	Midnight	4:00
				5:00	-
13	Hi	-	-	Midnight	3:00
				5:00	21:00
				22:00	-
14	Hi	-	-	Midnight	7:00
				8:00	19:00
				20:00	-
15	Hi	Midnight	-	3:00	5:00
				7:00	8:00
				16:00	17:00
				19:00	20:00
				21:00	22:00
16	Hi	6:00	12:00	-	-
		17:00	22:00		
17	Hi	Midnight	-	-	-
18	Hi	-	-	4:00	5:00
				8:00	10:00
				11:00	12:00
				15:00	16:00
				18:00	19:00
				22:00	-
19	Hi	-	-	5:00	8:00
				9:00	16:00
				17:00	21:00
20	Hi	-	-	6:00	7:00

17:00 19:00

Schoolcraft Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	Midnight	22:00	Midnight	5:00
				6:00	9:00
				10:00	21:00
				22:00	-
R-1	Res	-	-	8:00	11:00
R-2	Res	8:00	11:00	-	-

Imlay Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
R-1	Res	Midnight	-	Midnight	-

Springwells WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
11	Hi	-	-	Midnight	1:00
				2:00	3:00
				4:00	7:00
				8:00	9:00
				10:00	17:00
				19:00	23:00
12	Int	Midnight	1:00	Midnight	6:00
				7:00	9:00
				10:00	12:00
				13:00	14:00
				15:00	-
13	Hi	Midnight	3:00	Midnight	-
				6:00	-
14	Int	-	-	6:00	8:00
				9:00	11:00
				12:00	15:00
				16:00	19:00
				22:00	-
15	Hi	-	-	6:00	7:00
				10:00	11:00
				16:00	17:00
				21:00	22:00
16	Int	-	-	Midnight	7:00
				8:00	10:00
				11:00	13:00
				14:00	16:00
				18:00	22:00
				23:00	-
18	Int	Midnight	-	3:00	7:00
				8:00	9:00
				11:00	12:00

**Springwells WTP
(cont.)**

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
				15:00	16:00
				19:00	22:00
19	Hi	-	-	Midnight	-
20	Int	Midnight	-	6:00	8:00
				9:00	11:00
				12:00	15:00
				16:00	19:00
22	Int	-	-	Midnight	6:00
				7:00	9:00
				11:00	12:00
				15:00	18:00
				19:00	23:00
23	Hi	Midnight	-	Midnight	9:00
				11:00	12:00
				14:00	21:00
				23:00	-
24	Hi	Midnight	-	3:00	4:00
				9:00	10:00
				17:00	19:00
25	Hi	8:00	-	1:00	2:00
				7:00	8:00
				12:00	14:00
				22:00	-
26	Hi	Midnight	-	-	-

Orion Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	4:00	12:00	Midnight	1:00
		16:00	21:00	6:00	10:00
				18:00	21:00
2	Line	4:00	13:00	1:00	-
		15:00	21:00		
3	Line	Midnight	21:00	-	-
4	Line	Midnight	22:00	-	-

Adams Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	9:00	Midnight	-
		13:00	-		
2	Line	Midnight	-	Midnight	-
3	Line	Midnight	-	1:00	2:00
				4:00	9:00
				13:00	23:00
4	Line	4:00	-	6:00	7:00
				14:00	17:00
				18:00	22:00
R-1	Res	7:00	11:00	7:00	14:00
		19:00	21:00	17:00	18:00
R-2	Res	9:00	18:00	9:00	11:00

Southwest WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Int	-	-	Midnight	-
2	Int	Midnight	-	-	-
3	Int	Midnight	-	Midnight	6:00
				10:00	11:00
				13:00	16:00
				22:00	-
4	Int	Midnight	-	Midnight	-
5	Int	17:00	23:00	-	-

West Chicago Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	7:00	10:00	Midnight	1:00
		17:00	18:00	4:00	5:00
				22:00	-
2	Line	6:00	13:00	4:00	8:00
		17:00	23:00	16:00	17:00
				22:00	-
3	Line	Midnight	1:00	4:00	23:00
		5:00	6:00		
		7:00	-		
R-4	Res	18:00	22:00	18:00	22:00
R-5	Res	-	-	19:00	22:00

Wick Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	Midnight	-	Midnight	-
R-1	Res	19:00	22:00	19:00	22:00
R-3	Res	-	-	Midnight	2:00
				3:00	4:00
				6:00	16:00
				20:00	21:00
				23:00	-

Michigan Ave. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	6:00	-	Midnight	7:00
				10:00	-
2	Line	-	-	Midnight	7:00
				10:00	19:00
				20:00	-
3	Line	Midnight	7:00	5:00	18:00
		10:00	-	19:00	20:00
				22:00	23:00
R-4	Res	7:00	10:00	7:00	10:00
		17:00	22:00	17:00	22:00

Ford Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	4:00	Midnight	3:00
		6:00	-	4:00	7:00
				8:00	10:00
				11:00	15:00
				16:00	23:00
2	Line	Midnight	4:00	3:00	8:00
		5:00	-	10:00	12:00
				15:00	19:00
				23:00	-
3	Line	-	-	Midnight	4:00
				7:00	18:00
				19:00	-
4	Line	Midnight	1:00	Midnight	4:00
		23:00	-	7:00	18:00
				19:00	-
5	Line	Midnight	-	2:00	4:00
				7:00	11:00
				12:00	18:00
				19:00	22:00
				23:00	-
R-6	Res	-	-	7:00	11:00
				19:00	23:00
R-7	Res	10:00	11:00	-	-
		17:00	23:00		
R-8	Res	8:00	10:00	-	-
R-9	Res	7:00	8:00	-	-

Joy Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	4:00
				5:00	7:00
				9:00	19:00
				21:00	-
2	Line	Midnight	1:00	-	-
				7:00	-
3	Line	-	-	Midnight	5:00
				7:00	9:00
				10:00	21:00
				22:00	-
R-1	Res	-	-	6:00	8:00
				18:00	20:00
R-2	Res	5:00	6:00	-	-
		18:00	19:00		
R-3	Res	6:00	10:00	5:00	6:00
		19:00	22:00	8:00	10:00
				20:00	22:00

Franklin Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	6:00	15:00	Midnight	-
		18:00	22:00		
2	Line	4:00	-	4:00	6:00
				10:00	15:00
				16:00	19:00
				22:00	-
3	Line	Midnight	-	Midnight	4:00
				5:00	12:00
				15:00	16:00

**Franklin Booster Station
(cont.)**

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
				19:00	-
R-1	Res	6:00	10:00	6:00	10:00
				19:00	22:00
R-2	Res	19:00	22:00	-	-

Water Works Park WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
5	Int	Midnight	-	3:00	4:00
				5:00	8:00
				10:00	11:00
				12:00	13:00
				14:00	15:00
				16:00	21:00
				23:00	-
6	Int	Midnight	-	6:00	8:00
				18:00	21:00
7	Int	-	-	7:00	8:00
				18:00	19:00
9	Int	-	-	Midnight	7:00
				8:00	10:00
				11:00	12:00
				13:00	14:00
				15:00	18:00
				20:00	23:00
10	Int	-	-	4:00	5:00
				6:00	7:00
				8:00	10:00

Water Works Park WTP
(cont.)

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
				11:00	12:00
				15:00	18:00
				21:00	23:00
11	Int	8:00	23:00	8:00	9:00
				21:00	22:00
12	Int	-	-	Midnight	-

Ypsilanti Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	16:00	-	Midnight	-
3	Line	Midnight	6:00	5:00	10:00
		7:00	10:00	15:00	23:00
		15:00	19:00		

West Service Center Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line (int)	Midnight	-	Midnight	-
2	Line (int)	-	-	Midnight	-
3	Line (int)	Midnight	-	1:00	4:00
				5:00	9:00
				13:00	21:00
				23:00	-
4	Line (hi)	6:00	12:00	Midnight	-
		17:00	-		
5	Line (hi)	Midnight	-	Midnight	-
6	Line (hi)	5:00	-	Midnight	21:00

**West Service Center Booster Station
(cont.)**

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
				22:00	-
R-1	Res	17:00	23:00	6:00	7:00
				8:00	10:00
				11:00	12:00
				17:00	18:00
				20:00	23:00
R-3	Res	6:00	12:00	7:00	8:00
				10:00	11:00
				18:00	20:00

Lake Huron WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
3	Hi	Midnight	-	Midnight	-
4	Hi	Midnight	-	Midnight	-
5	Hi	Midnight	-	Midnight	21:00
				23:00	-
6	Hi	Midnight	-	Midnight	14:00
				15:00	19:00
7	Hi	Midnight	-	-	-

Rochester Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2		6:00	10:00	3:00	4:00
		18:00	23:00		
3		Midnight	14:00	Midnight	-
		15:00	-		
4		6:00	-	-	-

Newburgh Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	1:00
				2:00	10:00
				11:00	19:00
				20:00	23:00
2	Line	-	-	2:00	4:00
				5:00	10:00
				16:00	18:00
				20:00	23:00
3	Line	6:00	11:00	1:00	2:00
		18:00	23:00	4:00	22:00
				23:00	-
4	Line	5:00	-	6:00	9:00
				10:00	11:00
				18:00	20:00
5	Line	Midnight	-	19:00	20:00

North Service Center Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2-H	Line	Midnight	10:00	-	-
		17:00	-		
2-L	Line	-	-	2:00	3:00
				6:00	13:00
				14:00	17:00
				18:00	-
3-H	Line	Midnight	-	-	-
3-L	Line	-	-	2:00	3:00
				6:00	13:00
				14:00	17:00
				18:00	-
4-L	Line	-	-	2:00	3:00
				6:00	13:00
				14:00	17:00
				18:00	-
5-H	Line	Midnight	-	-	-
5-L	Line	-	-	7:00	10:00
				11:00	13:00
				14:00	17:00
				18:00	22:00
6-H	Line	6:00	21:00	-	-
6-L	Line	-	-	7:00	9:00
				18:00	21:00
7	Line	Midnight	-	Midnight	-
8	Line	Midnight	-	Midnight	-
9	Line	-	-	Midnight	2:00
				3:00	7:00
				10:00	11:00
				13:00	-
10	Line	-	-	Midnight	2:00
				3:00	7:00

North Service Center Booster Station (cont.)

		Actual*		Optimized	
Pump #	Line or Res	Time On	Time Off	Time On	Time Off
				13:00	18:00
				19:00	20:00
				21:00	23:00
R-1	Res	19:00	22:00	-	-
R-2	Res	9:00	14:00	-	-
R-3	Res	7:00	9:00	6:00	9:00
		21:00	22:00	17:00	22:00
R-4	Res	6:00	9:00	7:00	9:00
		17:00	21:00	19:00	21:00

Electric Ave. Booster Station

		Actual*		Optimized	
Pump #	Line or Res	Time On	Time Off	Time On	Time Off
1	Line	-	-	Midnight	1:00
				23:00	-
2	Line	-	-	Midnight	-
				22:00	
R-3	Res	6:00	11:00	6:00	11:00
		17:00	22:00	17:00	18:00
				19:00	22:00
R-4	Res	-	-	18:00	19:00

Eastside Booster Station

		Actual*		Optimized	
Pump #	Line or Res	Time On	Time Off	Time On	Time Off
3	Res	17:00	21:00	-	-

Year 2000 Min. Day Optimization Pump Logs (April 4, 1999)

* Actual times are those used to balance the model, which are based on System Control pump logs.

Northeast WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
11	Hi	-	-	Midnight	-
12	Hi	Midnight	-	Midnight	2:00
				3:00	9:00
				23:00	-
14	Hi	-	-	2:00	3:00
				9:00	23:00
17	Hi	Midnight	-	-	-
18	Hi	-	-	9:00	23:00

Schoolcraft Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Line	Midnight	-	Midnight	-

Imlay Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
R-1	Res	-	-	Midnight	-
R-3	Res	Midnight	-	-	-

Springwells WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
11	Hi	-	-	10:00	12:00
				14:00	17:00
				19:00	20:00
				22:00	23:00
12	Int	7:00	-	Midnight	-
13	Hi	-	-	5:00	8:00
				9:00	10:00
				12:00	14:00
				17:00	19:00
				20:00	22:00
15	Hi	-	-	23:00	-
				19:00	20:00
21	Hi	9:00	17:00	22:00	23:00
				-	-
23	Hi	Midnight	-	-	-
25	Hi	-	-	Midnight	5:00
				8:00	9:00
				10:00	12:00
				14:00	17:00

Orion Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	-	-	Midnight	7:00
				23:00	-
2	Line	20:00	-	7:00	23:00
3	Line	Midnight	20:00	-	-

Adams Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
2	Line	-	-	7:00	16:00
				17:00	22:00
4	Line	7:00	22:00	-	-

Southwest WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Int	9:00	17:00	-	-
3	Int	Midnight	9:00	-	-
		17:00	-		
4	Int	Midnight	2:00	Midnight	-

West Chicago Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Line	12:00	14:00	-	-
3	Line	-	-	12:00	14:00
R-4	Res	-	-	9:00	12:00
R-5	Res	-	-	9:00	12:00
R-6	Res	9:00	12:00	-	-

Wick Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-

Michigan Ave. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	10:00	1:00	2:00
3	Line	12:00	17:00	Midnight	1:00
		21:00	-	2:00	10:00
				12:00	17:00
				21:00	-
R-4	Res	10:00	12:00	10:00	12:00
				17:00	21:00
R-5	Res	17:00	21:00	-	-

Ford Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	1:00	4:00
				6:00	7:00
				8:00	11:00
				13:00	14:00
				15:00	-
2	Line	9:00	12:00	10:00	11:00
		15:00	-		
3	Line	-	-	Midnight	10:00
				11:00	-
4	Line	-	-	Midnight	2:00
				4:00	8:00
				11:00	13:00
				14:00	15:00
5	Line	-	-	Midnight	1:00
				4:00	6:00
				11:00	13:00
R-6	Res	-	-	7:00	10:00

Ford Rd. Booster Station
(cont.)

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
				12:00	15:00
R-8	Res	12:00	15:00	-	-
R-9	Res	7:00	10:00	-	-

Joy Rd. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	-	-	Midnight	9:00
				10:00	14:00
				22:00	-
2	Line	Midnight	-	-	-
3	Line	-	-	9:00	12:00
				14:00	22:00
R-1	Res	12:00	14:00	13:00	14:00
R-3	Res	-	-	12:00	13:00

Franklin Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	Midnight	-
3	Line	-	-	Midnight	1:00
				5:00	12:00
				14:00	-
R-1	Res	-	-	12:00	14:00
R-2	Res	12:00	14:00	-	-

Water Works Park WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Int	-	-	15:00	16:00
				17:00	18:00
5	Int	-	-	3:00	4:00
				9:00	10:00
				11:00	12:00
				16:00	17:00
				23:00	-
7	Int	11:00	17:00	-	-
9	Int	-	-	Midnight	3:00
				4:00	9:00
				10:00	11:00
				12:00	15:00
				16:00	17:00
				18:00	23:00
10	Int	Midnight	11:00	10:00	11:00
				12:00	15:00
				18:00	23:00
11	Int	Midnight	-	-	-

Ypsilanti Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	Midnight	-	14:00	16:00
				19:00	20:00

West Service Center Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line (int)	-	-	Midnight	-
2	Line (int)	-	-	10:00	12:00
3	Line (int)	Midnight	-	-	-
4	Line (hi)	-	-	Midnight	-
5	Line (hi)	Midnight	-	Midnight	2:00
				5:00	8:00
				9:00	12:00
				14:00	-
R-1	Res	-	-	17:00	22:00
R-2	Res	17:00	22:00	-	-

Lake Huron WTP

Pump #	Hi or Int	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
3	Hi	Midnight	-	Midnight	-
4	Hi	-	-	Midnight	2:00
				3:00	13:00
				21:00	22:00
6	Hi	Midnight	-	-	-

Rochester Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off

No pumps were operated at this station, actual or optimized

Newburgh Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
1	Line	9:00	-	1:00	3:00
				4:00	5:00
				7:00	23:00
2	Line	-	-	7:00	10:00
				11:00	23:00
3	Line	Midnight	-	Midnight	1:00
				5:00	7:00
				10:00	11:00
				23:00	-

North Service Center Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
3-L	Line	12:00	-	12:00	-
6-L	Line	Midnight	24:00	Midnight	24:00
7	Line	Midnight	22:00	Midnight	22:00
8	Line	7:00	-	7:00	-
R-3	Res	9:00	12:00	9:00	12:00

Electric Ave. Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Line	-	-	2:00	5:00
				23:00	-
R-3	Res	17:00	23:00	18:00	19:00
				20:00	23:00
R-4	Res	-	-	17:00	18:00
				19:00	20:00

Eastside Booster Station

Pump #	Line or Res	Actual*		Optimized	
		Time On	Time Off	Time On	Time Off
2	Res	9:00	12:00	-	-
3	Res	17:00	23:00	-	-