

**Sewerage and Water Board of New Orleans  
Sewer System Evaluation and Rehabilitation Program**

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*Final Report*

**Wastewater Collection System  
Force Main Capacity Report**

**February 1998**

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# Force Main Capacity Report

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## INTRODUCTION

### Background

The Pump Station and Force Main Capacity Plan completed in January of 1997, identified a plan to determine the capacities of the Sewerage and Water Board's (S&WB) pump stations and force mains. In partial fulfillment of that plan the S&WB had prepared and delivered the Pump Station Testing and Evaluation Report in August 1997. That report presented pump performance curves and the respective system curves for each of the public pump stations in the system. It also presented an inventory and assessment of the condition of major pump station equipment and structures.

Following the Pump Station Testing and Evaluation Report, simplified assessments of force main capacity were carried out by Montgomery Watson. The results of these early calculations were presented in the Final System Characterization Report of May 15, 1997. These assessments were based on two criteria:

- i. Estimated pump station capacities
- ii. Typical design velocities for force mains

The calculations covered the three principal force main systems delivering flow to the East Bank Treatment Plant. Those assessments estimated the total capacity of the force mains between 195 and 273 Million Gallons per Day (MGD).

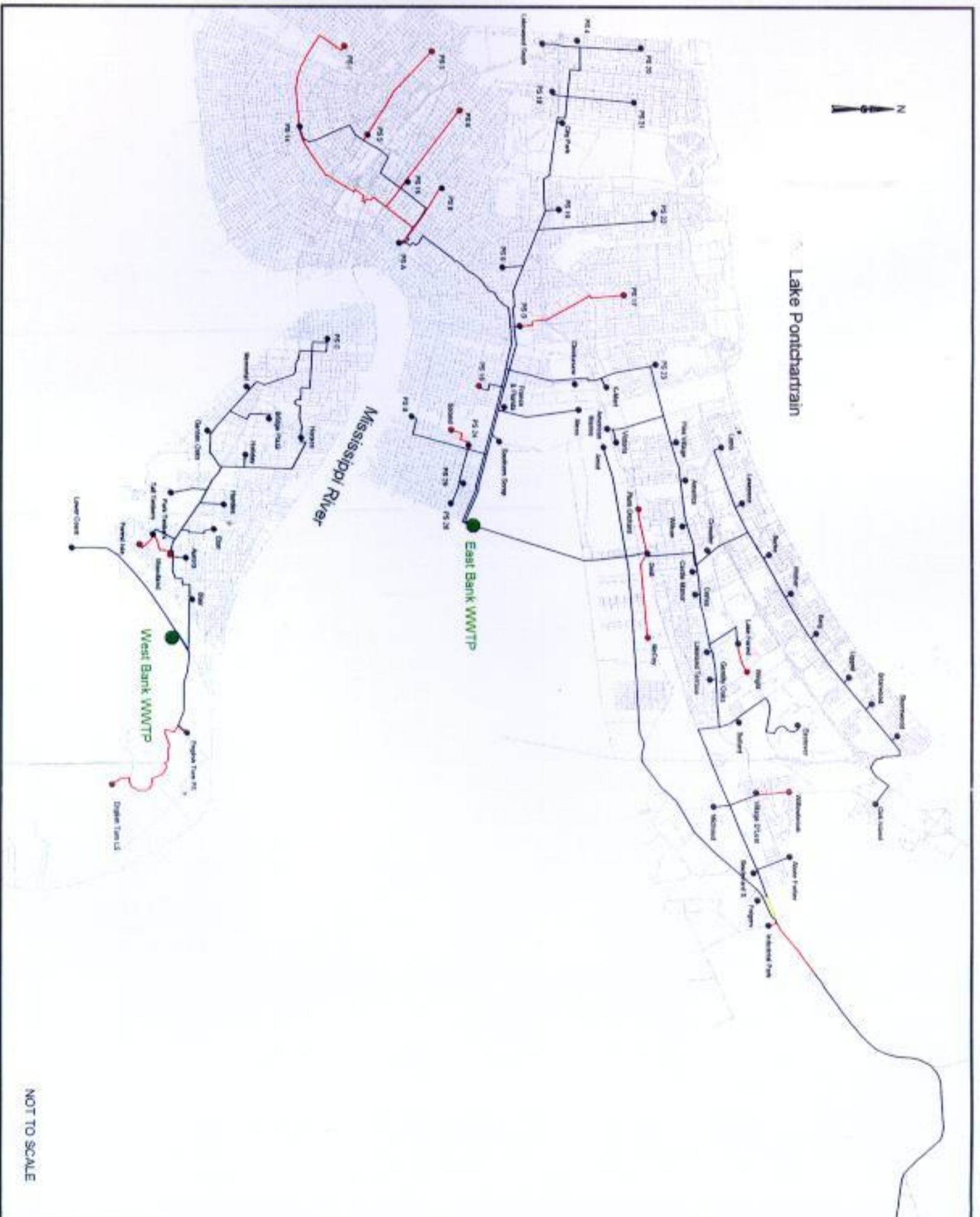
The analysis presented herein expands on the earlier assessments and considers all lengths of manifold force main and tries to reconcile the pressure heads required to deliver various flow rates with the delivery pressure which can be provided by the pumps. This report completes the pump station and force main capacity analyses anticipated in the Pump Station and Force Main Capacity Plan.

### Purpose of Analysis

This report presents further capacity analysis of the force main network system of the Sewerage and Water Board of New Orleans (S&WB) sanitary sewer collection system. The analysis presented herein is based on static rather than dynamic input. It is part of the ongoing process of development of the systemwide, dynamic, hydraulic model.

The results of this analysis will be utilized by the modeling team to target and prioritize future dynamic modeling efforts on areas with suspected deficiencies. The final force main capacity analysis, which will be based on dynamic input, will be completed with the development of the systemwide hydraulic model, scheduled for completion by December 31, 1998.

**Figure 1** presents the layout of the pump station and force main system.



NOT TO SCALE

**LEGEND**

- Pump Station
- Discharging to Gravity
- Discharging to Force Main
- Waste Water Treatment Plant
- Gravity Main
- Force Main
- Streets

SEWER SYSTEM EVALUATION AND REHABILITATION PROGRAM
FORCE MAIN CAPACITY REPORT
PUMP STATION LOCATION AND FORCE MAIN NETWORK
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FIGURE 1

## METHODOLOGY FOR ESTIMATING FORCE MAIN CAPACITY

### General

The flows and pressures in the force main system were estimated using the Hydroworks sewer analysis software. Hydroworks is capable of full dynamic simulation of sewerage systems, however, the full dynamic model of the New Orleans system is not scheduled for completion until December 1998. In order to get an initial understanding of the force main system, this analysis was carried out for steady state conditions using a simplified network as explained below. This steady state assumed that all pump stations connected to the manifold force main system would be pumping at the same time.

The public pump stations have already been inspected and tested by Montgomery Watson. The findings of this work are contained in Pump Station Testing and Evaluation Report produced in August 1997. Estimated pump capacities for the pump stations directly connected to the manifold force main system were abstracted from that report.

Some pump stations, such as PS 14, have two sets of pumps. One set delivers to the gravity system and the other to the manifold force main system. In such cases only the pumps feeding the force main system have been included.

An initial scenario was simulated with continuous inflows based on 100% of pump capacities. Analysis of these results suggest that in certain sections the current pumps might not be able to deliver full flow due to excessive force main pressure. The simulations were then repeated under inputs of 75% and 50% of pump capacity to try to get a match between force main pressures and pump delivery heads.

### Extent of Model

The model included only the lengths of manifold force mains and the directly connected pump stations which deliver flow to the East Bank Treatment Plant. Pump stations which lift directly to gravity sewers and isolated lengths of force main which discharge to gravity sewers were excluded as these interact with the gravity system. They will be included in the final assessments of system capacity when the calibrated dynamic model has been completed.

For the purpose of analyzing the results of the simulations, the manifold force main system was divided into three parts:

- i. The force mains connected to Station A and the 72" force main from Station A to the East Bank Treatment Plant
- ii. The manifold force main system down to Station D which includes contributions from pump stations in the Lakeview and Mid City SSES areas

- iii. The remaining manifold force main system covering 40 pump stations mainly in East New Orleans

A plan of the modeled force mains and pump stations is shown in **Figure 2**.

### **MODEL BUILD**

#### **Digitized Base Maps**

The details of the gravity sewers and force mains contained on S&WB's 600+ paper record plans have been digitized and the details downloaded into the Arcview GIS software. Using queries in the GIS software, the force mains were isolated and moved to a separate database. This data was then downloaded into Hydroworks format.

#### **Invert Levels and Ground Levels**

The only information on the invert levels of the force mains appears to be on construction/record drawings. At the stage of producing the force main model it had not been possible to obtain construction drawings of all the force main lengths. Partly for this reason and partly to expedite the interim analysis, it was assumed that all the force mains had a constant invert level and that the ground level was constant. It is believed that these assumptions would not severely affect the preliminary analysis as changes in physical level are relatively small compared to the pressure heads which drive the flow in the force mains.

#### **Force Main Connectivity**

There are a number of points where the manifold force mains cross connect with each other. The direction of flow at these points can generally be controlled by valves. For the purposes of this analysis, all valves at cross connections were assumed to be open so that the model could establish the path of least resistance. Future simulations may show that the performance of the force main system could be optimized by closure of some of these valves.

#### **Friction Factor**

All pipes were given a friction factor corresponding to a Manning's  $n$  of 0.013. This is representative of force mains in average condition. The friction factor is used to calculate the system pressure heads. However for the calibration of the detailed dynamic model, friction factors calculated from actual system data will be used. This data will be obtained from the SCADA system which includes measurement of delivery pressures at each of the pumps and from pressure information collected at tapping points along the manifold force main sections as part of the permanent flow survey.





## Summary of Model Build Assumptions

- Steady state analysis
- All connected pump stations operating simultaneously providing constant flows
- Force mains have same constant invert level
- Ground level is a constant
- Friction factor for force mains assumed at typical average value equivalent to a Manning's  $n = 0.013$
- All valves at force main intersections assumed open
- Transient pressure analysis (waterhammer) has not been carried out

## Limitations of Analysis

The static analysis performed for this preliminary assessment of force main capacity has limitations.

It assumes that all pumps will be equally affected by increasing pressures. In reality each pump has its own operating curve and will be affected in a different way. For example, in the reduced capacity scenarios the reality will be that some pumps are still pumping at near normal output while others are completely cut out because pressures exceed shut off head. The precise effect at each station will be predicted in the full dynamic model which allows for the actual operating curves of each pump station to be input.

The static analysis also assumes that all pumps are operating simultaneously. In reality, pumps will be switching on and off in response to their control levels. Again, such behavior patterns will be represented in the full dynamic model.

## ANALYSIS OF RESULTS

### General

The two aspects which have been considered in assessing the capacities of the force mains are pressure head and velocity.

Pressure head is important for two reasons. First, the force main must be strong enough to withstand the internal pressures needed to drive the flow. Second, the pumps must be capable of generating the pressure heads at the input points when delivering their design flow rate. A pump is usually chosen to work at a specific operating point i.e., specific values of pressure head and flow rate. At this operating point, it should be running at its optimum efficiency. If the pressure head moves away from this operating point, the operating efficiency of the pump will decrease. An increase in operating pressure above the operating point will cause a reduction in flow rate up to a point where the flow rate becomes zero, corresponding to shut off head. A decrease in operating pressure will cause an

increase in flow rate but if the pressure falls too low, there is a danger of the pump over-running and burning the motor out. For purposes of this analysis, the pressures have been grouped into five categories.

- <40 ft All pumps in danger of over-run
- 40-80 ft Most pumps at the lower end of their pressure range with a danger of over-run.
- 80-120 ft Most pumps within operating range
- 120-160 ft Most pumps above shut off head
- >160 ft All pumps above shut off head

Velocity is also important for two reasons. At low velocities, the flow will not be able to transport the solid matter in the sewage. Low velocities also increase the transport time through the force main system increasing the chance of the sewage becoming septic before it reaches the treatment plant; this is especially a risk in New Orleans during the hot summer months. If the velocities are too high, the friction resistance generated may start to tear off any protective lining fixed to the inside of the pipe and rates of erosion caused by hard suspended matter in the flow will be accelerated. High velocities are also more likely to give rise to transient pressure problems. For purposes of classifying the lengths of force main, the velocities have been divided into five bands.

- 0-1 ft/s Very low velocities where deposition of suspended matter is very likely and transport rates will be low with a risk of septicity
- 1-2.5 ft/s Velocities below the normal threshold for self cleansing design
- 2.5-7 ft/s Velocities in the normally acceptable range for design
- 7-10 ft/s Velocities acceptable for short time durations
- >10 ft/s Excessive velocity

### Station A System

The simulations with 100% of tested flows from the pump stations produces pressure heads at the pump stations which are in the range reconcilable with the tested delivery pressures. Also, the velocities produced in the force mains do not exceed design maximums and in most cases fall in the band required for self cleansing.

**Table 1** below lists the Station A system pump station input flows and resultant discharge pressure heads.



**Table 1**  
**Station A System - Input Flows and Discharge Pressures**

Pump Station	100% Pump Capacity	
	Flowrate (mgd)	Pressure (feet)
5	23.76	49.24
8	6.48	18.31
14	8.06	53.14
15	5.04	25.53
A	72.00	6.11

The pressure heads and velocities at numerous points in the Station A system for 100% flows are shown in **Figure 3**.

### Station D System

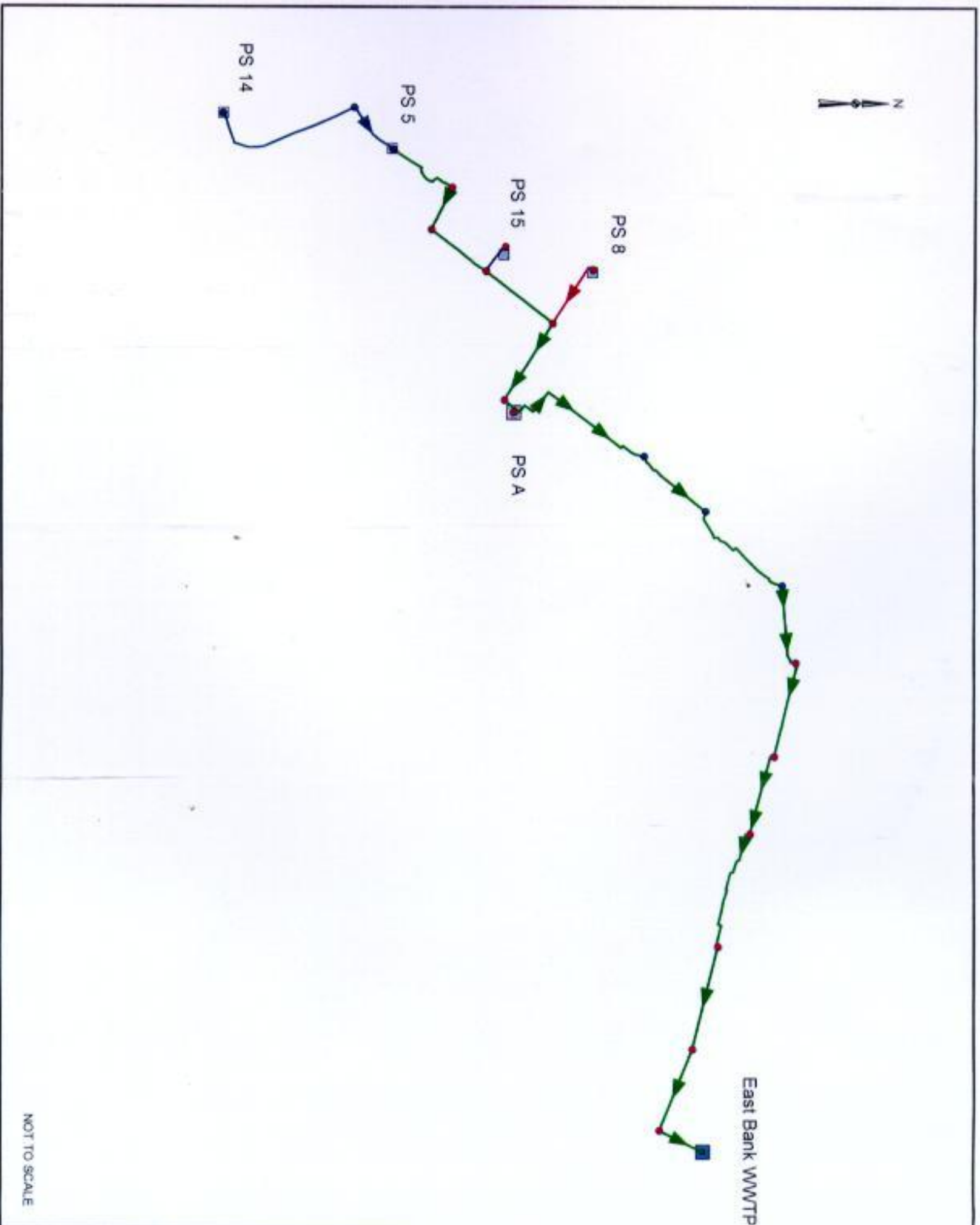
The simulations with 100% of tested flows produce pressure heads for the three pump stations located in the upper western reaches of the system, Lakewood South, PS 4 and PS 20, that are above shut off head. Reducing the flows to 75% of pump capacity reduces pressures at the pump stations in the upper western reaches to a level at which they could start pumping. Reducing flows to 50% of pump capacity brings these pump stations to well within their operating range. However, at 50% flow rates, the velocities in most of the force main lengths are below self cleansing.

**Table 2** below contains a summary of the pump station input flows and the resulting pressure heads for the three scenarios:

**Table 2**  
**Station D System - Input Flows and Discharge Pressures**

Pump Station	100% Pump Capacity		75% Pump Capacity		50% Pump Capacity	
	Flowrate (mgd)	Pressure (feet)	Flowrate (mgd)	Pressure (feet)	Flowrate (mgd)	Pressure (feet)
4	4.32	140.56	3.24	88.04	2.16	50.20
9	9.94	36.01	7.45	29.00	4.97	24.00
18	3.74	70.11	2.81	48.21	1.87	32.50
19	10.37	51.81	7.78	37.91	5.18	27.94
20	2.30	156.68	1.73	97.17	1.15	54.13
21	5.47	81.84	4.10	54.78	2.74	35.40
22	5.90	63.04	4.43	44.21	2.95	30.74
City Park	0.54	59.32	0.41	42.13	0.27	29.81
Lakewood South	1.94	141.59	1.46	88.62	0.97	50.46

The pressure heads and velocities at numerous points in this system for 100% flows are shown in **Figure 4**, for 75% flows in **Figure 5**, and for 50% flows in **Figure 6**.



**LEGEND**

**Node Pressures**

- < 40 feet
- 40 - 80 feet
- 80 - 120 feet
- 120 - 160 feet
- > 160 feet

**Force Main Velocities**

- ~ < 1 ft/sec
- ~ 1 - 2.5 ft/sec
- ~ 2.5 - 7 ft/sec
- ~ 7 - 10 ft/sec
- ~ > 10 ft/sec

**Pump Stations**

- Pump Stations
- Pump Station 'A'
- East Bank WWTP

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FORCE MAIN CAPACITY REPORT

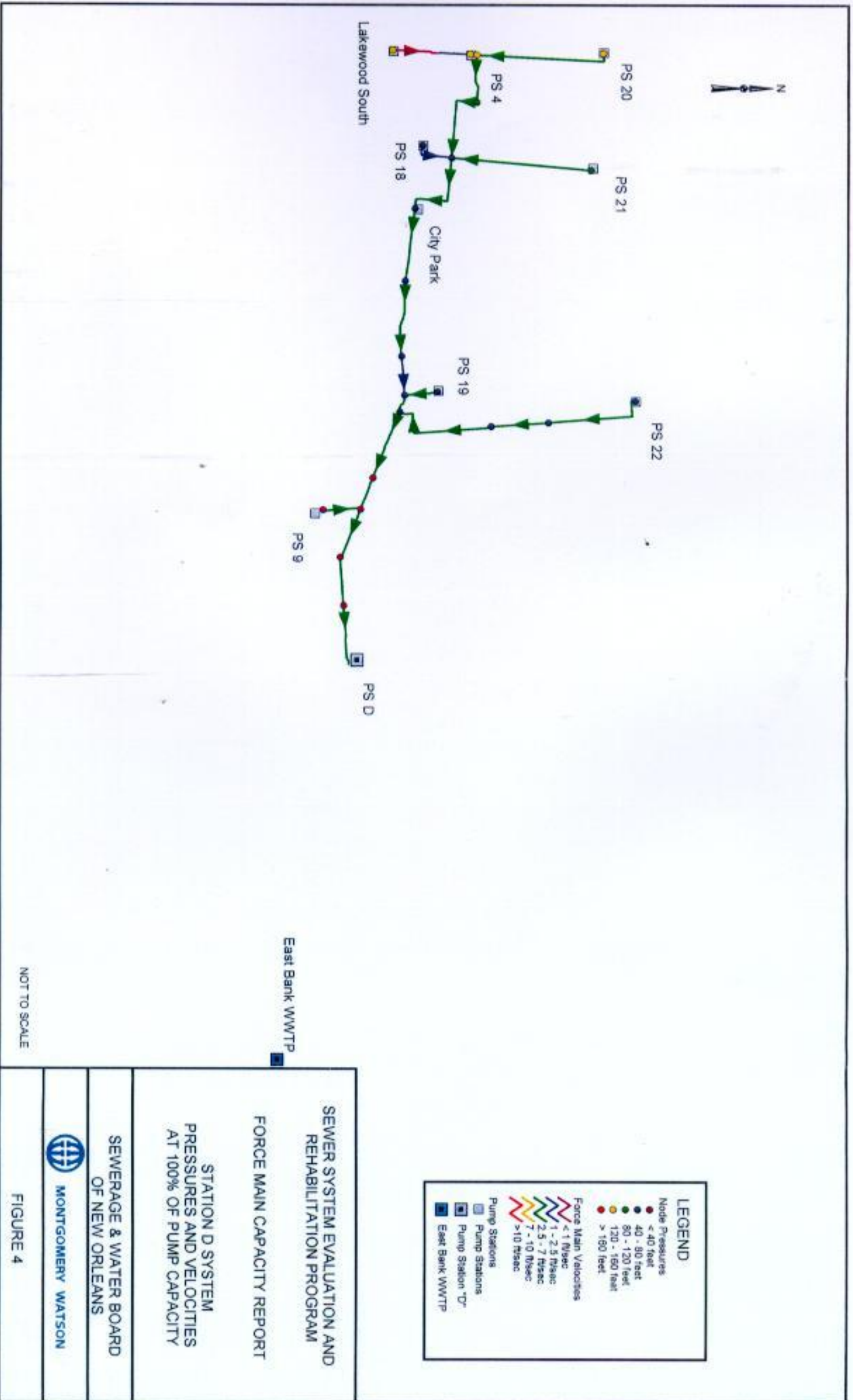
STATION A SYSTEM PRESSURES AND VELOCITIES AT 100% OF PUMP CAPACITY

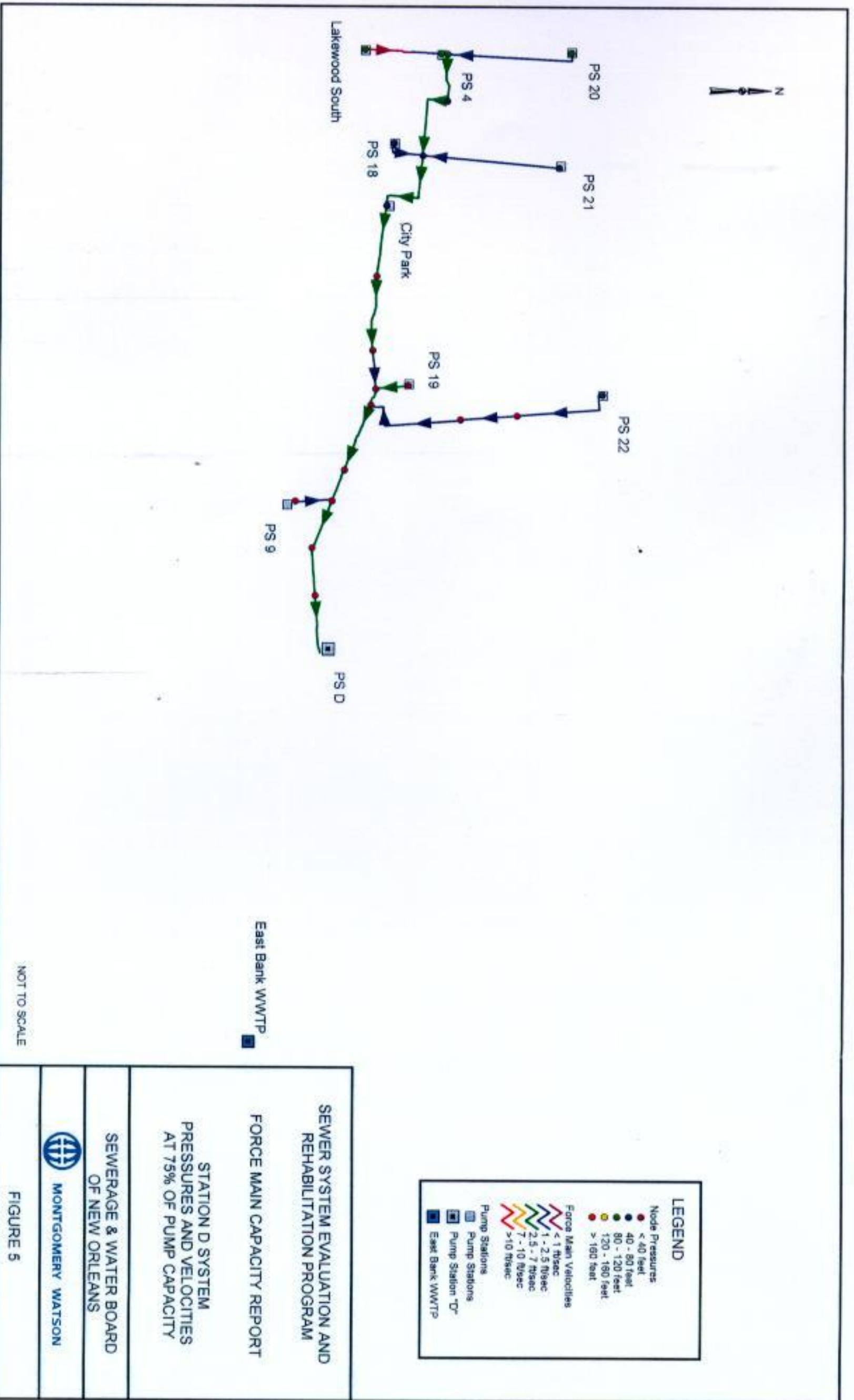
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FIGURE 3

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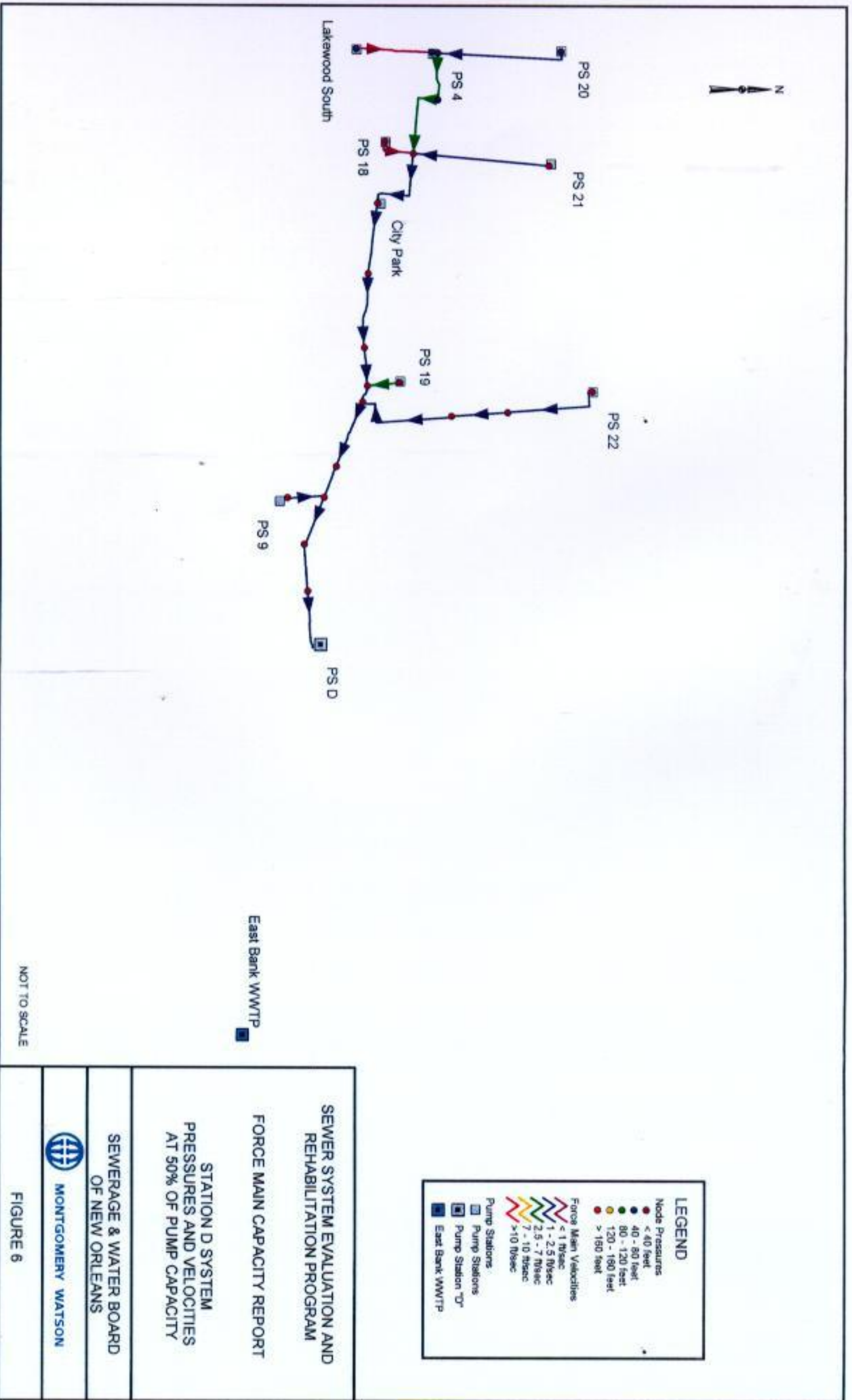




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<p>SEWER SYSTEM EVALUATION AND REHABILITATION PROGRAM</p> <p>FORCE MAIN CAPACITY REPORT</p> <p>STATION D SYSTEM PRESSURES AND VELOCITIES AT 75% OF PUMP CAPACITY</p>
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<p>FIGURE 5</p>





SEWER SYSTEM EVALUATION AND REHABILITATION PROGRAM

FORCE MAIN CAPACITY REPORT

STATION D SYSTEM

PRESSURES AND VELOCITIES AT 50% OF PUMP CAPACITY

SEWERAGE & WATER BOARD OF NEW ORLEANS

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FIGURE 6



### East New Orleans System

The simulations with 100% input of tested flows produce pressure heads at a majority of pump stations which are in excess of the tested shut off heads of the stations. This scenario would therefore not be sustainable in practice unless these pump stations were equipped with different pumps. In order to transport these flows, the force mains would need to withstand pressures greater than 250ft head, in some places. At the time of producing this report, it was not possible to establish the pressure rating of the critical sections of force main to confirm that they could withstand these pressures. Also, the velocities in some sections of the two principal force mains feeding the East bank Plant would exceed those normally used for design velocities.

The simulation with 75% of pump flow rates produced lower pressure heads but still in excess of the shut off heads of some of the pumps. When the flows were reduced to 50% of assessed pump capacity, the pressures at the input points drop into a range which would be compatible with the tested delivery pressures of the pumps. Under this scenario, the velocities in the principal force mains feeding the plant also fall within the normally accepted design range, but elsewhere the velocities in the force mains are below that required for self cleansing.

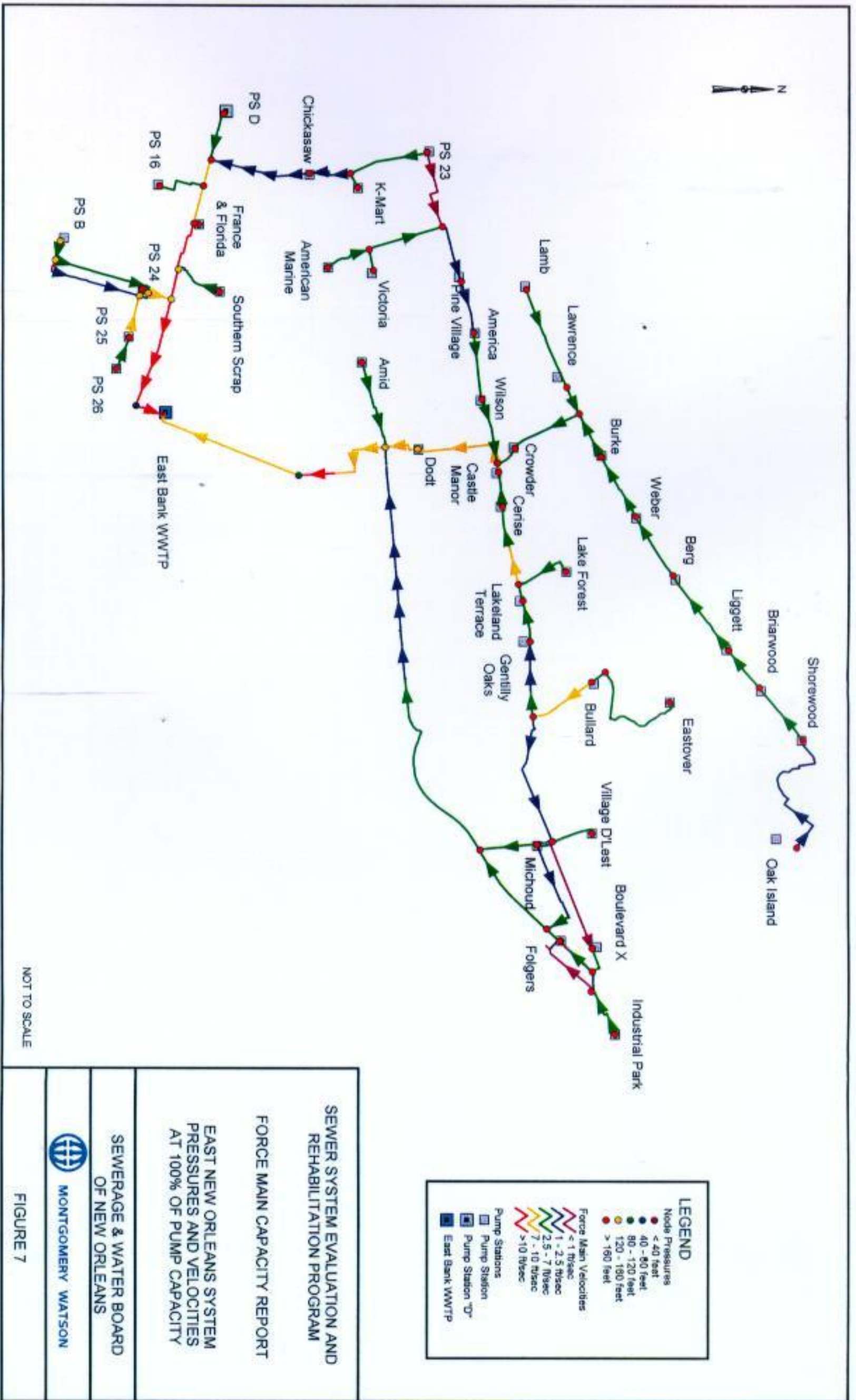
**Table 3** contains the pump station input flows and resulting pressure heads for the three scenarios.

The pressure heads and velocities at numerous points in this system for 100% flows are shown in **Figure 7**, for 75% flows in **Figure 8**, and for 50% flows in **Figure 9**.

## Force Main Capacity Report

**Table 3**  
**New Orleans East System - Input Flows and Discharge Pressures**

Pump Station	100% Pump Capacity		75% Pump Capacity		50% Pump Capacity	
	Flowrate (mgd)	Pressure (feet)	Flowrate (mgd)	Pressure (feet)	Flowrate (mgd)	Pressure (feet)
16	7.92	213.27	5.94	126.95	3.96	65.06
23	11.52	218.95	8.64	130.08	5.76	66.40
24	5.90	183.72	4.43	110.31	2.95	57.65
25	4.03	191.64	3.02	114.77	2.02	59.63
26	2.45	221.97	1.84	131.72	1.22	67.08
America	5.26	214.21	3.94	127.38	2.63	65.17
America Marine	0.72	328.08	0.54	283.17	0.36	134.16
Amid	3.60	166.83	2.70	100.76	1.80	53.35
B	10.22	143.36	7.67	87.68	5.11	47.64
Berg	4.32	223.82	3.24	132.76	2.16	67.53
Boulevard "X"	5.47	261.27	4.10	153.71	2.74	76.70
Briarwood	3.17	250.59	2.38	147.81	1.58	74.21
Bullard	2.88	328.08	2.16	212.83	1.44	102.91
Burke	3.82	198.09	2.86	118.29	1.91	61.10
Castle Manor	3.89	188.48	2.92	112.88	1.94	58.68
Cerise	3.89	201.28	2.92	120.06	1.94	61.87
Chickasaw	3.89	195.84	2.92	117.16	1.94	60.73
Crowder	2.30	186.32	1.73	111.67	1.15	58.16
D	76.32	202.28	57.24	120.79	38.16	62.35
Dodt	5.33	158.49	4.00	96.02	2.66	51.20
Eastover	3.60	328.08	2.70	246.29	1.80	117.99
France and Florida	2.45	168.52	1.84	101.80	1.22	53.90
Folger's	1.44	234.43	1.08	138.60	0.72	69.97
Gentilly Oaks	2.45	254.86	1.84	150.15	1.22	75.18
Industrial Park	3.17	251.44	2.38	148.14	1.58	74.18
K-Mart	3.38	225.72	2.54	133.96	1.69	68.20
Lake Forest	1.87	255.92	1.40	150.73	0.94	75.43
Lakeland Terrace	3.89	247.41	2.92	145.98	1.94	73.34
Lamb	3.96	262.75	2.97	154.57	1.98	77.14
Lawrence	5.90	199.63	4.43	119.16	2.95	61.49
Liggett	2.30	235.97	1.73	139.59	1.15	70.56
Michoud	2.88	245.85	2.16	145.03	1.44	72.84
Oak Island	3.31	292.34	2.48	171.38	1.66	84.75
Pine Village	2.16	217.00	1.62	128.96	1.08	65.89
Shorewood	3.02	275.65	2.27	161.94	1.51	80.52
Southern Scrap	0.55	226.42	0.42	134.44	0.28	68.44
Victoria	2.16	328.08	1.62	191.61	1.08	93.43
Village D'Lest	2.38	306.01	1.78	178.93	1.19	87.91
Weber	5.04	206.52	3.78	123.03	2.52	63.21
Wilson	4.90	203.64	3.67	121.42	2.45	62.51



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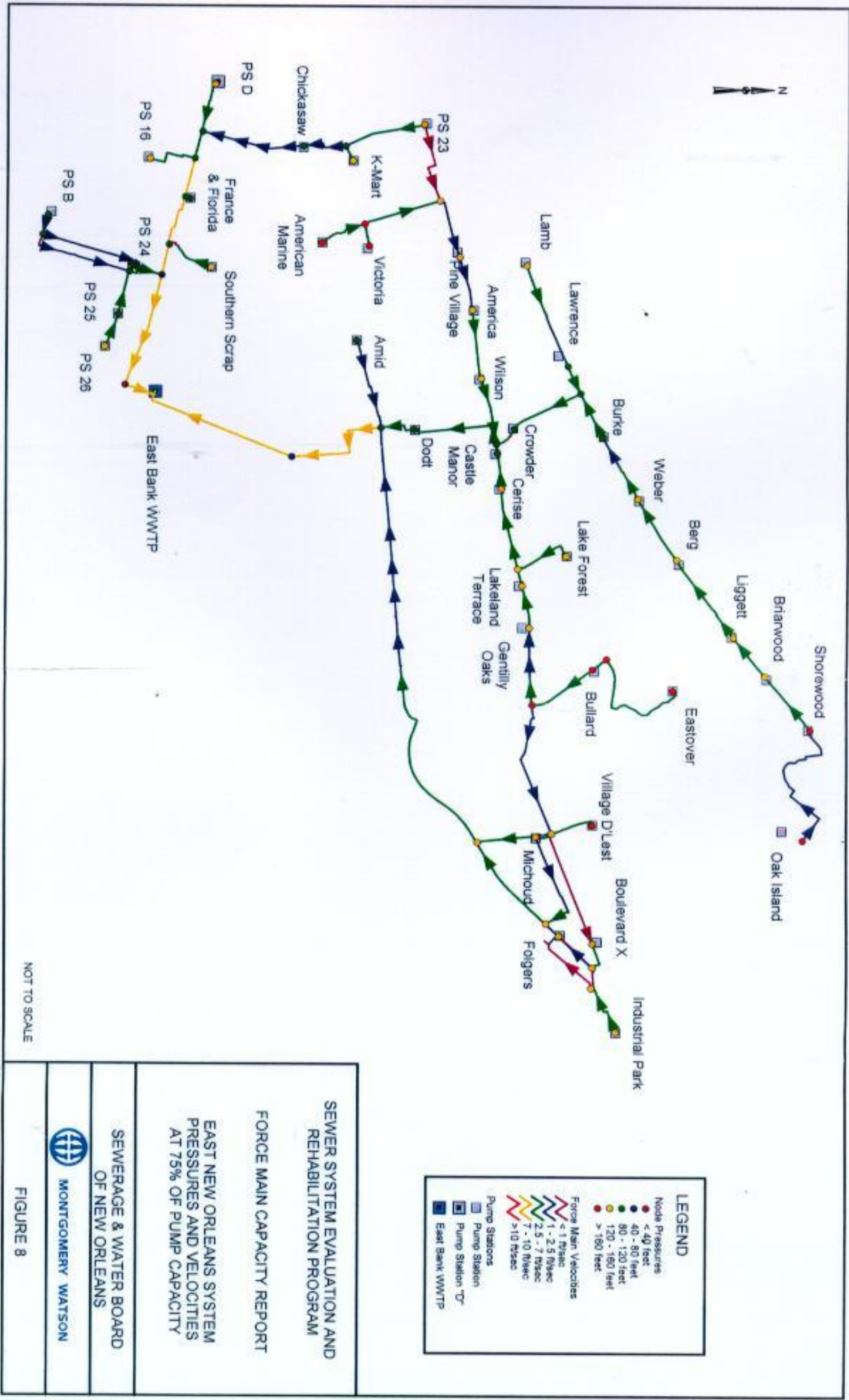
FORCE MAIN CAPACITY REPORT

EAST NEW ORLEANS SYSTEM PRESSURES AND VELOCITIES AT 100% OF PUMP CAPACITY

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FIGURE 7



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**SEWER SYSTEM EVALUATION AND REHABILITATION PROGRAM**

**FORCE MAIN CAPACITY REPORT**

**EAST NEW ORLEANS SYSTEM PRESSURES AND VELOCITIES AT 75% OF PUMP CAPACITY**

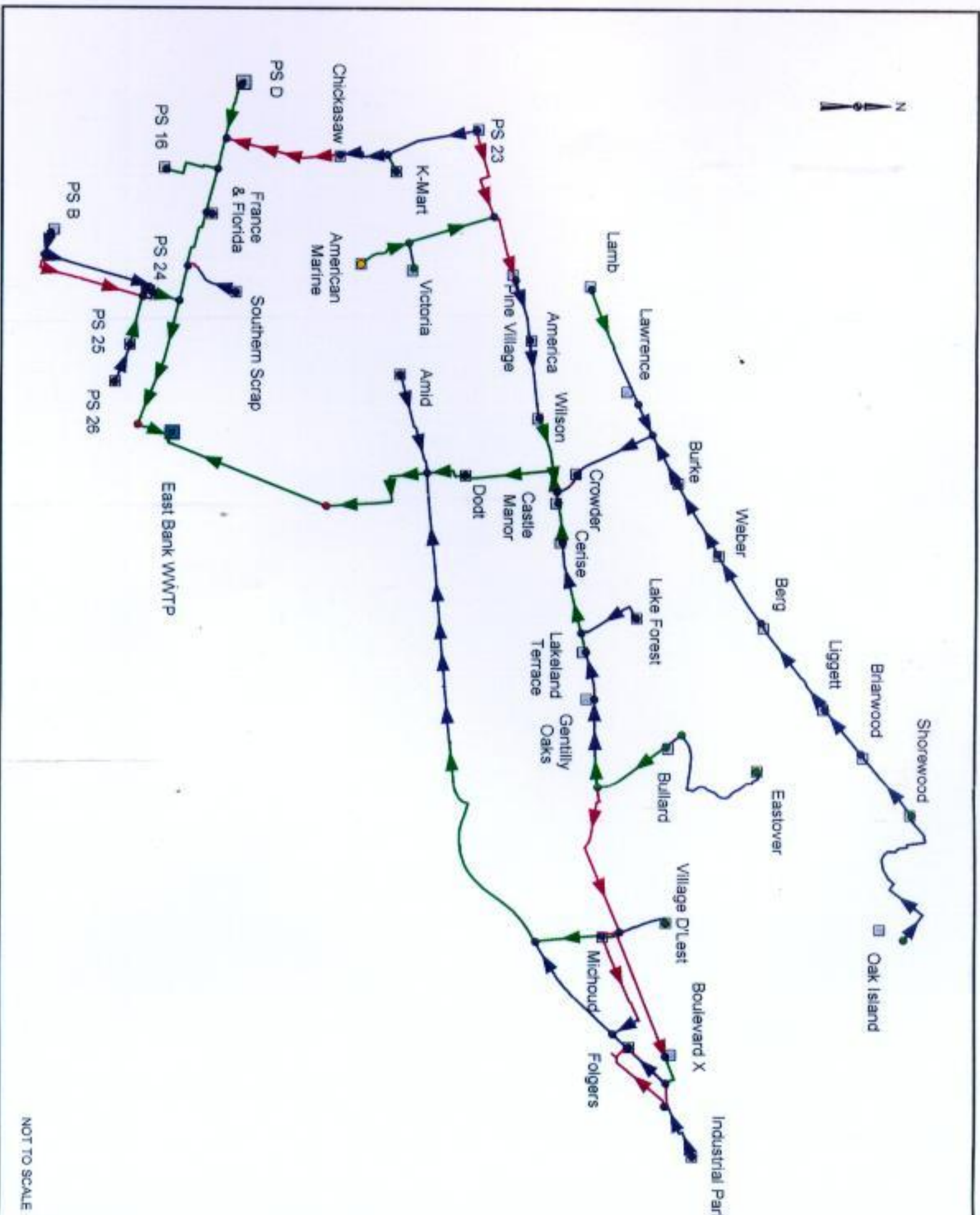
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**FIGURE 8**





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**EAST NEW ORLEANS SYSTEM PRESSURES AND VELOCITIES AT 50% OF PUMP CAPACITY**

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**FIGURE 9**

**LEGEND**

**Node Pressures**

- < 40 feet
- 40 - 80 feet
- 80 - 120 feet
- 120 - 180 feet
- > 180 feet

**Force Main Velocities**

- ▶ < 1 ft/sec
- ▶ 1 - 2.5 ft/sec
- ▶ 2.5 - 7 ft/sec
- ▶ 7 - 10 ft/sec
- ▶ > 10 ft/sec

**Pump Stations**

- P Pump Station
- U Pump Station "U"
- E East Bank WWTP



## CONCLUSIONS

### Summary of Apparent Force Main Capacity Problems

The results of this analysis suggest that most of the manifold force main segments have the capacity to transport 100% of currently installed pump capacity to the treatment plant. This is subject to confirmation that certain segments could withstand the associated pressures. The segments which may be under capacity at 100% flows are the lengths of 54" main feeding the East Bank Treatment Plant where the velocities would be greater than 10 ft/s.

Under the 50% flow scenario for both the Station D and East New Orleans systems, the velocities in several sections of the force mains fall below the design velocity required for self cleansing. Under dry weather conditions the flows, and velocities, would be even lower. This suggests that certain lengths of force main may be over-sized for delivery of dry weather flows.

Force main capacity aside, only the Station A system pump stations appear capable of delivering 100% of capacity. The Station D and East New Orleans system stations only appear capable of delivering 50% of capacity due to system pressures that exceed station operating ranges.

If system conditions enabled the delivery of 100% of calculated pump station flow, a total peak flow of 299 MGD would be delivered to the East Bank Treatment Plant. However, under current conditions, the maximum flow which could be delivered would be 185 MGD.

All of the preliminary conclusions drawn by this analysis will be confirmed upon completion of the systemwide, dynamic, hydraulic model. Any identified modifications to existing pump stations and force mains required to adequately convey dry and wet weather flows will be detailed in the Remedial Measures Action Plans for each basin as part of the Comprehensive System Remediation Program.

### Future Investigations

- The detailed dynamic model will be used to assess optimum pump capacities at each pump station
- The detailed dynamic model will be used to investigate Real Time Control (RTC) possibilities to prevent simultaneous operation of all pump stations thereby reducing maximum pressures in the force main system
- The detailed dynamic model will be used to investigate optimizing the system by controlling the flow at force main intersections using valves
- The detailed dynamic model will determine where force main upgrades are needed when existing system optimization strategies fail to provide sufficient capacity to transport peak design flows

## Force Main Capacity Report

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- The detailed dynamic model will be utilized in conjunction with other system information to investigate opportunities for force main redundancy