CITY OF LYNNWOOD
SNOHOMISH COUNTY, WASHINGTON

LYNNWOOD INFILTRATION AND INFLOW STUDY

G&O #08624
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Gray & Osborne, Inc.
CONSULTING ENGINEERS

CITY OF LYNNWOOD

SNOHOMISH COUNTY, WASHINGTON

Lynnwood

INFILTRATION AND INFLOW STUDY

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EXECUTIVE SUMMARY

The purpose of this study is to identify sources of infiltration and inflow (I/I) in the City of Lynnwood's sewer system. The sources of infiltration and inflow were identified using a number of methods including; evaluation of maintenance records, evaluation of previous studies, flow monitoring, smoke testing, manhole inspection, and television inspection. This study summarizes the findings and identifies and prioritizes repairs. Recommendations are provided for additional investigation, modifications to the City's municipal code, and sewer system repairs and rehabilitation. The study takes into account the constraints imposed by engineering, economics, regulatory requirements, and political frameworks while achieving the goal of a realistic, implementable, and sustainable City program for removal of I/I from the sanitary sewer system.

Infiltration is groundwater entering a sewer pipe by means of defective pipes, pipe joints, or manhole walls. Inflow is the surface water entering the sewer system from yard, roof, and footing drains, from cross connections with storm drains, through holes in manhole covers, and through illicit connections to the sanitary sewer system. Infiltration and inflow comes from groundwater or surface water sources that ends up being conveyed in the sewer system and treated at the City's Wastewater Treatment Plant (WWTP). Eliminating excessive I&I flow will decrease the frequency of sewer system back-ups, increase system capacity, and reduce wear and tear and operating costs at the lift stations and for equipment at the WWTP.

The first element of the study included flow monitoring to determine infiltration and inflow rates and to identify areas for further investigation. Twelve flow meters were installed throughout the City in the winter of 2008/2009. The 2006 Wastewater Comprehensive Plan shows an average base sanitary sewer flow of 2.82 at the WWTP. The I/I for the City's entire sanitary sewer system as measured at the WWTP can be seen in Table ES-1 below. The peak day infiltration rate was measured at 5.36 mgd or an increase of 190 percent over the average base sanitary sewer flow. The instantaneous inflow rate was measured at 15.00 mgd or an increase of 532 percent over the average base sanitary sewer flow. These results showed that both infiltration and inflow are problems in the City. However, inflow is seen to be greater than the infiltration with a flow of 15.00 mgd compared to 5.36 mgd.

TABLE ES-1

WWTP I/I Summary

Location	Peak Day Infiltration Rate (mgd)	Peak Day Infiltration Flow Increase	Inflow Influenced Instantaneous I/I Rate (mgd)	Instantaneous Inflow Flow Increase
WWTP	5.36	190%	15.00	532%

Certain areas of the City exhibited more I/I than other areas. The older areas of the City's sewer system with more concrete sewer pipe were shown to have more infiltration and inflow. The areas which drain to Lift Station #10 and Lift Station #12, both at or near capacity were also found to have more infiltration and inflow. The areas with more concrete pipe and higher I/I rates were targeted for further investigation using smoke testing, manhole inspection, and TV inspection. Approximately 126,100 lineal feet of pipe were smoke tested. 34 manholes were inspected, and approximately 64,100 lineal feet of pipe were TV inspected. The inspections found a total of 847 problems. A problem is defined as any identifiable structural defect that allows I/I to enter the system. All the inspection records were reviewed and each of the problems were ranked by the severity of the problem as seen in Table ES-2.

TABLE ES-2

All Problems Identified Severity

Severity	Number of Problems
Severe	1
Heavy	131
Medium	169
Light	526
Unknown	12
None	8
Total	**847**

Discussions with City staff led us to develop separate point repair project types describing the proposed method of repair. All of the problems were separated into one of thirteen point repair projects and a standard cost estimate was prepared for each of the 13 point repair projects. Organizing the problems into the point repair projects types allowed us to establish the benefits of each. Certain point repair projects target inflow while others target infiltration. In addition, some point repair project types are good candidates for capital improvement projects and others can more efficiently be performed by City staff. A summary of the point repair project types including the estimated costs can be seen in Table ES-3.

TABLE ES-3

Point Repair Project Costs

Point Repair Project Types	Project Description	Number of Problems	Estimated Cost per Each	Total Cost
Cleanout Cap Repair	Replace or repair damaged or leaking cleanout cap	41	$1,180	$48,380
Side Sewer Tee Repair	Replace damaged "hammer tap" concrete side sewer tee with new PVC tee and pipe	140	$11,580	$1,621,200
Mainline Point Repair	Replace damaged section of concrete sewer pipe with section of PVC sewer pipe	346	$11,010	$3,809,460
Manhole Cleaning	Vactor clean manhole	5	$950	$4,750
Manhole Grouting	Chemically grout leaky manhole	72	$2,190	$157,680
Manhole Replacement	Replace damaged manhole	1	$23,410	$23,410
Pipe Cleaning	Vactor clean sewer pipe	14	$950	$13,300
Adjust Manhole Lid	Raise or repair damaged lid and risers	8	$3,830	$30,640
Relay Sagging Pipe	Relay section of sewer pipe that has sags	52	$16,030	$833,560
Root Removal	Remove roots in sewer pipe or manhole	42	$1,400	$58,800
Side Sewer Grinding	Grind concrete side sewer protruding into sewer main	3	$1,400	$4,200
Side Sewer Point Repair	Replace damaged section of concrete side sewer pipe with new section of PVC sewer pipe	66	$8,400	$554,400
Storm Drain Piping	Install new storm drain pipe to connect source of stormwater that is currently connected to the sewer	21	$13,360	$280,560
None	Problems with no recommended repair	36	$0	$0
Total Problems = 847			**Total Cost = $7,438,940**	

The estimated total cost to repair all of the 847 problems is more than $7.4 million. Because of the large number of problems and large total cost, problems were prioritized based on the severity and the benefits. As seen in Table ES-1, the inflow is approximately 2.8 times greater than the infiltration into the sanitary sewer system. The highest priority should be to reduce inflow into the sanitary sewer system. The point repair project types which remove the most inflow are the "Storm Drain Piping" and

"Cleanout Cap Repair" projects. These projects may be located on private property which will require education, outreach and notification before any repairs are started. It may be possible to require private property owners to perform some of the repairs or the City may find it to be more efficient to perform the work using City crews and equipment. Often, the work itself is minor in nature and can be performed with a minimal disruption to existing lawn or landscaping.

The second priority should be for the City to develop the program with City staff performing point repair projects. Again, projects that remove inflow should be highest priority. In addition, some severe structural problems have been identified in the study such as protruding side sewers, offset pipe joints, cracks in the pipe, or debris in the pipe or manholes. The severe structural problems have the potential to block sewer pipes and cause backups, surcharge events and overflow events.

The third priority should be for the City to review their municipal code regarding illicit connections to the sanitary sewer system and develop a strategy for enforcement of the code and removal of sources identified. Although illicit stormwater connections to sewer system are currently prohibited, the existing City code does not provide a clear approach for enforcement. An analysis of the City's code regarding illicit connections to the sanitary sewer system and sample codes from other City's and County's in Washington State is found in this study.

We recommend that the City use this study to develop a long term, sustainable I/I removal program. We recommend the City set a goal to perform a certain number of point repair projects every year using City staff to perform the repairs wherever possible. If the budget permits, problems can be combined and entire runs of pipe can be repaired or rehabilitated by using open cut, cured-in-place pipe, or pipe grouting. These entire pipe run repairs are good candidates for capital improvement projects. The City should also consider revisions to the City municipal code regarding illicit connections to the sanitary sewer system and the maintenance and repair of private side sewer lines. A large portion of the flows entering the sanitary sewer system appear to be coming from private property sources. Consequently, a strategy to eliminate these sources will require outreach and education to individual property owners. The I/I removal program should include a plan for annual inspection of a certain portion of the sanitary sewer system. An effective I/I removal program is a long term commitment. To be successful, the program will need to be developed to be consistently implemented over a period of years.

BACKGROUND

The City of Lynnwood authorized Gray & Osborne to conduct an Infiltration and Inflow (I/I) Study in December 2008 in order to identify sources of infiltration and inflow into the sewer system. The sources of infiltration and inflow were identified using a number of methods including; evaluation of maintenance records, evaluation of previous studies, flow monitoring, smoke testing, manhole inspection, and television inspection. This study summarizes the findings, identifies and prioritizes repairs, and provides methods for implementing repairs.

Because of the large amount of information that was assembled as part of this study, major sections of information are included in the Appendices. In general, the body of the report will contain a brief analysis of each aspect of the study or inspection. The background information and inspection records will be included in the Appendices.

The 2006 Wastewater Comprehensive Plan identified significant impacts from I/I on the City's wastewater collection system. Sewer lines and lift stations were recommended to be upgraded to accommodate I/I related flows. The City has also implemented an aggressive program to identify and reduce I/I through an ongoing effort of flow monitoring, smoke testing, and television inspection. This study is part of this continuing effort at I/I reduction.

FLOW MONITORING

Flow monitoring was used to determine the extent and general locations of the I/I and to identify areas for further investigation. Twelve flow meters were installed simultaneously throughout the City. The City was divided up into eleven drainage basins with the twelfth flow meter placed on 76th Avenue before the sewer system enters the WWTP. In addition, effluent flow meter records from the WWTP were used to analyze the entire City. The period of flow monitoring began on December 23, 2008, and ended on March 16, 2009. The locations of the flow meters can be seen in Figure 1. The full analysis of the flow monitoring can be found in Appendix A.

Each of the flow meter basins were analyzed for I/I using data from the flow meters and precipitation records. Flow meter data has been summarized for both the peak day I/I and the instantaneous I/I.

PEAK DAY INFILTRATION

The peak day analysis was used to analyze the infiltration component of I/I. Infiltration is groundwater entering a sewer pipe by means of defective pipes, pipe joints, or manhole walls. Infiltration quantities exhibit seasonal variation in response to groundwater levels. Storm events trigger a rise in the groundwater levels and increase infiltration. The greatest infiltration is observed following significant storm events with prolonged periods of precipitation.

INSTANTANEOUS INFLOW

The instantaneous analysis was used to analyze the inflow component of I/I. Inflow is the surface water entering the sewer system from yard, roof, and footing drains, from cross connections with storm drains, through holes in manhole covers, and through illicit connections to the sanitary sewer system. Peak inflow occurs during heavy storm events when storm sewer systems are taxed beyond their capacity, resulting in hydraulic backups and local ponding.

The I/I rates are summarized in Table 1. The Peak Day Infiltration rate was calculated by comparing the difference between the daily flow after the major rain event with the average dry weather flow. The Instantaneous Inflow rate was calculated by comparing the difference between the peak instantaneous flow for the major rain event and the dry weather diurnal flow. The results show that the City has both infiltration and inflow. When compared with the WWTP effluent flow meter records, it is clear that I/I is a city-wide problem. The I/I rates in GPAD calculated from the flow meters are not extremely high for the majority of the basins, however, the flow monitoring period took place in a fairly dry winter with only one major storm event of 0.91 inches on January 7th, 2009. In addition, we did not capture data for all the flow meters during the one major rain event.

TABLE 1

I/I Summary

Flow Meter Basin	Basin % Concrete Sewer Pipe	Drainage Basin	Peak Day Infiltration Influenced Rate (GPAD)	Instantaneous Inflow Influenced Rate (GPAD)
1	63.1%	Lift Station #8	111	408
2	66.5%	Lift Station #10	(1)	(1)
3	88.7%	Lift Station #10	1,002	2,612
4	92.7%	Lift Station #10	(1)	(1)
5	77.7%	Lift Station #10	520	1,206
6	66.2%	Lift Station #10	(1)	(1)
7	93.3%	Lift Station #12	(1)	(1)
8	92.6%	Lift Station #12	782	(1)
9	46.6%	NE Gravity	329	(1)
10	72.8%	NW Gravity	330	889
11	100%	W Gravity	425	(1)
12	N/A	To WWTP	(2)	(1)
WWTP	N/A	Entire City and Portion of Edmonds	879	2,459

(1) Unable to calculate due to insufficient data
(2) Unable to calculate due to inaccurate flow meter readings

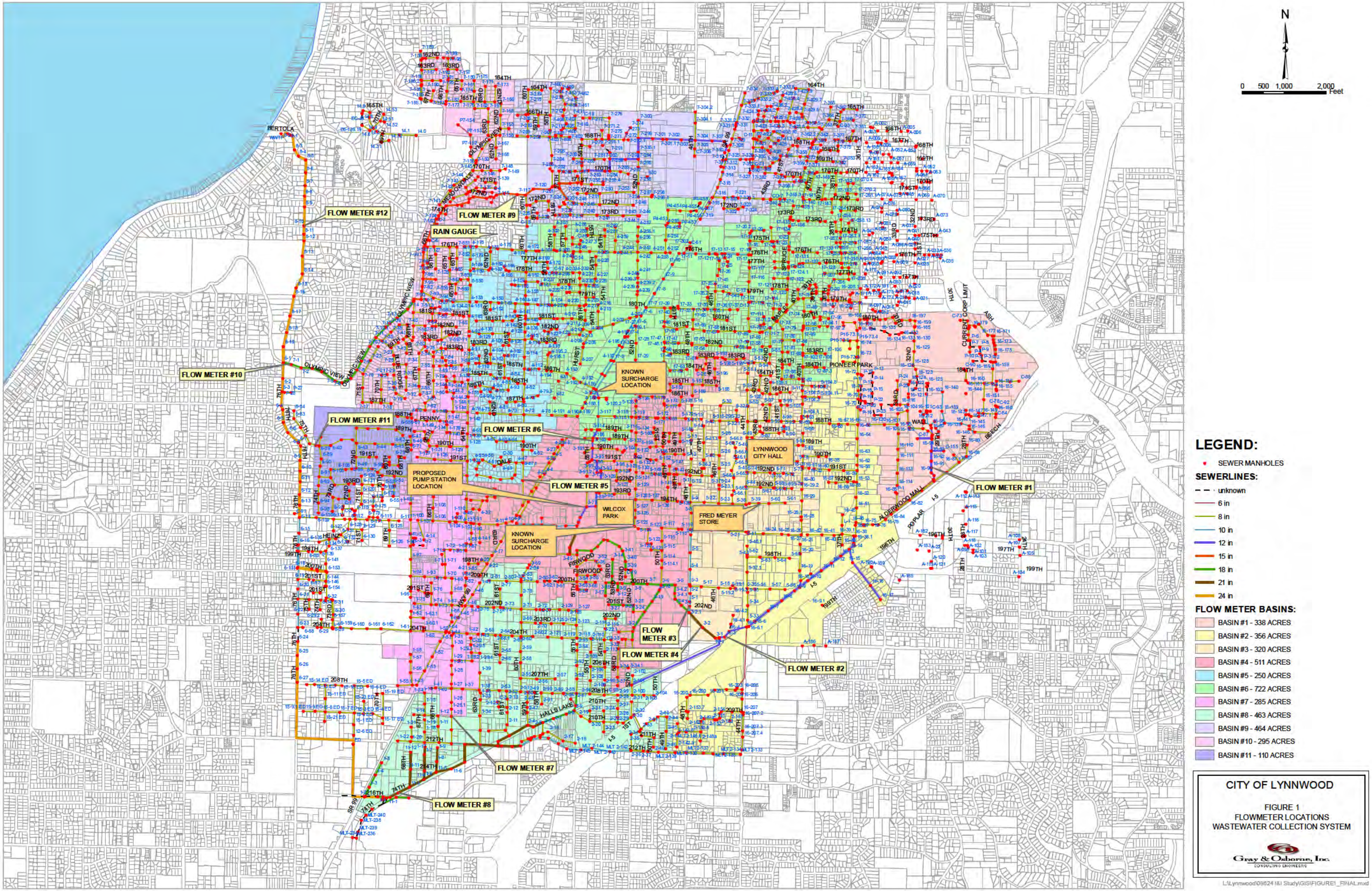

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FIGURE 1
FLOWMETER LOCATIONS
WASTEWATER COLLECTION SYSTEM

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The results shown in Table 1 are not unexpected. The older areas of the City's sewer system with more concrete sewer pipe are shown to have more infiltration and inflow. The areas which drain to Lift Station No. 10 and Lift Station No. 12, both at or near capacity are also shown to have more infiltration and inflow. The Flow Meter Basin No. 3 is shown to be the worst basin with respect to both infiltration and inflow. We expect that Flow Meter Basin No. 4 also has high I/I since it is a known problem area, but did not capture sufficient data for this basin. Flow Meter Basin No. 8 is shown to have a high rate of infiltration and we expect the results would show a high rate of inflow if the January 7th storm event was captured. Flow Meter Basin No. 5 is shown to have a moderate rate of both infiltration and inflow. The remainder of the Flow Meter Basins all show moderate to low rates of I/I.

SMOKE TESTING

Smoke testing was targeted for areas that showed greater inflow during the flow monitoring. We worked with City staff and smoke tested sections of Flow Meter Basin Nos. 3, 4, 5, 7 and 8. A total of approximately 126,100 linear feet of sanitary sewer pipe has been smoke tested including the results from the 1992 I/I study. A breakdown of the smoke testing by basin can be seen in Table 2. The total portion of the City's sewer system that has been smoke tested can be seen in Figure 2. The full analysis of the smoke testing inspection and results can be found in Appendix B.

TABLE 2

Smoke Testing Pipe Lengths

Flow Meter Basin	Sewer Pipe Smoke Tested (lf)
Flow Meter Basin No. 3	33,200
Flow Meter Basin No. 4	6,500
Flow Meter Basin No. 4 (1992)	19,600
Flow Meter Basin No. 5	29,900
Flow Meter Basin No. 7	24,300
Flow Meter Basin No. 8	32,200
Total	**126,100**

A total of 98 problems were identified through the smoke testing results. A typical problem included smoke coming out of roof drains, leaky cleanout caps, or through the ground indicating leaking or broken sewer pipe. Each of the smoke testing problems were ranked by the severity of the problem. The severity of each problem was broken down into the following categories; Severe, Heavy, Medium, Light, Unknown, and None. The Unknown category included problems where the severity and the source of the problem is not known. An example of the Unknown category is smoke emanating from under a deck on private property and staff were unable to enter the site to determine the problem. The None category includes problems located in the field which were later determined to not be problems. An example of the None category is smoke coming through a small hole in a cleanout cap. These severity designations will be used to describe the results from all the different phases of inspection throughout this study. Results of the smoke testing are seen in Table 3.

TABLE 3

Smoke Testing Problems Severity

Flow Meter Basin	Severe	Heavy	Medium	Light	Unknown	None	Total
Flow Meter No. 3 Basin	0	2	11	5	3	0	21
Flow Meter No. 4 Basin	0	0	4	0	0	0	4
Flow Meter No. 4 Basin (1992)	0	0	12	14	2	0	28
Flow Meter No. 5 Basin	0	0	10	2	1	0	13
Flow Meter No. 7 Basin	0	0	1	7	0	3	11
Flow Meter No. 8 Basin	0	0	7	6	7	1	21
Total	**0**	**2**	**45**	**34**	**13**	**4**	**98**

MANHOLE INSPECTION

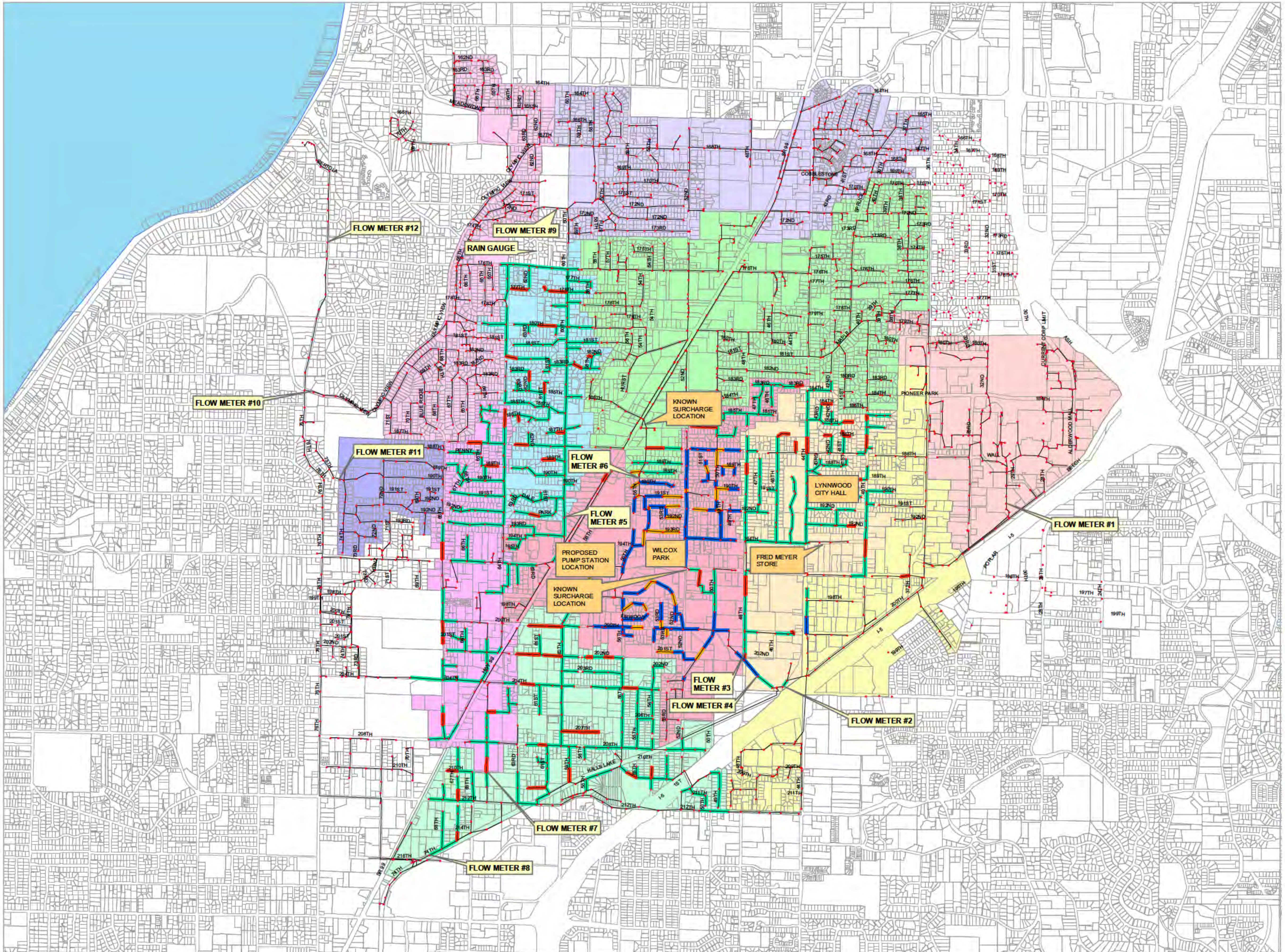
A total of 34 manholes were inspected in 6 Flow Meter Basins. The manholes were chosen from manholes identified during TV inspection and from discussions with City staff. The manholes inspected can be seen in Figure 3. The number of manholes inspected in each Flow Meter Basin is shown in Table 4. The full analysis of the manhole inspection and results can be found in Appendix C.

TABLE 4

Manholes Inspected

Flow Meter Basin	Manholes Inspected
Flow Meter Basin No. 1	2
Flow Meter Basin No. 3	6
Flow Meter Basin No. 4	22
Flow Meter Basin No. 5	1
Flow Meter Basin No. 6	2
Flow Meter Basin No. 7	1
Total	**34**

A total of 34 problems were identified through manhole inspection. Typical problems included leaks in the manhole lid, adjustment rings or pipe penetrations with mineral deposits. Each of the manhole problems were ranked by the severity of the problem. The severity of each problem was broken down into the same categories used to define smoke testing problems. Most of the manholes inspected were in relatively good condition with 31 manholes having either light or no problems. However, three manholes were



N

0 1,000 2,000 Feet

LEGEND:

- SEWER MANHOLES
- SEWERLINES:
- SMOKE TESTING PROBLEM IDENTIFIED - 1992
- SEWER LINE SMOKE TESTED - 1992
- SMOKE TESTING PROBLEM IDENTIFIED - 2009
- SEWER LINE SMOKE TESTED - 2009

FLOW METER BASINS:

- BASIN #1 - 338 ACRES
- BASIN #2 - 356 ACRES
- BASIN #3 - 320 ACRES
- BASIN #4 - 511 ACRES
- BASIN #5 - 250 ACRES
- BASIN #6 - 722 ACRES
- BASIN #7 - 285 ACRES
- BASIN #8 - 463 ACRES
- BASIN #9 - 464 ACRES
- BASIN #10 - 295 ACRES
- BASIN #11 - 110 ACRES

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FIGURE 2
1992 & 2009 SMOKE TESTING RESULTS

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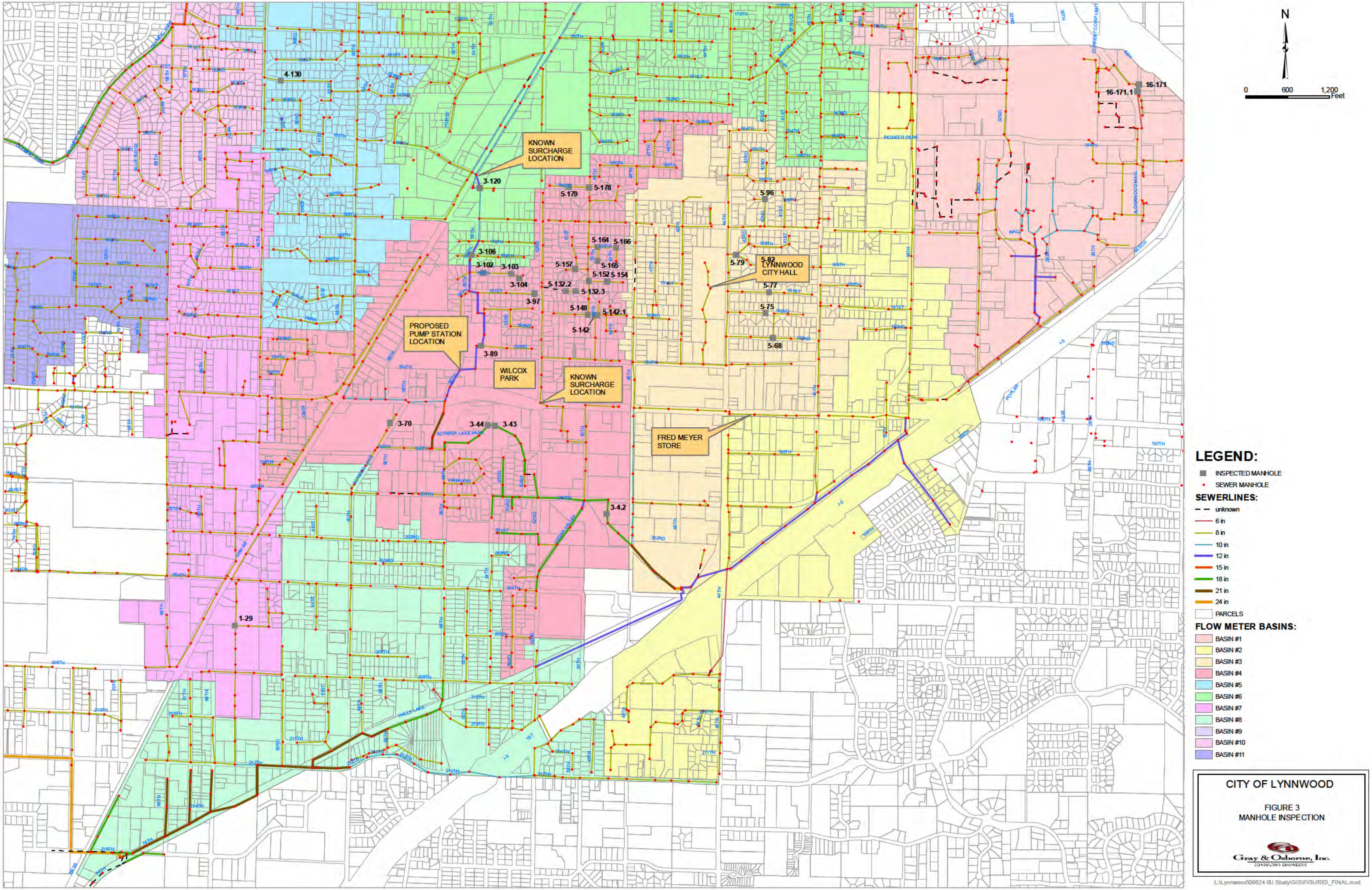
KNOWN SURCHARGE LOCATION
PROPOSED PUMP STATION LOCATION
WILCOX PARK
KNOWN SURCHARGE LOCATION
LYNNWOOD CITY HALL
FRED MEYER STORE
4-130
3-120
3-106
3-102
3-103
3-104
3-97
3-89
3-70
3-44
3-43
3-4.2
1-29
5-179
5-178
5-164
5-166
5-157
5-165
5-152
5-154
5-132.2
5-132.3
5-148
5-142.1
5-142
5-96
5-79
5-82
5-77
5-75
5-68
16-171
16-171.1
N
0
600
1,200
Feet
LEGEND:
INSPECTED MANHOLE
SEWER MANHOLE
SEWERLINES:
unknown
6 in
8 in
10 in
12 in
15 in
18 in
21 in
24 in
PARCELS
FLOW METER BASINS:
BASIN #1
BASIN #2
BASIN #3
BASIN #4
BASIN #5
BASIN #6
BASIN #7
BASIN #8
BASIN #9
BASIN #10
BASIN #11
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FIGURE 3
MANHOLE INSPECTION
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L:\Lynnwood\08624 I&I Study\GIS\FIGURE3_FINAL.mxd

identified with medium problems showing mineral deposits and visible infiltration into the manhole. Results are seen in Table 5.

TABLE 5

Manhole Problems Severity

Severity	Number of Problems
Severe	0
Heavy	0
Medium	3
Light	27
Unknown	0
None	4
Total	**34**

TV INSPECTION

Television inspection was targeted for areas that showed signs of both infiltration and inflow and included portions of Flow Meter Basin Nos. 3, 4, 6, and 8. Approximately 64,100 linear feet of mainline sewer pipe was inspected and 101 side sewer laterals were inspected. The total length of sewer pipe that was TV inspected in each Flow Meter Basin can be seen in Table 6 below. The total length of pipe that was TV inspected can be seen in Figure 4. The full analysis of the TV inspection and results can be found in Appendix D. The original TV inspection DVDs can be found in Appendix E.

TABLE 6

TV Inspection Pipe Lengths

Flow Meter Basin	Sewer Pipe TV Inspected (lf)
Flow Meter Basin No. 3	28,700
Flow Meter Basin No. 4	32,800
Flow Meter Basin No. 6	2,400
Flow Meter Basin No. 8	200
Total	**64,100**

A total of 715 problems were identified through the TV inspection. Typical problems included broken and leaking pipes or joints, roots in the sewer line, damaged or leaking side sewer tees, offset joints, or debris in the pipe. Each of the TV inspection problems were ranked by the severity of the problem using the same designations as the other inspection results. Results are seen in Table 7.

TABLE 7

TV Inspection Problems Severity

Severity	Number of Problems
Severe	1
Heavy	111
Medium	138
Light	465
Unknown	0
None	0
Total	**715**

INSPECTION SUMMARY

A total of 847 problems were identified through the smoke testing, manhole inspection and TV inspection. The inspection reports and background information and inspection records for each of the different problems identified can be seen in detail in Appendices B, C, and D. The location of each of the problems identified and the severity of the problem can be seen in Figure 5. The breakdown of all the problems by the severity can be seen in Table 8.

TABLE 8

All Problems Identified Severity

Severity	Number of Problems
Severe	1
Heavy	131
Medium	169
Light	526
Unknown	12
None	8
Total	**847**

For additional analysis, all the information on each of the problems identified through all the various inspections and testing methods has been combined and organized. Table 9 provides a description of the information that has been assembled for each of the 847 problems.