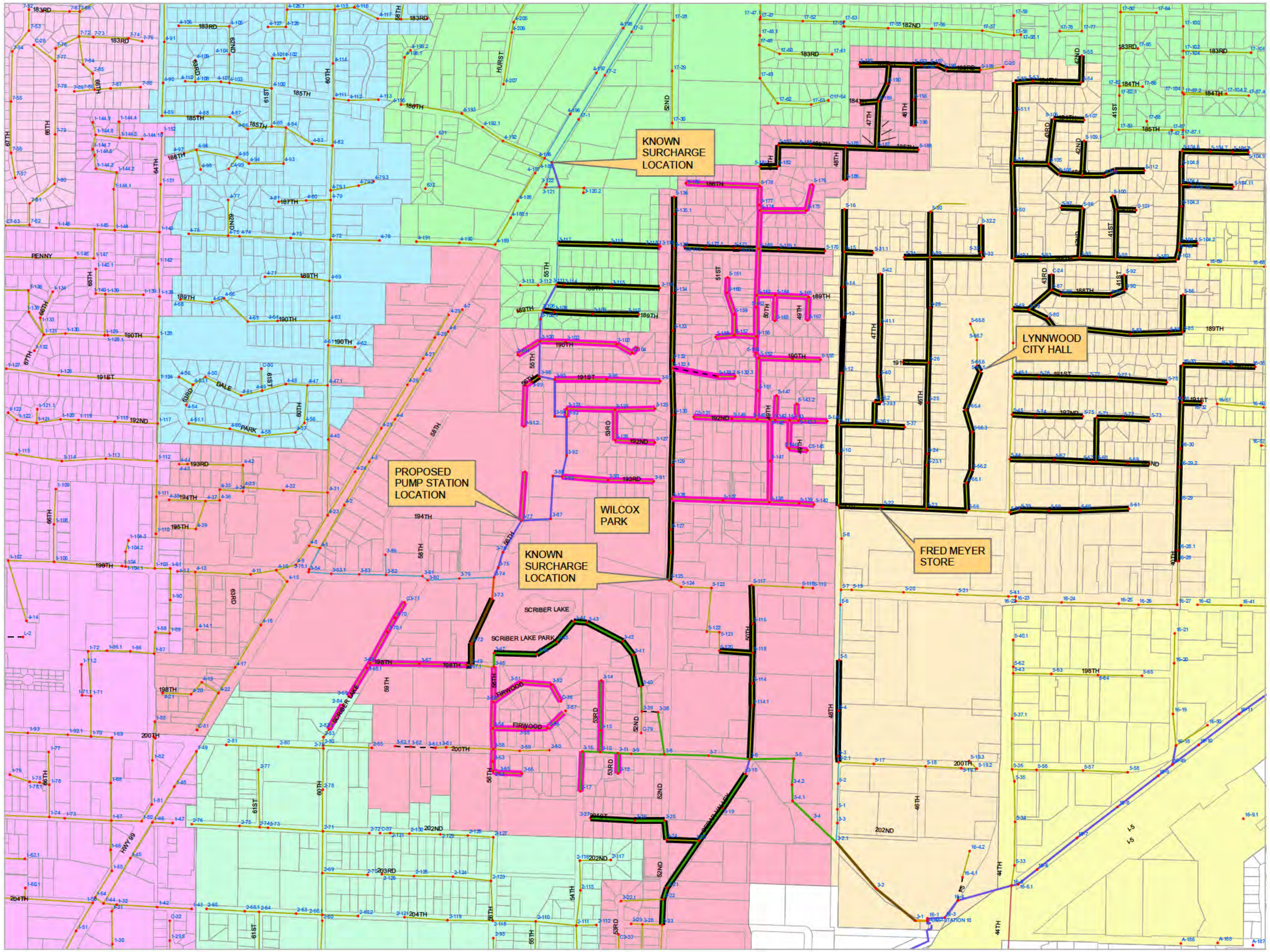

LEGEND:

- SEWER MANHOLES

SEWERLINES:

- unknown
- 6 in
- 8 in
- 10 in
- 12 in
- 15 in
- 18 in
- 21 in
- 24 in
- TV INSPECTION PHASE 1 (18835 LF)
- TV INSPECTION PHASE 2 (45279 LF)
- PARCELS

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

CITY OF LYNNWOOD

FIGURE 4
TV INSPECTION AREA

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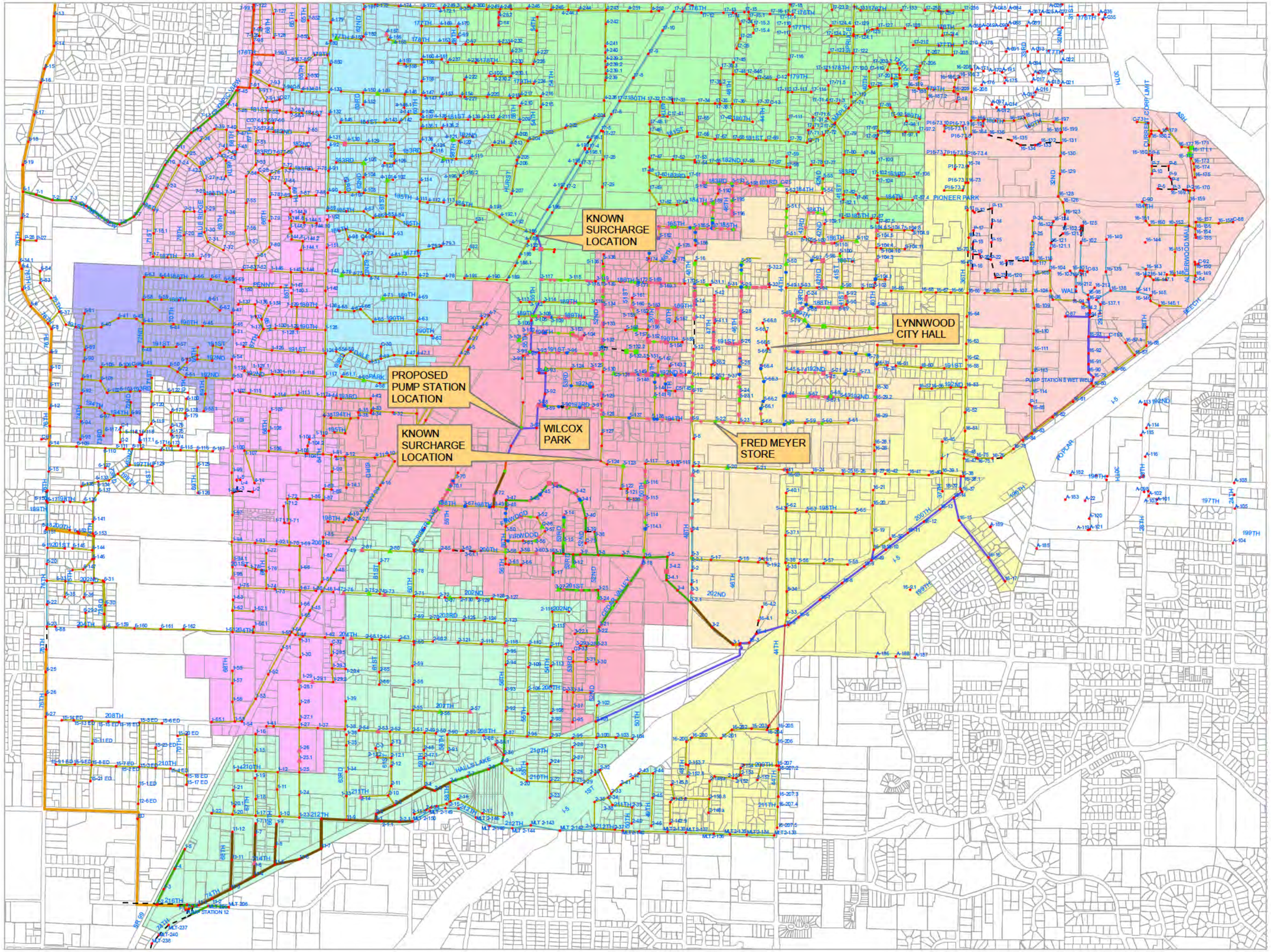

LEGEND:

TV INSPECTION:
- SEVERE
- HEAVY
- MEDIUM
- LIGHT

MANHOLE INSPECTION:
- MEDIUM
- LIGHT

SMOKE TESTING:
- HEAVY
- MEDIUM
- LIGHT
- SEWER MANHOLES

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

CITY OF LYNNWOOD

FIGURE 5
ALL PROBLEMS IDENTIFIED

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CONSULTING ENGINEERS

TABLE 9

All Problems Identified Descriptions

Column	Description
Project Priority	Ranks the project based on the severity of the problem
Problem Number	Gives the project number that has been assigned to the problem. This number is consistent throughout the study and can be used to reference background information on the problem that is found in the Appendices. The problem number is the upstream manhole number and the length the problem is located downstream the sewer mainline from the upstream manhole.
Severity	Ranks the seriousness of the problem. The severity of each problem was broken down into the following categories; Severe, Heavy, Medium, Light, Unknown, and None problems. The Severe category included the most serious problems and the Light category included least serious problems. The Unknown category included problems where the severity and the source of the problem could not be determined. The None category includes problems located in the field which were later determined to not be problems.
DVD Number	References the DVD on which the TV inspection video can be viewed. This only applies to problems that were located by TV inspection. The TV inspection DVDs can be found in Appendix E.
Upstream MH	Number of upstream manhole nearest to problem
Downstream MH	Number of downstream manhole nearest to problem
Location	Provides the nearest cross streets to the problem
Roadway Type	Describes the type of roadway at the location of the problem
Access: Public/Private	Describes the access to the problem location. The access was defined in the following categories; Public, Easement, and Private.
Description	Provides a brief description of the problem
Project Type	Presents a solution for the repair of the problem. Each problem was included in one of fourteen project types which will be discussed in more detail later in this study.
Cost	Provides a basic cost for the repair of the problem. The costs are based on the project type and will be discussed in more detail later in this study.
No. of Problems in Pipe Run	Includes the number of problems identified in this run of sewer pipe between manholes.
Distance to Reading	Gives the distance to the problem along the sewer mainline measured from the upstream manhole. This information is also included in the Problem Number.

TABLE 9 – (continued)

All Problems Identified Descriptions

Column	Description
Reference	Provides the reference number related to the type of inspection so the inspection records can be located in the appropriate Appendix. S-# reference numbers can be found in Appendix B – smoke testing, M-# reference numbers can be found in Appendix C – Manhole Inspection, and TV-# reference numbers can be found in Appendix D – TV Inspection.
Type of Testing	Describes the type of testing which located the problem. The three types of testing included; Smoke Testing, Manhole Inspection, and TV Inspection.
Year Tested	Provides the year the testing or inspection was performed
Basin	Gives the Flow Meter Basin in which the problem is located
Distance to Lateral	Provides the distance the problem is located up the side sewer lateral. This column applies only to problems identified during the side sewer launch TV inspection.

The results of all the inspection methods have been sorted based on the severity of the problems. The combined results of all the problems identified as part of this study can be found in Appendix F.

POINT REPAIR PROJECT TYPES

The 847 problems identified as a part of this study were initially sorted by the severity of the problem. Discussions with City staff led us to develop separate point repair project types describing the proposed method of repair for each of the problems identified in the study. Organizing the problems into the point repair projects types allowed us to establish the benefits of each. Certain point repair project types result in a greater reduction of the inflow into the sanitary sewer system and others result in a greater reduction of infiltration. In addition, some point repair project types are good candidates for capital improvement projects and others can more easily be performed by City staff.

Thirteen general point repair project types were chosen and each of the 847 problems was identified with the point repair project type that was the most appropriate method of repair. The fourteenth point repair project type "None" included problems where no repair was recommended. Each of the Point Repair Project Types are described in further detail including a more detailed description of the problems, the method of repair, and the benefits of the project.

CLEANOUT CAP REPAIR

This point repair project type includes the repair or replacement of a damaged or leaking cleanout cap. Through the smoke testing, a number of problems were located where smoke was observed exiting cleanouts. A number of cleanouts were observed with the cap missing and a number had poorly fitted caps. The majority of these problems were observed on private property. Approximately 41 problems were identified for this method of repair. The leaking cleanout caps allow inflow to enter into the sanitary sewer system. Although the quantity of inflow that enters the sanitary sewer system through this source is not large, the problem is easy to repair. These repairs can be performed by the City crews.

SIDE SEWER TEE REPAIR

This point repair project type includes the repair of a damaged concrete side sewer tee with a new PVC tee and pipe. The repair includes a short run of PVC pipe on the mainline with couplings to join to the existing concrete sewer pipe and a short run of PVC pipe on the side sewer with a coupling to join to the existing side sewer pipe. These side sewer tee problems were identified through the TV inspection. The problems included visible infiltration at the tee, dirt or mineral deposits entering and obstructing flow at the tee, and offset, broken, or damaged pipe. A large number of the side sewer tees in older concrete sewer pipe were installed using the “hammer tap” method. A hammer was used to break a hole in the mainline pipe. The side sewer pipe was positioned at the location of the hole and the entire connection was surrounded by grout. This method of construction does not create a watertight seal. Approximately 140 problems were identified for this method of repair. The problems identified for side sewer tee repair include both structural problems as well as sources of infiltration the sanitary sewer system. These repairs can be performed by City crews, but a number of factors should be considered prior to construction including; the depth of the side sewer, the temporary pumping requirements, the location in an easement or roadway, and the level of traffic control required.

MAINLINE POINT REPAIR

This point repair project type includes the repair of a damaged section of concrete sewer mainline pipe with a new section of PVC pipe and couplings to join to the existing pipe. These mainline problems were identified through TV inspection. The problems included visible infiltration into the pipe, dirt or mineral deposits entering the pipe, holes in the pipe, cracked pipe, and offset pipe joints. Approximately 346 problems were identified for this method of repair. The problems identified for mainline point repair include both structural problems as well as sources of infiltration the sanitary sewer system. These repairs can be performed by City crews, but a number of factors should be considered including; the depth of the side sewer, the temporary pumping requirements, the location in an easement or roadway, and the level of traffic control required.

MANHOLE CLEANING

This point repair project type includes the cleaning of a manhole containing debris by use of a vactor truck. These problems were identified through the TV inspection and manhole inspection. The problems all included various amounts of debris in the manhole and on the manhole bench. Approximately five problems were identified for this method of cleaning. The problems are mostly a maintenance issue, however, if the debris is allowed to build up, there is a potential that a blockage or surcharge event can occur. These repairs can be performed by City crews or a cleaning/vactor company can be used to perform the service.

MANHOLE GROUTING

This point repair project type includes the grouting of leaky manholes. Typically, grouting is accomplished by drilling small holes into the manhole structure near the sources of infiltration. A chemical grout material is forced under pressure through the holes. The chemical grout hardens and creates a watertight seal. These manhole problems were identified through TV inspection and manhole inspection. The problems included visible infiltration into the manhole at different locations including the pipe penetrations, manhole benches, manhole sections, adjustment rings, or cracks in the manhole. Approximately 72 problems were identified for this method of repair. The problems identified for manhole grouting are all associated with infiltration of varying degree into the manhole. Grout manufacturers sell the equipment and will train crews to perform the repairs. However, there are a number of local firms that specialize in manhole grouting and can perform this service.

PIPE CLEANING

This point repair project type includes the cleaning of debris in a pipe by use of a vactor truck. These problems were identified through the TV inspection. The problems all include various amounts of debris in the sewer pipe. Approximately 14 problems were identified for cleaning. The problems are mostly a maintenance issue, however, if the debris is allowed to build up, there is a potential that a pipe blockage can occur causing a surcharge or backup overflow event. These repairs can be performed by City crews or a cleaning/vactor company can be used to perform the cleaning.

ADJUST MANHOLE LID

This point repair project type includes the installation of new manhole riser sections and lids. The manhole lid problems were identified through TV inspection and manhole inspection. The problems included manhole lids located in areas below the surrounding grade where water could pond above the manhole lid. The problems also included damaged or leaking riser sections of the manhole. Approximately eight problems were identified for adjusting the manhole lid. These problems can eliminate a source of inflow

for the manholes located in low areas or a source of infiltration for the leaky riser sections. These repairs can be performed by City crews.

RELAY SAGGING PIPE

This point repair project type includes the replacement of a section of concrete sewer pipe that has sagged with new PVC sewer pipe at a constant grade and couplings to join to the existing pipe. The sags in the pipe were identified through TV inspection. The problems all include sags in the mainline pipe of varying depth and length. Approximately 52 sags were identified for this method of repair. The problems are mostly a maintenance issue. Debris can build up in the sags and decrease the capacity of the pipe. If enough debris builds up, there is a potential that a pipe blockage can occur causing a surcharge or backup overflow event. If the sags are kept from accumulating debris through routine maintenance, the sagging pipe should not need to be relayed. The maintenance can be performed by City crews.

ROOT REMOVAL

This point repair project type includes the removal of roots that have been found in sewer lines or manholes. The roots can be removed by several different methods including mechanically cutting or grinding the roots or the use of chemicals to kill the roots. The roots were identified through TV inspection and manhole inspection. The problems included roots entering sewer lines or manholes through cracks, holes or joints. The amount and location of the roots varied greatly. Approximately 41 problems were identified for root removal. The problems identified for root removal are primarily a maintenance problem, but the location where roots enter the sewer pipe or manhole can also be a source of groundwater infiltration. Large root clusters decrease the capacity of the pipe and have the potential to cause surcharge or overflow events. Chemicals used to kill the roots and equipment to cut the roots from sewer pipes is widely available. City crews can perform this maintenance if they have the equipment. In addition, a number of local firms provide this service. The majority of the companies that provide video inspection services also have equipment to cut roots from sewer pipes and manholes.

SIDE SEWER GRINDING

This point repair project type includes the grinding or cutting of a side sewer pipe that is protruding into the sewer main line. The protruding side sewers were identified through TV inspection. The problems included concrete side sewers protruding into the sewer main line of varying depths. Three problems were identified for side sewer grinding. The problems identified for side sewer grinding are primarily a maintenance problem, but can also be a source of groundwater infiltration into the sanitary sewer system. Protruding side sewers decrease the capacity of the pipe and have the potential to cause surcharge or overflow events. The majority of the companies that provide video inspection services also have equipment to grind protruding side sewers.

SIDE SEWER POINT REPAIR

This point repair project type includes the repair of a damaged section of concrete side sewer pipe with a new section of PVC pipe and couplings to join to the existing pipe. These side sewer problems were identified through the side sewer launches of the TV inspection and smoke testing. The problems identified through TV inspection included visible infiltration into the side pipe, dirt or mineral deposits entering the pipe, holes in the pipe, cracked pipe, and offset pipe joints. The problems identified through smoke testing were seen as smoke exiting the ground or cracks in the sidewalk where the exact nature of the problem could not be seen. These problems were observed both in the right-of-way and on private property. In many cases the locations of the problems were identified by the length up the side sewer from the sewer mainline, so their precise location in the right-of-way or private property is unknown. Approximately 66 problems were identified for this method of repair. The problems identified for side sewer point repair include both structural problems as well as sources of infiltration the sanitary sewer system. These repairs can be performed by City crews, but a number of factors should be considered including; the depth of the side sewer, and the location in a private property, an easement, or roadway.

STORM DRAIN PIPING

This point repair project type includes the installation of new storm drain piping. The project disconnects a source of stormwater that is currently connected to the sanitary sewer system and connects to the storm system. These problems were identified through smoke testing. The problems included various sources of stormwater including yard drains, roof drains and downspouts connected to the sanitary sewer system. The majority of these problems were observed on private property. Approximately 21 problems were identified for this method of repair. The problems identified for storm drain piping are all sources of inflow into the sanitary sewer system. These repairs can be performed by City crews, but a number of factors should be considered including; the depth of the side sewer, and the location in a private property, an easement, or roadway. City code prohibits the discharge of storm water into the sanitary sewer system, so the responsibility for this work can potentially be placed on the homeowner. The City code is discussed in more detail later in the study.

NONE

This point repair project type includes the remainder of the problems identified during the study for which no repair is recommended. The problems were identified through all phases of inspection including TV inspection, manhole inspection, and smoke testing. Many of the problems were pipes or manholes found to be surcharging because of high sewage flows during the inspection. Approximately 32 problems were identified for no repair.

A summary of each the point repair project types including the number and severity of problems identified for each type of repair is seen below in Table 10.

TABLE 10

Point Repair Project Types

Point Repair Project Types	Number of Problems	Severe	Heavy	Medium	Light	Unknown
Cleanout Cap Repair	41	0	2	7	24	8
Side Sewer Tee Repair	140	0	28	20	92	0
Mainline Point Repair	346	1	28	66	251	0
Manhole Cleaning	5	0	0	0	5	0
Manhole Grouting	72	0	24	9	39	0
Manhole Replacement	1	0	1	0	0	0
Pipe Cleaning	14	0	7	1	6	0
Adjust Manhole Lid	8	0	0	1	7	0
Relay Sagging Pipe	52	0	4	10	38	0
Root Removal	42	0	5	10	27	0
Side Sewer Grinding	3	0	0	2	1	0
Side Sewer Point Repair	66	0	11	28	23	4
Storm Drain Piping	21	0	18	1	0	2
None	36	0	0	0	0	0
Total	**847**	**1**	**128**	**155**	**513**	**14**

PROJECT COSTS

To determine the scale of the problems identified during this study, the cost to repair all the problems was determined. With a total of 847 problems identified and 811 identified as candidates for repair, the individual conditions at each project location varied greatly. To simplify the process, a standard cost estimate was prepared for each of the 13 point repair project types as described above. Certain assumptions were made for each of the cost estimates including; equipment and number of crew required, the depth and size of the sewer line, the location of the project in the right-of-way or private property, the location of the project outside of a major street thoroughfare, and a number of other assumptions. These assumptions were made to standardize a cost for each of the point repair project types and to determine the cost to construct the average project for each. The cost estimates were prepared with the labor costs and materials costs separated because the City crews plan to repair some of the problems. Separating the labor and material costs allows the City crews to determine the materials, crew, and equipment required to perform the repair. In addition, this allows the City to determine the cost savings of performing the work themselves.

The cost estimates for each of the point repair project types can be seen in Appendix G. The cost estimates include a basic description of the project and all the assumptions on

which the cost estimate was based. The labor costs and materials costs are separated and the sales tax is included for a total estimated project cost. Also included is a photo of the average problem for which the repair is being made. Included with each cost estimate is a summary table with all of the problems identified during this study for which this method of repair is recommended. The summary tables are prioritized by the severity of the problem in the recommended order of construction. The first problems on the list are the most serious and recommended for construction first. Included in this table is the location of the project and the project Problem Number. The problems number corresponds to the problem number as seen in Table 7 and also the problem number listed in the inspection and testing results as seen in Appendices B, C, and D. This allows the City to locate the inspection and testing records for each problem.

A summary of the costs broken down by each type of repair and the total cost to repair all the projects identified during this study can be seen below in Table 11. The total estimated cost is $7,438,940. However, it should be noted that many problems were identified adjacent to other problems. Some runs of pipe with numerous problems would be better suited for total line rehabilitation or replacement instead of individual repair projects. The areas that are candidates for pipe rehabilitation or replacement will be discussed further later in the report.

TABLE 11

Point Repair Project Costs

Point Repair Project Types	Project Description	Number of Problems	Estimated Cost	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

TABLE 11 – (continued)

Point Repair Project Costs

Point Repair Project Types	Project Description	Number of Problems	Estimated Cost	Total Cost
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 Cost				**$7,438,940**

POINT REPAIR PROJECT BENEFITS

A total of 847 problems were identified during this study with an estimated cost of over $7 million to repair all the problems. Because of the large number of problems and large total cost, problems should be repaired based on how much benefit their repair provides to the City. The benefits received for each problem identified varies often with the type of repair that was recommended. This report is an infiltration and inflow study, so I/I reduction will be the first focus. However, in addition to I/I we found a number of structural problems such as protruding side sewers, offset pipe joints, cracks in the pipe, or debris in the pipe or manholes. Depending on the severity of these structural problems, they have the potential to block sewer pipes and cause backups, surcharge events and overflow events.

Infiltration is previously defined as 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.

Inflow is previously defined as 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 flow monitoring that was performed to measure the I/I entering the sewer system is analyzed in depth in Appendix A. The analysis shows that both infiltration and inflow are problems in the City. Certain areas of the City exhibit more I/I than other areas. The areas that show signs of greater I/I generally tend to be older areas of the system with more concrete sewer pipe. However, infiltration and inflow are both city wide problems as seen in Table 12 which shows the I/I as measured at the WWTP.

TABLE 12

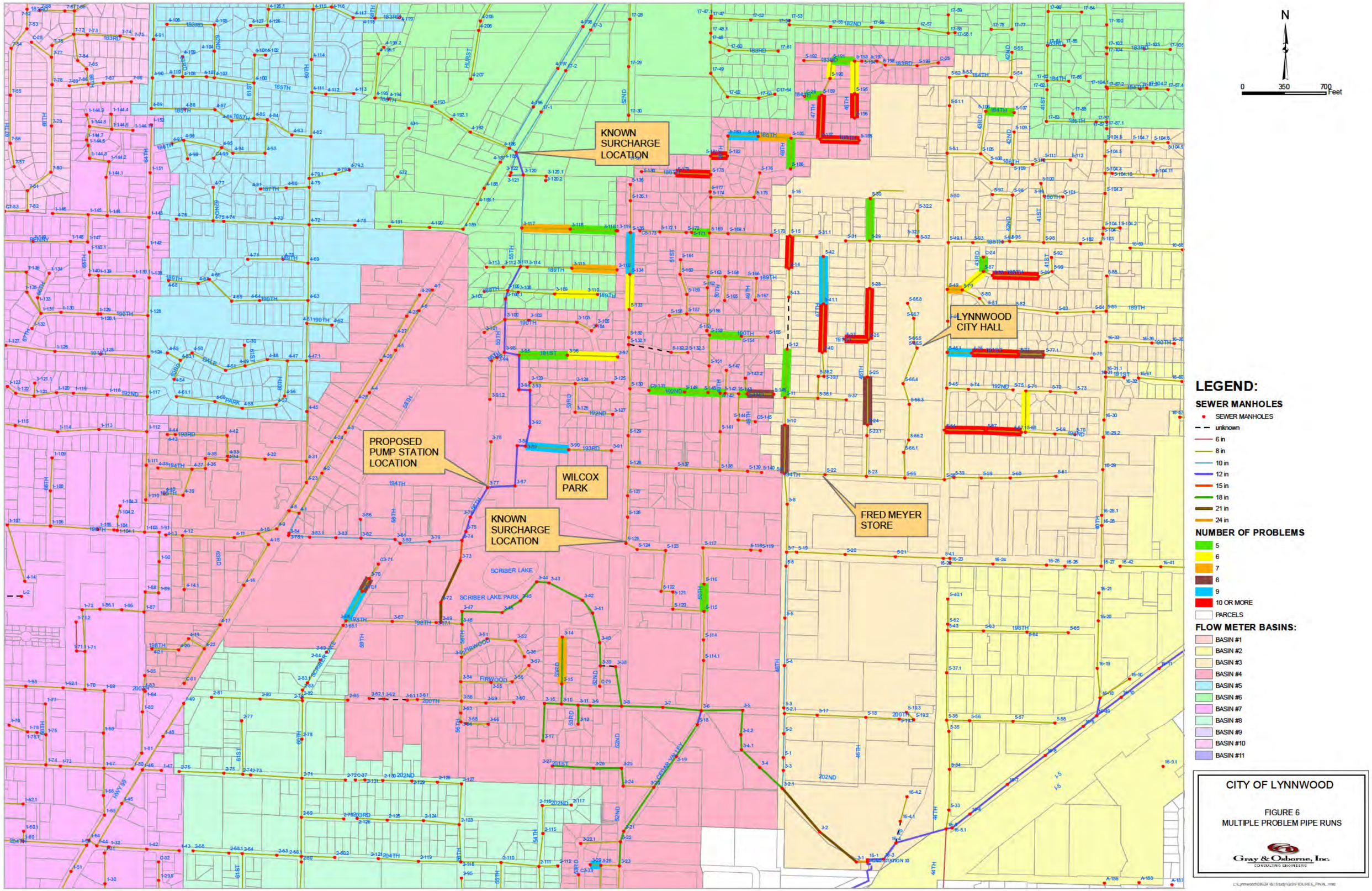
WWTP I/I Summary

Location	Peak Day Infiltration Rate (GPAD)	Peak Day Infiltration Rate (mgd)	Inflow Influenced Instantaneous I/I Rate (GPAD)	Inflow Influenced Instantaneous I/I Rate (mgd)
WWTP	879	5.36	2,459	15.00

The 2006 Wastewater Comprehensive Plan shows an average base sanitary sewer flow of 2.82 at the WWTP. As seen above in Table 13, the infiltration influenced I/I was measured at 5.36 mgd or an increase of 190 percent over the average base sanitary sewer flow. The inflow influenced I/I was measured at 15.00 mgd or an increase of 532 percent over the average base sanitary sewer flow.

MULTIPLE PROBLEM AREAS

Many of the 847 problems identified as a part of this study were located adjacent to other problems in the same run of sewer pipe. For example, one 348 foot length run of 8-inch concrete sewer pipe between Manholes 5-67 and 5-44 contained 19 separate problems. The location of each pipe runs containing five or more problems can be seen in Figure 6 and in Table 13 below. Specific information on each of the problems in the can be found in Appendix H.



CITY OF LYNNWOOD

FIGURE 6
MULTIPLE PROBLEM PIPE RUNS

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TABLE 13

Multiple Problem Pipe Runs

# of Problems	Upstream MH	Downstream MH	Location
Ten or More	5-15	5-14	48th Avenue West and 188th Street SW
	5-67	5-44	44th Avenue West and 192nd Street SW
	5-41.1	5-40	47th Avenue West and 188th Street SW
	5-196	5-195	46th Place West and 183rd Place SW
	5-189	5-187	47th Place West and 185th Place SW
	5-27	5-26	46th Avenue West and 191st Street SW
	5-67.1	5-67	44th Avenue West and 192nd Place SW
	5-89	5-88	41st Place West and 188th Street SW
	5-29.1	5-29	46th Avenue West and 188th Street SW
	5-179	5-178	186th Place West
	5-182	5-181	49th Place West and 185th Place SW
	5-76	5-77	44th Avenue West and 191st Street SW
	5-188	5-187	185th Place SW and 46th Place West
Nine	5-42	5-41.1	47th Avenue West and 188th Street SW
	5-76	5-46.1	44th Avenue West and 191st Street SW
	3-90	3-89	193rd Place SW
	5-28	5-29	46th Avenue West and 188th Street SW
	3-70.1	3-68	Scriber Lake Road
	5-135	5-134	52nd Avenue West and 189th Street SW
	5-184	5-183	49th Place West and 185th Place SW
Eight	3-70	3-70.1	Scriber Lake Road
	5-10	5-9	48th Avenue West and 194th Street SW
	5-25	5-24	46th Avenue West and 192nd Street SW
	5-146	5-143.1	192nd Street SW
	5-77.1	5-77	44th Avenue West and 191st Street SW
Seven	5-79	5-49	44th Avenue West and 189th Place SW
	3-14	3-15	53rd Avenue West and 200th Street SW
	3-118	3-117	188th Street SW and 55th Avenue West
	5-116	5-117	50th Avenue West and 196th Street SW
	5-185	5-184	48th Avenue West and 185th Place SW
Six	5-71	5-68	40th Avenue West and 192nd Street SW
	5-87	5-79	43rd Place West and 188th Place SW
	3-97	3-96	191st St SW
	5-28	5-26	46th Avenue West and 191st Street SW
	3-110	3-109	189th Place SW and 52nd Avenue W
	5-134	5-133	52nd Avenue West and 189th Street SW
	5-191	5-190	47th Place West and 183rd Place SW
	5-195	5-193	46th Place West and 183rd Place SW

TABLE 13 – (continued)

Multiple Problem Pipe Runs

# of Problems	Upstream MH	Downstream MH	Location
Five	5-87	C-24	43rd Place West and 188th Street SW
	3-96	3-95	191st Street SW
	5-11	5-12	48th Avenue West and 192nd Street SW
	5-30	5-29	46th Avenue West and 188th Street SW
	3-118	3-118.1	188th Street SW and 52nd Avenue West
	5-107	5-106	18427 42nd Place West, Lynnwood, WA
	5-115	5-116	50th Avenue West and 196th Street SW
	5-142.1	5-142	192nd Street SW
	5-143.1	5-143	192nd Street SW
	5-148	5-142	192nd Street SW
	5-149	5-148	192nd Street SW
	5-154	5-152	190th Street SW
	5-171	5-169	188th Street SW and 51st Place West
	5-185	5-186	48th Avenue West and 185th Place SW
	5-189 CO	5-189	184th Place SW and 47th Place West
	5-193	5-191	183rd Place SW and 46th Place West
	C5-131	5-149	5103 192nd Street SW, Lynnwood, WA

Of the 847 problems identified as a part of this study, 444 of them are located in the 55 runs of sewer pipe containing five or more problems as shown in Table 14. The point repair project types discussed earlier in the study repair only individual problems. The costs to repair all of the problems in a pipe run individually as separate point repair projects are summarized in Appendix H for each pipe run. At some point, the runs of pipe with multiple problems become better suited for total line rehabilitation or replacement instead of point repair projects.

METHODS OF PIPE REHABILITATION AND REPLACEMENT

The objective of sewer rehabilitation or replacement is to maintain the overall viability of a wastewater collection and conveyance system by ensuring its structural integrity, reducing excessive I/I, and limiting the potential for raw sewage overflows. Sewer rehabilitation can be achieved by a number of methods including in-place construction of linings or pipe grouting. In addition, pipe replacement can be performed by pipe bursting or open cut excavation. The method or rehabilitation or replacement will depend on the objectives.

Rehabilitation methods include the lining of existing pipes as well as grouting, leaky pipe joints. Rehabilitation methods generally cost less than conventional (open cut

excavation) replacement and involve less impact on the surrounding environment and public (i.e., open trench excavation, traffic disruption, public inconvenience, access restrictions to businesses, utility hazards, etc.). However, rehabilitation methods are generally not as effective in reducing I/I, providing structural integrity, and correcting problems of pipe grade as pipe replacement. Lining an existing pipe typically changes the pipe diameter size to reduce the flow area. Despite reductions in flow area, available capacity; however, can often be maintained because of reductions in I/I entering the system and reductions in existing internal pipe roughness. Lining existing pipes does not address hydraulic capacity problems and is not recommended where lines have significant pipe sags, offset joints or protruding laterals.

Sewer pipe replacement represents a proven method for increasing the structural integrity of the collection system, and in most cases, a way to significantly reduce I/I. If serious structural damage has occurred or differential settlement has affected sewer pipe grade, or the existing pipelines have exceeded their life expectancy (with signs of severe deterioration), replacement may be the only reasonable approach. Where pipelines are determined to be hydraulically overloaded and upgrade rehabilitation will not improve the flow condition, pipeline replacement is also recommended. However, replacement represents a more expensive method of sewer rehabilitation.

CURED-IN-PLACE PIPE (CIPP)

Cured-in-place pipe is a method of rehabilitation where a new pipe is formed within an existing pipe. A resin impregnated liner is inserted into the sewer segment from a manhole and extended to another manhole, expanded using a hydrostatic head of water to press the liner firmly against the existing host pipe. The liner is cured by heating the water to activate the resin and harden the liner pipe. This method can be used to line multiple sewer segments at once and the hardened liner is cut out of the intermediate manholes after the pipe has cured. Active side sewers are reconnected by remote controlled cutters in conjunction with TV inspection or by excavating the point of connection and externally reconnecting the lateral to the mainline pipe. This method of installation does not remove sources of infiltration from the side sewers tees or side sewer lines.

Pipe segments that are good candidates for this rehabilitation method should have little to no sags, no offset pipe joints, side sewer laterals intact with the mainline, and slope that provides a self-cleansing velocity of 2 fps. This method of rehabilitation is good for pipes with numerous cracks or holes. Before the liner is installed, the existing pipe interior wall surface must be prepped. Prepping involves cleaning the pipe interior, including removing any and all debris. In addition the existing pipe will need to be plugged upstream of the repaired pipe section and the flows bypassed. The diameter of the liner pipe is smaller than the existing pipe. However, the liner pipe is generally smoother than the existing pipe wall so the hydraulic capacity of the pipe is only reduced slightly.

FOLD AND FORM PIPE (FAFP)

Fold and form pipe rehabilitation is accomplished by using either folded PVC or HDPE pipe that is inserted into the pipe. Once inserted, the folded pipe is heated with steam to activate the liner material, expanding it to take the shape of the existing pipe. The liner is then allowed to cool and harden. After cooling, any lateral pipes are located, the liner cut with a TV robotic cutter, and the main line is placed back into service. Once again, this method of installation does not remove sources of infiltration from the side sewer tees or side sewer lines.

Pipe segments that are good candidates for this rehabilitation method should have little to no sags, no offset pipe joints, side sewer laterals intact with the mainline, and slope that provides a self-cleansing velocity of 2 fps. This method of rehabilitation is good for pipes with numerous cracks or holes. Before the liner is installed, the existing pipe interior wall surface must be prepped. Prepping involves cleaning the pipe interior, including removing any and all debris. In addition the existing pipe will need to be plugged upstream of the repaired pipe section and the flows bypassed. The thickness of the liner pipe is generally greater than that of CIPP resulting in a decrease in the hydraulic capacity of the new lined pipe.

PIPE GROUTING

Pipe grouting is a solution to prevent infiltration in structurally adequate sewer systems. It is the oldest pipeline rehabilitation process and was first developed and applied in 1955. A CCTV grouting machine is inserted into the sewer pipe and a bladder is expanded on both sides of the leaking pipe areas. Grouting chemicals are forced through cracks or joints extending out into the surrounding soil. The grout gels with the soil to form a waterproof collar around a leaking pipe. This watertight collar adheres to the outer surface of the pipe and will remain indefinitely unless removed by an excavation.

Pipe grouting has no structural properties capable of ensuring an effective seal where joints or circumferential cracking problems are due to ongoing settlement or shifting of the pipelines. Therefore, it is not effective to use pipe grouting to seal longitudinal cracks or to seal joints where the pipe near the joint is longitudinally cracked. Pipe grouting machines can also grout leaky side sewers including the connection to the mainline and several feet up the side sewer line. However, a separate machine is required to perform the side sewer grouting than the machine that performs the mainline grouting.

SLIPLINING

Sliplining is a rehabilitation method that inserts a new HDPE pipe inside a host pipe, creating a decrease in inside diameter. The annular space between the host and new pipe is backgrouted, providing additional structural capacity. Access to the host pipe is provided from the existing manhole and active laterals are reconnected to the mainline by an open cut excavation and installation using gasketed connections.

Advantages of sliplining are reduced surface disturbances and a short construction period when compared to pipe replacement by open cut excavation. Disadvantages of sliplining include a decrease in pipe diameter. Pipe segments that would be good candidates for this method should have little to no sags, side sewer laterals intact with the mainline, and excess capacity.

PIPE BURSTING

Pipe bursting is a semi-trenchless rehabilitation/replacement method capable of maintaining or increasing the diameter of the existing host pipe. The pipe bursting process also allows the upsize of lines without total excavation. Generally, the new pipe size is limited to an increase of one pipe size larger than the host pipe. Upsizing the pipe two pipe sizes is possible with good soil conditions. Pipe bursting is accomplished by pulling new pipe behind a 'bursting head." New manholes are typically provided at the insertion and withdrawal pits. The pipe bursting head is inserted from one pit and pulled through the host pipe by a winch, breaking the existing pipe ahead of the new pipe and forcing the ground outward to accommodate the new pipe, which is attached to the rear of the bursting head. Active laterals are individually excavated and reconnected to the new pipe. The head can be equipped with an expander that can further displace the host pipe fragments. The replacement pipe is usually standard diameter (SDR) 17 HDPE to protect against gouging during pipe installation; however, ductile iron, vitrified clay pipe, fusible PVC, and reinforced concrete pipe have also been used.

Prior to any bursting activity the existing line must be removed from service and bypass pumping provided. Side services should be excavated prior to bursting to allow for quick reconnection.

Sewer segments that are candidates for this method are in areas that require the benefits of minimal surface disturbance, increased hydraulic capacity, have silty-clay soil conditions, and an easily breakable host pipe such as concrete. While this method does replace the existing pipe, it is important to note that it will not eliminate sags or high points in the mainline. However, pipe bursting methods can "bridge" some small sags that may be present.

Difficult pipe bursting conditions are encountered in non-expansive soils that do not move well to accommodate the new pipe. However, when obstructions are encountered, the pipe generally deflects away from them. In severe cases, obstructions can cause the bursting head and new pipe to rotate, and can prevent forward movement. When this occurs, it is necessary to excavate the area and expose and remove the obstruction before the pipe bursting process can continue. This is also a good method for replacement of side sewer lines in poor condition with less surface restoration.

OPEN CUT

Pipe replacement by open cut excavation is the conventional method of replacing sewer pipes in past years. This method requires excavation and either removal of the existing sewer pipe and installation of a new pipe on the same alignment, or abandonment of the existing pipe and installation of a new sewer pipe along an alternate alignment. Surface restoration costs tend to be expensive, such as when the pipe is located in a paved roadway, and in general will cause more disruption to the area in terms of the number of working days to construct the work. In addition, this method can be expensive for deep excavations and where excessive groundwater is present.

Open cut methods of construction typically provide for better alignment and grade control, as well as better access to side service connections. Furthermore, when existing sewer segments are observed to have major sags and/or side sewer laterals have broken off in the mainline, this method becomes the preferred option. This is also a good method for replacement of side sewer lines in poor condition.

SUMMARY AND RECOMMENDATIONS

The purpose of this Infiltration and Inflow Study is to provide a prioritized listing of short-term and long-term recommendations to reduce I/I entering the City's sewer system. This includes recommendations for additional investigation, recommendations for sewer system rehabilitation and repair, including estimated project costs, and an analysis of the City's code.

Approximately 74 percent of the City's sewer system is constructed of concrete pipe installed in the 1960s and 1970s that is nearing the end of its lifespan. The majority of the problems identified by this study were found in the areas with concrete sewer pipe. Eliminating excessive I&I flow to the sanitary sewer system will not only decrease the frequency of sewer system back-ups, but will also increase system capacity and reduce wear and tear and operating costs at the lift stations and for equipment at the WWTP. Benefits will include both lower pumping costs along through the conveyance system and a lower peak hydraulic flow at the WWTP.

INVESTIGATIVE ACTIVITIES

The following section summarizes the I/I investigation that took place as part of this study and provides recommendations for additional I/I investigation activities. Because of the extent of the monitoring and inspection that were performed as a part of this study, little additional investigation activities are recommended until the City has repaired some of the problems identified in this study.

FLOW MONITORING

The purpose of flow monitoring is to locate and isolate the areas where infiltration/inflow exists for further examination and to eliminate from further investigation the portions of the sewer system that pose insignificant I/I problems. Flow monitoring was performed for the entire sewer system as part of this study. Although the flow monitoring did not capture results for the entire sewer system during the highest flow event, it did show that there is a system-wide I/I problem. In general, the flow monitoring showed that the older areas of the sewer system and the basins with more concrete pipe exhibited more I/I. These areas are where additional investigation was focused as part of this study and where any additional investigation should be focused in the future. We do not recommend any additional flow monitoring.

WWTP FLOWS AND PRECIPITATION

A new influent flow meter has recently been installed at the WWTP. The WWTP also includes a rain gage which records daily precipitation data. The WWTP flow data and daily precipitation should be observed to determine if I/I are being reduced as repairs and rehabilitation are completed.

TV INSPECTION

Based on the results of previous studies and the flow monitoring activities, specific sewer line reaches were selected for internal television inspection. Television inspection utilized a closed-circuit television camera to observe conditions within the sewer lines. Documentation of the internal inspection was recorded on a DVD for review and analysis and as a historical record. The inspection results of this study can be found on the DVDs in Appendix E. Approximately 64,100 lineal feet of sewer pipe, or 12.5 percent of the entire sewer system was TV inspected as part of this study.

We recommend that the City develop a TV inspection program that continues to inspect the remainder of the sewer system. Approximately 74 percent of the City's sewer system is concrete pipe which was installed in the 1960s and 1970s. Generally, concrete sewer pipe has an effective lifetime of approximately 50 years, so this older concrete pipe is nearing the end of its effective lifetime. Numerous problems were identified through the TV inspection and we expect that similar problems will be found in the remainder of the City's sewer system. There are a number of local firms that perform TV inspection and the cost for cleaning the sewer line and performing the TV inspection ranges from $2.00 to $2.50 per lineal foot of pipe. In addition, City staff have TV inspection equipment and the capability to perform the TV inspection themselves. A program should be developed to TV inspect a portion of the sewer system every year.

SMOKE TESTING

Smoke testing was performed to identify I/I sources by filling certain sewer sections with non-toxic smoke and pressurizing the line with an air blower. Locations where smoke exits the collection system identify potential sources of I/I. Smoke testing was specifically used to identify illicit connections to the sewer system. Approximately 106,500 lineal feet of sewer pipe, or 21 percent of the entire sewer system was smoke tested as part of this study.

This study identified numerous illicit connections of stormwater roof drains or yard drains connected to the sewer system. The majority of these connections were located on private property. These illicit stormwater connections were largest source of inflow entering the City's sewer system identified during this study. Smoke testing can be performed for an estimated cost of between $0.25 to $0.50 per lineal foot of sewer pipe. In addition, the smoke testing equipment can be purchased for a small cost.

We recommend that a program to smoke test the remainder of the sewer system be developed in conjunction with changes to or enforcement of City Code regarding illicit connections. Because the majority of the illicit connections are on private property, the smoke testing program will only prove useful for reducing inflow if City is prepared to take action when illicit connections are identified. A discussion of the City's code regarding illicit connections is discussed further in Appendix I.

MANHOLE INSPECTIONS

Manhole inspections were performed to identify I/I sources entering manholes. Manholes with problems observed during TV inspection and smoke testing, or from conversations with City staff were identified for a more thorough manhole inspection. We recommend that the City continue a manhole inspection program. Manholes showing I/I during additional TV inspection and smoke testing should be identified for a thorough manhole inspection by City staff.

SUMP PUMP INSPECTIONS

The City indicated early in this study that sump pumps are known to be connected to the sanitary sewer system. Sump pumps discharge groundwater or stormwater flows to the sanitary sewer system that can be discharged to the stormwater system. We believe a major component of the inflow entering the City's sanitary sewer system is from illicitly connected sump pumps. We attempted to locate the sump pumps through smoke testing, but were unable because a check valve is a standard piece of the sump pump connection. In addition, we tried to locate sump pumps through TV inspection side sewer launches, but did not positively identify any sump pumps.

We recommend the City develop a program to identify sump pumps through the use of City records or a survey or letter sent to homeowners or businesses. Positive responses

could be followed up with a dye test of the sump pump and visual inspection of the storm system and the sanitary sewer system for the dye. This work would require coordination with the private property owners. The sump pump inspections will only prove useful for reducing inflow if City is prepared to take action when illicit connections are identified. A discussion of the City's code regarding illicit connections is discussed further in Appendix I.

REPAIR AND REHABILITATION

A total of 847 problems were identified as a part of this study. Organizing the problems and providing recommendations for their repair or rehabilitation is a complex process. Some problems are best suited for point repairs. Other problems are better suited to be grouped together and repaired as part of an entire pipe run repair or rehabilitation. The City has indicated that their maintenance crew is ready to perform some of the repairs themselves. Certain problems are more appropriate for City staff to perform and others require more specialized expertise and equipment and would be better candidates for capital improvement projects. In addition, the benefits received for each type of repair or rehabilitation are different. Certain repairs remove I/I and others repair structural deficiencies.

I/I REMOVAL POINT REPAIRS

All the problems identified in this study were separated into one of the thirteen point repair project types. These point repairs project types including the estimated costs, materials, and project assumptions are seen in Appendix G. Appendix G also organizes each of the point repair projects by the severity of the problem.

Table 14 organizes and ranks the point repair projects types based on I/I removal. Inflow is the larger component of the I/I entering the City's sewer system, so projects which remove inflow receive a higher priority recommendation. Projects which remove infiltration are the next to be recommended. Projects with little or no I/I removal are the last to be recommended. The City should examine the benefits of each point repair type before proceeding with construction. Some of the point repair project types are on private property and right-of-entry may be necessary. In addition, the records included in the appendix for each individual repair should be examined before construction. Some variables for each project include the depth and size of the sewer line, the location of the project in or out of a major street thoroughfare.

TABLE 14

I/I Removal Point Repair Project Type Recommendations

Priority	Project Repair Type	Analysis
1	Storm Drain Piping	• Removes major source of inflow • Project is located on private property • Project can be performed by City staff or placed on homeowner
2	Cleanout Cap Repair	• Removes smaller source of inflow • Project may be located on private property • Easily performed project
3	Mainline Point Repair	• Removes source of infiltration or structural defect • Project is located in right-of-way or easement • Project can be performed by Ccity staff or a contractor as a public works/small works project • Project can be combined with other projects as part of a mainline repair/rehabilitation project
4	Side Sewer Tee Repair	• Removes source of infiltration or structural defect • Project is located in right-of-way or easement • Project can be performed by City staff or a contractor as a public works/small works project • Project can be combined with other projects as part of a mainline repair/rehabilitation project
5	Manhole Grouting	• Removes a source of infiltration • Project is located in right-of-way or easement • Project may be better performed by a specialized contractor as a public works/small works project
6	Side Sewer Point Repair	• Removes source of infiltration or structural defect • Project is potentially located on private property • Project can be performed by City staff or a contractor as a public works/small works project
7	Adjust Manhole Lid	• Removes source of infiltration or structural defect • Project is located in right-of-way or easement • Project can be performed by City staff or a contractor as a public works/small works project
8	Manhole Replacement	• Removes a structural defect • Project is located in right-of-way or easement • Project can be performed by City staff or a contractor as a public works/small works project

TABLE 14 – (continued)

I/I Removal Point Repair Project Type Recommendations

Priority	Project Repair Type	Analysis
9	Side Sewer Grinding	• Removes a structural defect and potential source of sewer backup • Project is located in right-of-way or easement • Project may be better performed by a specialized contractor as a public works/small works project
10	Root Removal	• Removes a potential source of sewer backup • Project is located in right-of-way or easement • Project may be better performed by a specialized contractor as a public works/small works project
11	Pipe Cleaning	• Removes a potential source of sewer backup • Project is located in right-of-way or easement • Project can be performed by City staff or a contractor as a public works/small works project
12	Manhole Cleaning	• Removes a potential source of sewer backup • Project is located in right-of-way or easement • Project can be performed by City staff or a contractor as a public works/small works project
13	Relay Sagging Pipe	• Removes a potential source of sewer backup • Project is located in right-of-way or easement • Project can be performed by City staff or a contractor as a public works/small works project • Project can be combined with other projects as part of a mainline repair/rehabilitation project

STRUCTURAL PROBLEM POINT REPAIRS

This report is an I/I study, so recommendations have focused on repairing problems which will remove inflow or infiltration from the sewer system. However, in addition to I/I problems, many problems with structural deficiencies were identified. The structural problems include broken pipe and joints, soil migration into the pipe, protruding side sewer pipes into the mainline, debris, and roots. The more severe structural problems decrease the capacity of the sewer system with the potential to cause surcharge or overflow events during periods of high sewer flow. In addition, the decreased capacity can create a location where debris can accumulate further reduceing capacity and potentially leading to complete pipe blockages. Table 15 includes some of the most severe structural problems with the greatest potential to cause surcharge or overflow events.

TABLE 15

Structural Point Repair Project Recommendations

Problem Number	Severity	Description	Project Type	Ref.	Estimated Cost
3-90-74	Severe	Medium infiltration at joint- medium mineral deposits at joint and pipe segment joint- pipe segment joint is broken- severe infiltration at main pipe segment joint	Mainline Point Repair	TV-42	$11,010
3-50-104	Heavy	Heavy circular crack- pipe broken; heavy infiltration	Mainline Point Repair	TV-11	$11,010
3-50-106	Heavy	Large longitudinal crack on each side of pipe; heavy infiltration	Mainline Point Repair	TV-12	$11,010
5-144-81	Heavy	Heavy mineral deposits	Mainline Point Repair	TV-102	$11,010
3-97-417	Heavy	Heavy break in pipe- medium infiltration	Mainline Point Repair	TV-131	$11,010
5-42-176.7	Heavy	Large hole in top of pipe- top of pipe caved in- mineral deposits and light infiltration through hole	Mainline Point Repair	TV-266	$11,010
5-39-85.2	Heavy	Heavy break in pipe- TV inspection abandoned	Mainline Point Repair	TV-291	$11,010
5-36.1-96	Heavy	Heavy debris in pipe- mineral deposits at joint- blocking flow if there is any- infiltration runner through deposits at joint	Mainline Point Repair	TV-293	$11,010
5-68-28.9	Heavy	Heavy break in pipe- appears to be hole in pipe at break- soil visible and infiltration through hole- may be due to a deflected joint	Mainline Point Repair	TV-328	$11,010
5-88-7.3	Heavy	Offset joint inside lateral- heavy infiltration through visible soil at offset joint	Mainline Point Repair	TV-402	$11,010
5-77.1-191.4	Heavy	Heavily grouted joint- survey abandoned	Mainline Point Repair	TV-415	$11,010
3-118-203	Heavy	Severely broken pipe, soil visible, circular and longitudinal cracks, pipe bottom is corroding with voids visible	Mainline Point Repair	TV-472	$11,010
5-171-0	Heavy	Circular crack with water spraying in; heavy solids in channel	Mainline Point Repair	TV-512	$11,010
5-195-250.2	Heavy	Severely broken pipe, soil visible, chunks of pipe missing, infiltration visible, void space behind pipe visible	Mainline Point Repair	TV-583	$11,010

TABLE 15 – (continued)

Structural Point Repair Project Recommendations

Problem Number	Severity	Description	Project Type	Ref.	Estimated Cost
5-191-3.0	Heavy	Circular crack, heavy mineral deposits, visible infiltration	Mainline Point Repair	TV-588	$11,010
5-189-237.5	Heavy	Offset broken connection, visible infiltration and gasket at joint	Mainline Point Repair	TV-601	$11,010
3-26-72.9	Medium	Side sewer protrudes into main.	Side Sewer Grinding	TV-451	$1,400
3-116-243.3	Medium	Side sewer protrudes into main.	Side Sewer Grinding	TV-476	$1,400
3-91-215	Heavy	Heavy roots at lateral joint	Root Removal	TV-39	$1,400
3-70.1-222	Heavy	Heavy root problem in lateral	Root Removal	TV-55	$1,400
3-70-90	Heavy	Heavy root problem in lateral	Root Removal	TV-62	$1,400
3-68-377	Heavy	Heavy root problem in lateral	Root Removal	TV-72	$1,400
5-66.3-295.2	Heavy	Root ball in pipe- blocking entire pipe- survey abandoned	Root Removal	TV-356	$1,400
2-84-29	Heavy	Heavy rock debris in pipe	Pipe Cleaning	TV-1	$950
3-50-273	Heavy	Heavy debris in pipe- blocking camera passage	Pipe Cleaning	TV-14	$950
5-50-125.6	Heavy	Heavy debris in pipe- perhaps rocks- disallowing camera to continue- survey abandoned	Pipe Cleaning	TV-370	$950
5-87-125	Heavy	Heavy rock debris in pipe- appears to be close to cleanout- survey abandoned	Pipe Cleaning	TV-375	$950
5-90-14.3	Heavy	Concrete debris- halts and redirects flow- survey abandoned	Pipe Cleaning	TV-387	$950
5-76-8.9	Heavy	Heavy debris	Pipe Cleaning	TV-656	$950
5-76-20.3	Heavy	Heavy rock debris	Pipe Cleaning	TV-657	$950
3-127-35	Heavy	Broken lateral joint	Side Sewer Tee Repair	TV-17	$11,580
5-26-233.4	Heavy	Heavy mineral deposits and debris at lateral joint- appears to be completely blocking potential flow- joint offset- light infiltration at joint	Side Sewer Tee Repair	TV-211	$11,580
5-25-10.7	Heavy	Heavy mineral deposits and light infiltration through lateral joint- joint may be offset or cracked- deposits severely blocking flow	Side Sewer Tee Repair	TV-213	$11,580
5-15-32.3	Heavy	Offset lateral joint and heavy mineral deposits in lateral	Side Sewer Tee Repair	TV-235	$11,580
5-11-179.4	Heavy	Heavy mineral deposits in lateral flow channel	Side Sewer Tee Repair	TV-257	$11,580