2023 INFLOW & INFILTRATION INVESTIGATIONS PROJECT

Preliminary Engineering Report

City of Manor
Public Works Department

SOW No. 22

GBA NO. 15333

April 24, 2023

FINAL REPORT

GBA

CITY OF MANOR EST. 1872 TEXAS

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Definitions and Abbreviations

CCTV	Closed-Circuit Television
CIPP	Cured-In-Place Pipe
City	City of Manor
DS	Downstream
DSMH	Downstream Manhole
FBS	Frame Base Seal
FL	Fracture Longitudinal
GBA	George Butler Associates, Inc.
GIS	Geographic Information System
GPM	Gallons Per Minute
I&I	Inflow and Infiltration
IR	Infiltration Runner
MCU	Miscellaneous Camera Under Water
MH	Manhole
MSA	Miscellaneous Survey Abandoned
MWLS	Miscellaneous Water Level Survey
PACP	Pipeline Assessment Certification Program
PVC	Polyvinyl Chloride
SSO	Sanitary Sewer Overflow
UMH	Unknown Manhole
US	Upstream
USMH	Upstream Manhole
VCP	Vitrified Clay Pipe

1 Project Background and Description

1.1 Introduction and Objectives

This Field Work Summary presents the results of the Inflow and Infiltration (I&I) Field Investigations Project performed for the City of Manor (City) by George Butler Associates, Inc. (GBA). The field investigations for this Work Order included manhole condition assessments, closed-circuit televising (CCTV), smoke testing, and dyed water testing of sanitary sewer lines within a specific area of the City. Additionally, flow monitoring was performed at 12 locations through the City for a contracted period of 90 days from September 1 through November 30, 2022, although meters were installed several days prior to the start date and remained installed through at least December 10th.

The objectives for this project are:

1. Check for pipe connectivity, structural defects, and potential sources of I&I in existing manholes and sanitary sewer lines within the specific neighborhoods selected to be investigated.
2. Collect flow and rainfall data and perform I&I analysis on the separated sanitary sewers in the City of Manor.
3. Use the data collection to update the City's GIS
4. Ensure accurate routing is documented

The ultimate goal for the City of Manor is to reduce the flows in its sanitary sewer system. The City has documented several instances of sanitary sewer overflows (SSO's) as well as concerns of residential sewer backups. The Pilot Areas identified for field investigations were systems of particular concern based on the results of previous flow monitoring performed in 2021.

1.2 Project Area

This project encompassed two project areas:

Area 1 – the entire City of Manor was studied by the installation of flow meters and rain gauges. This area is shown on Figure 1-1.

Area 2 – a specific subsection of the City specifically identified for in-depth Sanitary Sewer Evaluation Study (SSES) will be referred to as the "Pilot Area". This area is generally bound by Wedding Drive on the North, Old HWY-20 on the South, Beltex Drive on the East, and Skimmer Run on the West. This area is shown on Figure 1-2.

Both areas are made up of primarily residential neighborhoods as well as a limited amount of commercial development throughout the area. Most of the existing infrastructure was originally built between 1985 and 2005 and is comprised of 6 to 24 inch diameter, predominantly PVC, sewers. The general flow of the project area is from the outside northeast and southwest corners into the treatment plant located at the center of the City near E Parsons St and Llano St. The study area included facilities within the Wilbarger Creek watershed. However, wastewater collected from a portion of the Cottonwood watershed is pumped into the Wilbarger Creek watershed.

The City's Wilbarger Creek Wastewater Treatment Plant (WWTP) is located at 547 Llano Street. Reducing the amount of I&I in the project area will reduce the stress on this WWTP during wet weather events.

1.3 Project Background and Past Field Studies

The City of Manor has encountered high wastewater collection and treatment system flows during storm events and rainy periods. These high flows jeopardize the City's ability to meet permitted flow requirements at treatment plant facilities (excursions) and present potential for system spills (bypasses).

In the Fall of 2021, the City contracted with GBA to perform city-wide flow monitoring. The locations of 2021 flow meters are shown on Figure 1-3. That flow monitoring and subsequent analysis indicated several drainage basins in the City had particularly high I&I rates. Two of the basins metered in 2021 showed especially elevated levels of I&I (Sites 6 and 7) and as such were selected for further SSES investigations in this 2022 project. The City then engaged GBA to conduct this focused scope investigation with the purpose of identifying surface water inflow and ground water infiltration into the City's existing wastewater system in an effort to identify deficiencies contributing to high wastewater collection and treatment system flow conditions.

Figure 1-1 – Flow Monitoring Project Area

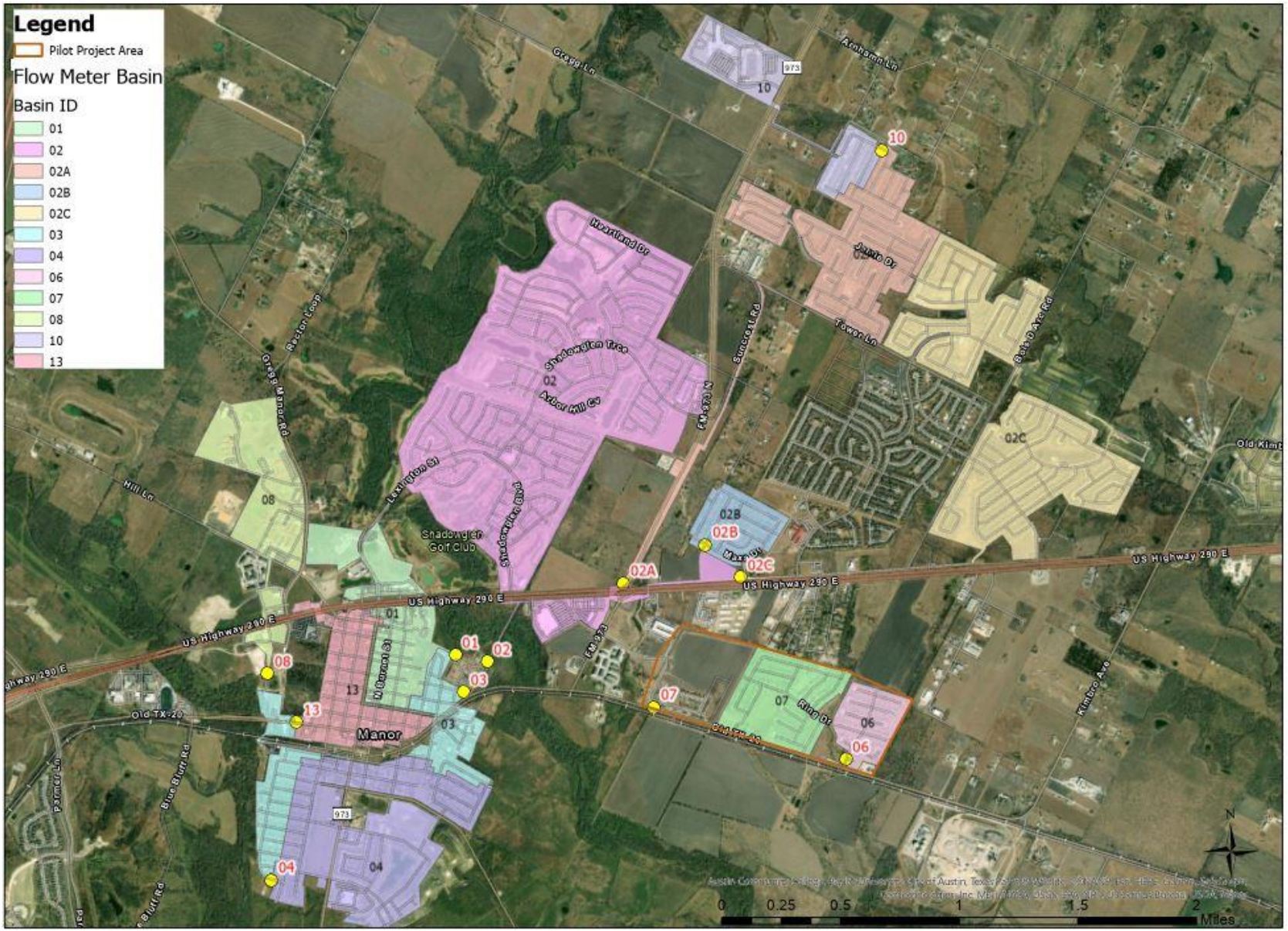
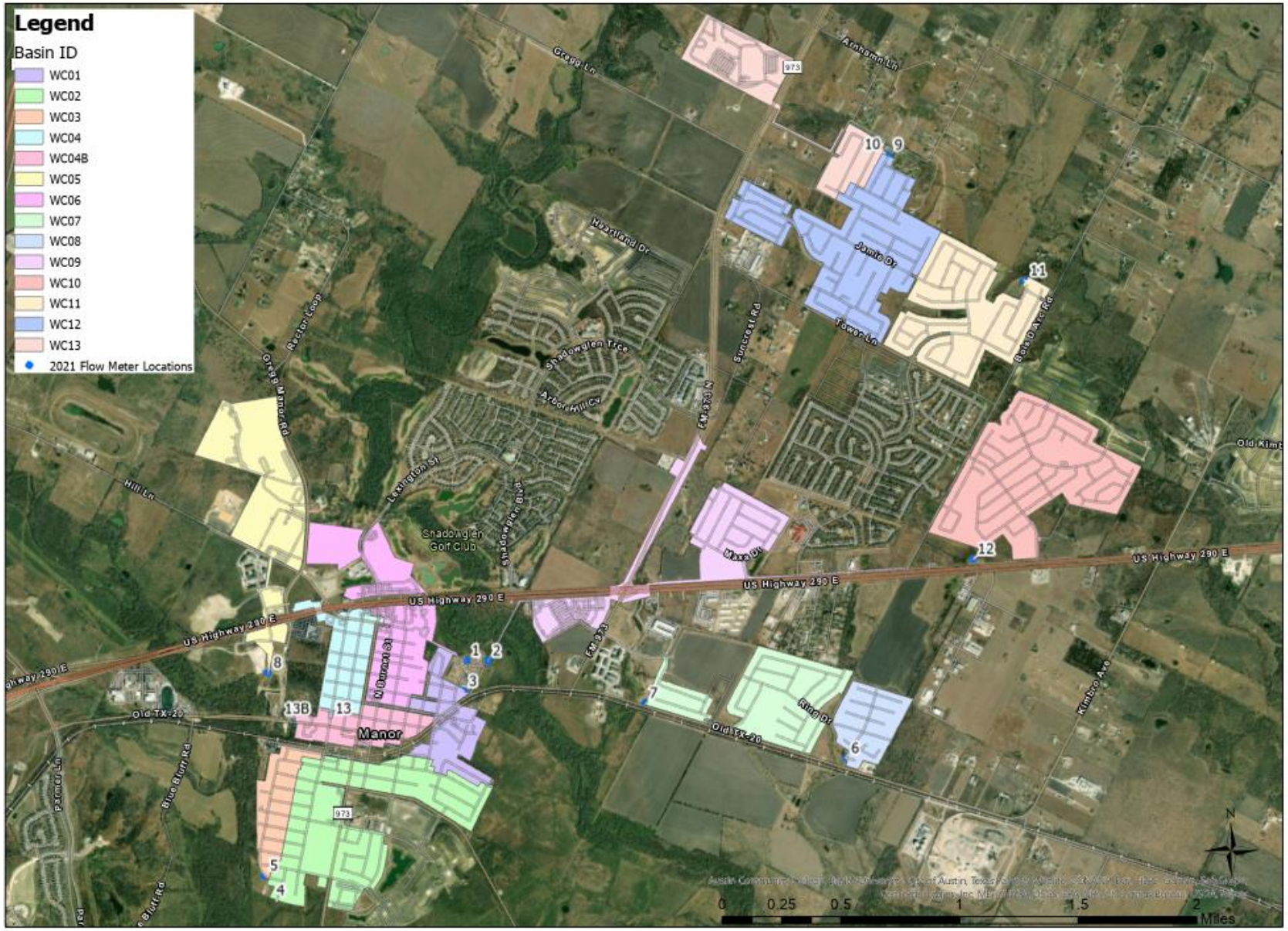


Figure 1-2 – SSES Pilot Area

Figure 1-3 – 2021 Flow Monitoring Locations



2 Flow and Rainfall Monitoring and Analysis

The 2021 flow monitoring period experienced very low rainfall levels. In order to perform more precise I&I analysis, it was decided to repeat the flow monitoring in 2022. The results from this repeat flow monitoring are summarized in the following sections.

2.1 Flow and Rainfall Monitoring

2.1.1 Metering Plan

The metering plan for the City of Manor, TX 2022 flow monitoring included 12 flow meter sites and 3 rain gauges. All of the flow meter locations are in the Wilbarger Creek Watershed.

Site investigations at monitoring sites were conducted prior to and during installation. All meter sites are listed in Table 2-1 and the rain gauges are listed in Table 2-2. The monitoring basins are shown on Figure 2-1. Figures 2-2 and 2-3 show more focused pictures of the meter sites and rain gauges.

2.1.2 Installation and Servicing of Meters

Installation of the 12 flow meters began on 8/21/2022 and was completed by 8/22/2022. A change from the 2021 flow monitoring, the basin which contributed to meter site 2 was broken up into three (3) smaller basins – 2A, 2B, and 2C in an effort to identify a more precise location for the significant I&I previously measured at Site 2 during the 2021 investigations.

The monitoring equipment was inspected and checked biweekly to download data and collect manual measurements for velocity and depth adjustments. The flow meters were synchronized to collect data on a 5-minute interval and on a concurrent basis. Flow monitoring was contracted to last for a 90-day period through the end of November, however meter removal did not take place until 12/16/2022. It was desired to capture rainfall that was anticipated at the beginning of December, so the meters were left in place until the 16th.

Rainfall monitoring was conducted at three locations that were selected to accurately represent the rainfall received in each meter basin. Rain gauge locations are listed in Table 1-2.

2.1.3 System Characteristics

Flow monitoring sites were selected to isolate areas in the system and establish basin flow characteristics. A basin inventory for each meter site including acreages, sewer footages tributary to the meter sites, and inch-diameter mile totals are listed in Table 2-3. A basin flow schematic diagram was created to represent the established basins. This schematic shows how meters and basins are inter-connected. The basin flow schematic is provided as Figure 2-4.

Table 2-1 – Flow Monitoring Site Summary

Meter ID	Manhole Number	Address	Metered Segment	Meter Basin	Pipe Diam (in)	Analysis Period Start	Analysis Period End	Equipment
1	N10-004	547 Llano St.	N10-005_N10-004	1	15	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
2	N11-003	546 Llano St.	N11-004_N11-003	2	24	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
2A	M12-034	12131 FM 973	M12-035_M12-034	2A	15	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
2B	M12-006	18001 Maxa Dr.	M12-006_M12-005	2B	10	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
2C	M12-013	13100 Greenbury Dr.	M12-014_M12-013	2C	15	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
3	O10-027	Gregg St.	O10-027_011-004	3	15	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
4	P09-034	11806 Athens St.	P09-035_P09-034	4	12	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
6	O13-007	13300 Prairie Sage Cv.	O13-007_O13-006	6	8	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
7	O12-003	Old TX-20	O12-004_O12-003	7	15	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
8	N09-001	11616 US HWY 290	N09-002_N09-001	8	12	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
10	I13-003	12002 Pyrite Rd.	I13-003_I13-003	10	12	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor
13	O09-007	409 Parsons St.	O09-007_O09-007	13	12	8/22/2022	12/16/2022	ISCO 2150 - A/V Sensor

Table 1-2 – Rain Gauge Summary

Rain Gauge ID	General Location
RG 1	Wilbarger Creek Sludge Processing Plant
RG 2	Wildhorse Creek Lift Station Site
RG 3	Stonewater North Lift Station Site

Figure 2-1 – Flow and Rainfall Monitoring Locations

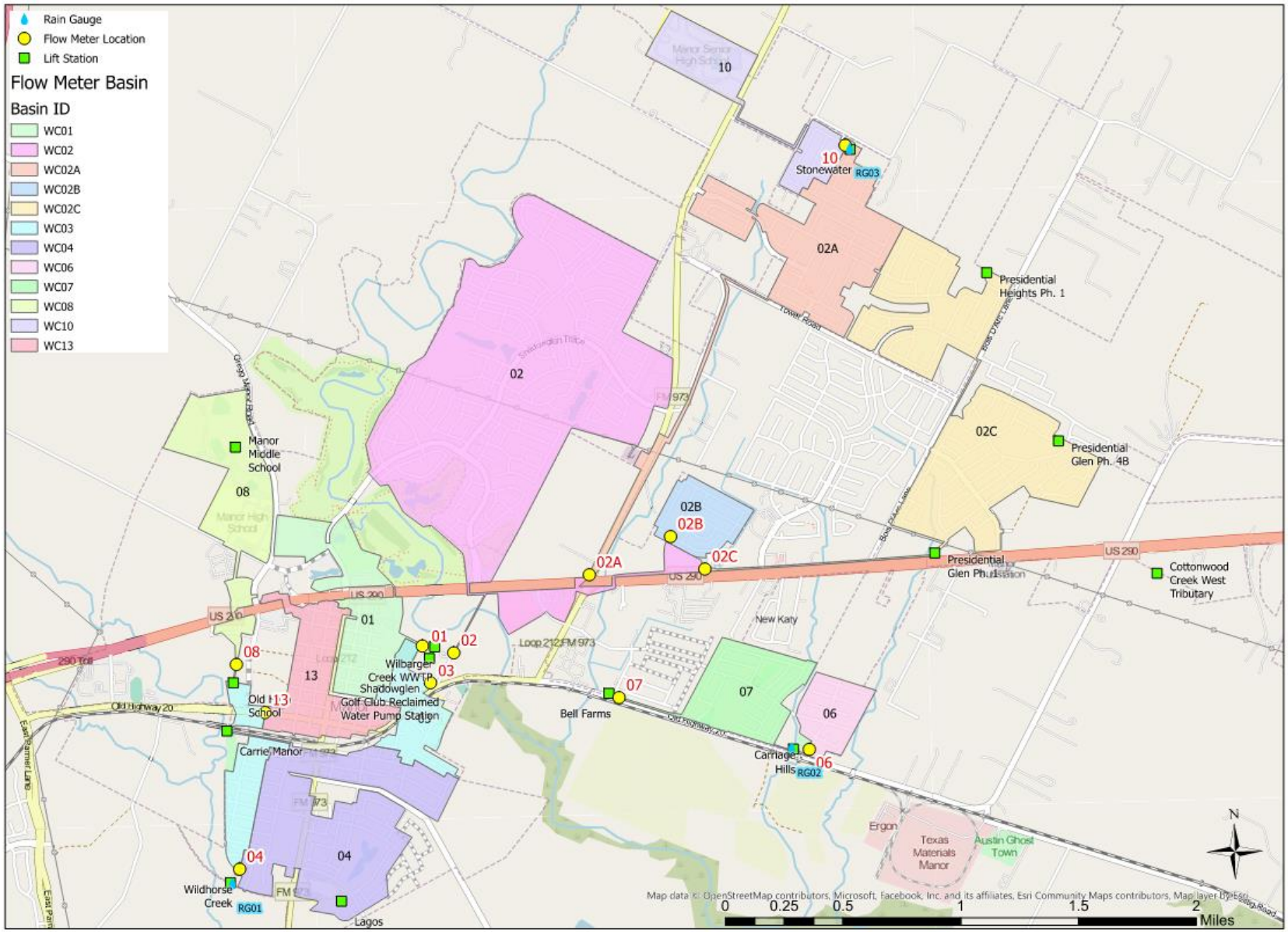


Figure 2-2 – Flow and Rainfall Monitoring Locations (Continued)

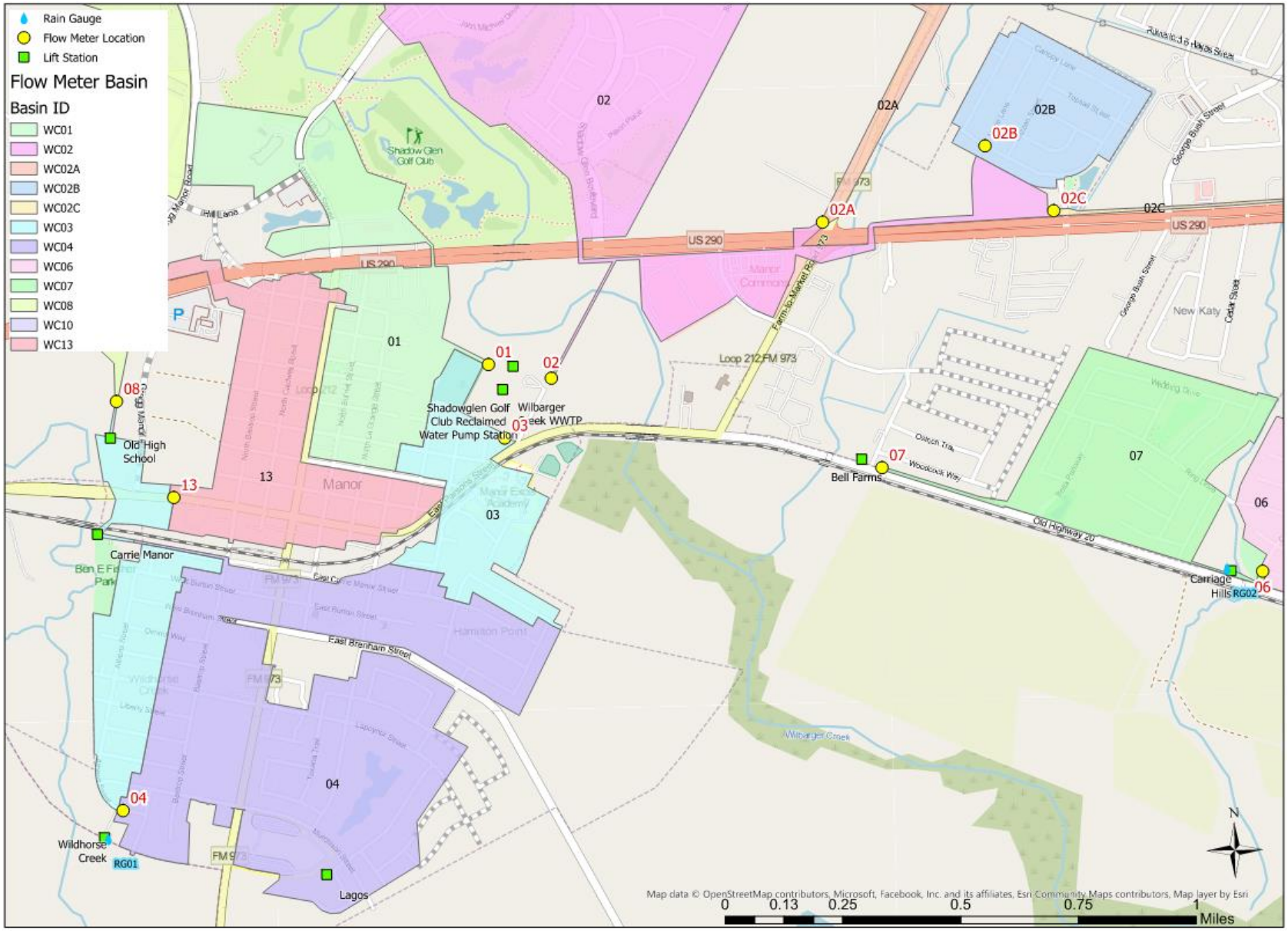


Figure 2-3 – Flow and Rainfall Monitoring Locations (Continued)

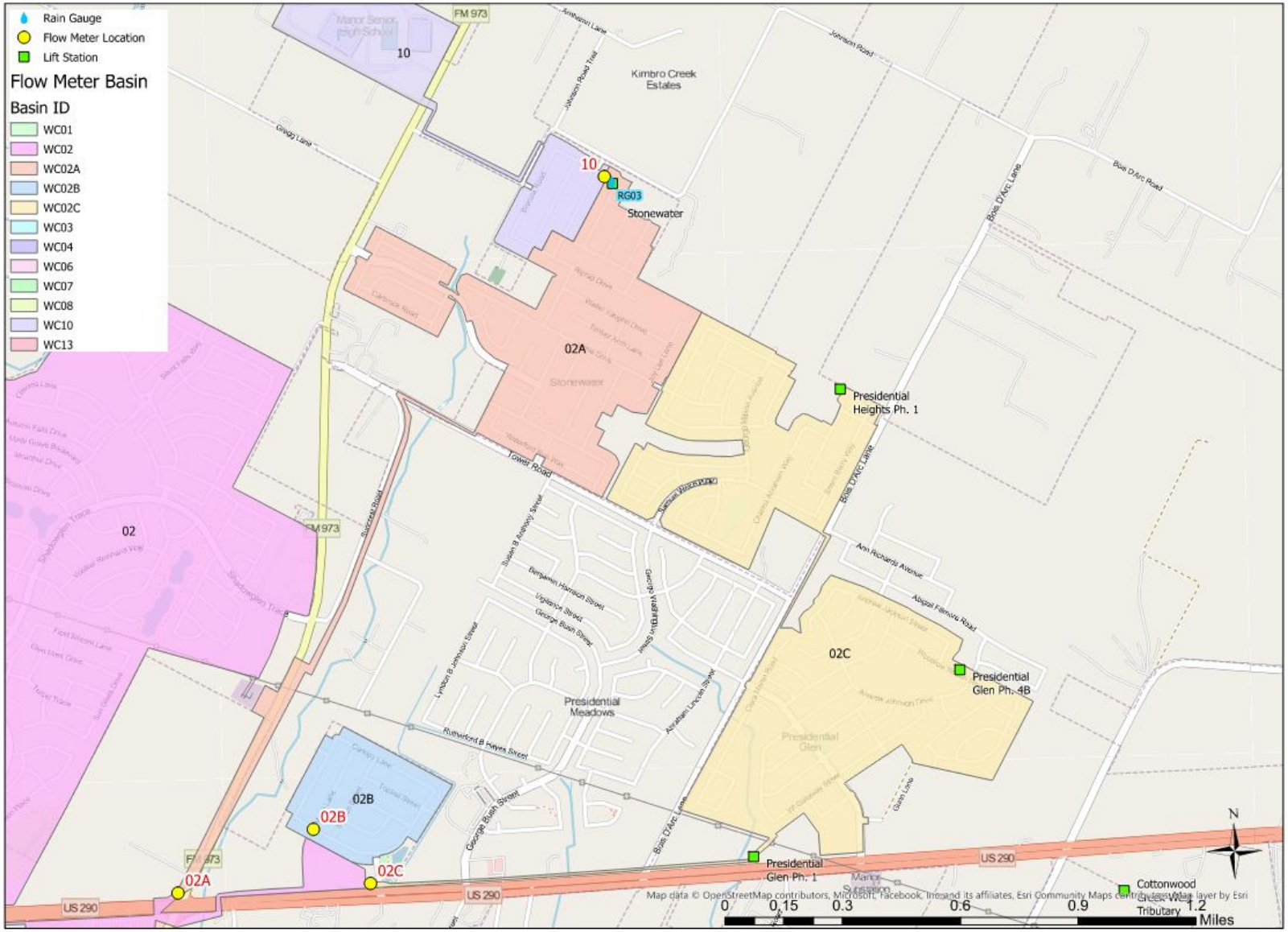


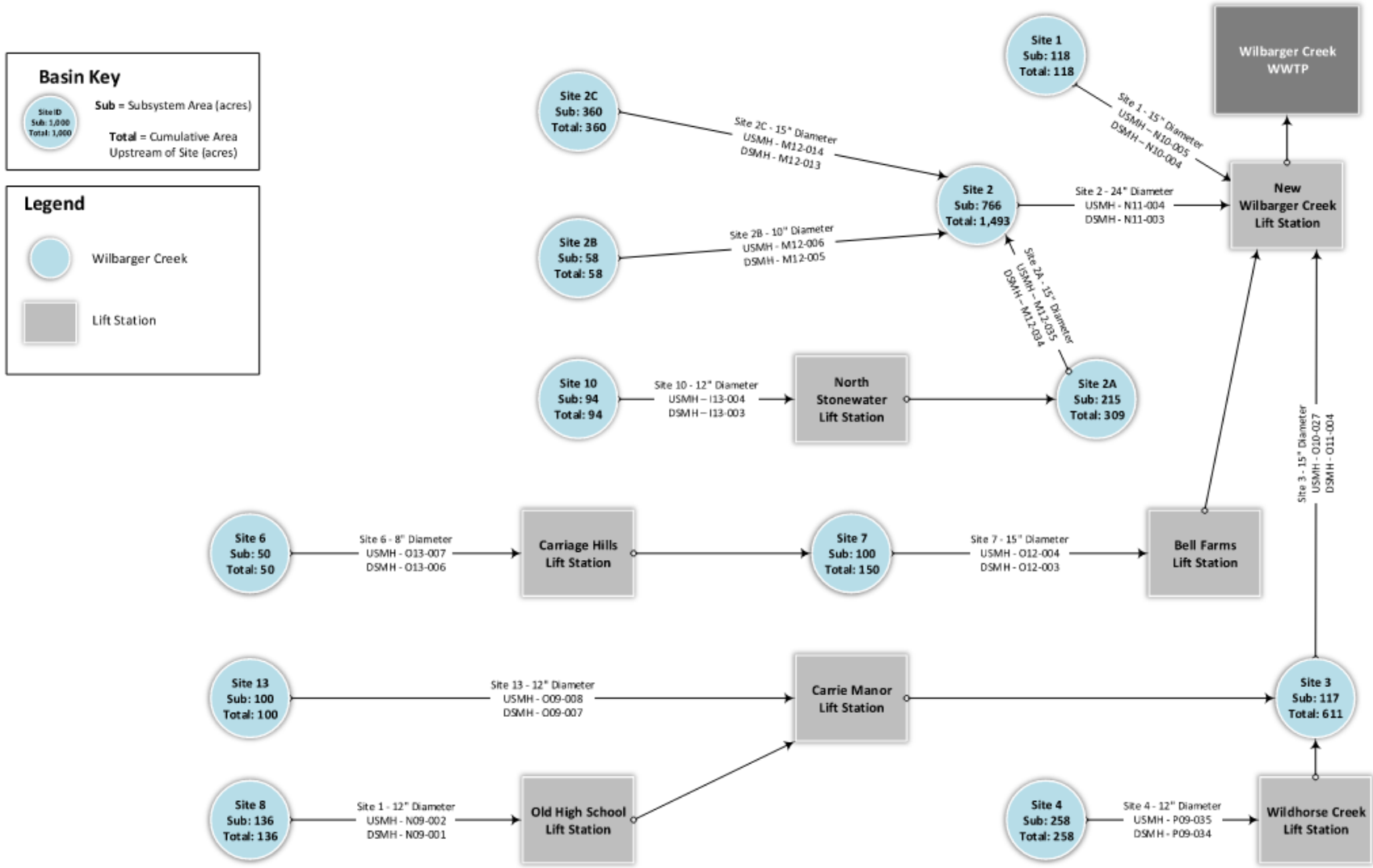
Table 2-3 – City of Manor Subsystem Characteristics

Site/ Subsystem	Subsystem Area (acres)	Cumulative Area (acres)	Subsystem Length (ft)	Cumulative Length (ft)	Subsystem IDM	Cumulative IDM
1-N10-004	118	118	16,668	16,668	27	27
2-N11-003	766	1,493	103,846	215,660	198	385
2A-M12-034	215	309	36,064	43,430	63	75
2B-M12-006	58	58	9,396	9,396	14	14
2C-M12-013	360	360	58,988	58,988	97	97
3-O10-027	117	611	22,230	87,886	36	131
4-P09-034	258	258	37,396	37,396	55	55
6-O13-007	50	50	8,913	8,913	14	14
7-O12-003	100	150	17,328	26,241	31	44
8-N09-001	136	136	10,672	10,672	18	18
10-I13-003	94	94	7,366	7,366	13	13
13-O09-007	100	100	17,588	17,588	23	23

Notes:

(1) IDM = inch-diameter miles, a benchmark used to quantify total amount of sanitary sewer pipe in each subsystem. It is cound by taking the product of the diameter in inces and multiplying it by the length in miles.

Figure 2-4 – City of Manor Subsystem Flow Diagram



2.2 Evaluation of Collected Data

2.2.1 Manual Field Measurements

Manual measurements for level and velocity were taken at the metering sites to compare to meter readings. The manual measurements were used to calibrate the flow monitoring data. Adjustments to level could be made in the field but adjustments to velocity were generally made in the office. Adjustments were made in the field only when excessive discrepancies were identified. The relative accuracy of the collected flow data can be evaluated by comparison of real-time flow meter readings and manually obtained flow-profiling data. These measurements have a generally accepted percentage error of 10%. This error is compounded under the following conditions: high velocity (3 feet per second (fps) and higher), low velocity (1 fps and lower), low flow level (less than 1 inch), or silting conditions in the pipe. Manual field measurements compared to meter readings are summarized for each flow monitoring site in Appendix A.

2.2.2 Mass Balance Checks

Mass balance checks were performed during flow monitoring as a quality assurance measure. These checks involved summing daily flows at each meter site throughout the monitoring period and comparing upstream to downstream base flows for connected meter sites. Daily volumes from flow meter data were calculated and summarized. The mass balance was conducted to provide assurance that recorded flows were acceptably accurate. A summary of the mass balance performed is provided in Table 2-4.

There were only a handful of days with negative mass balance results and most were attributed to meter malfunctions. Since subsystem calculations are performed by subtracting contributing flow meters from the cumulative meter in question, if the cumulative meter gets fouled and misses readings, the mass balance results in a negative value. There were no imbalances that raised concern for system routing or exfiltration during this project.

Table 2-4 – Mass Balance – All Meters

Date	Site 1 - Cumulative Flow Volume (MG)	Site 2 - Cumulative Flow Volume (MG)	Site 2 - Subystem Flow Volume (MG)	Site 2A - Cumulative Flow Volume (MG)	Site 2A - Subsystem Flow Volume (MG)	Site 2B- Cumulative Flow Volume (MG)	Site 2C- Cumulative Flow Volume (MG)	Site 3 - Cumulative Flow Volume (MG)	Site 3 - Subsystem Flow Volume (MG)	Site 4 - Cumulative Flow Volume (MG)	Site 6 - Cumulative Flow Volume (MG)	Site 7 - Cumulative Flow Volume (MG)	Site 7 - Subsystem Flow Volume (MG)	Site 8 - Cumulative Flow Volume (MG)	Site 10 - Cumulative Flow Volume (MG)	Site 13 - Cumulative Flow Volume (MG)	RG 1 Daily Total (in)	RG 2 Daily Total (in)	RG 3 Daily Total (in)	Average Rain Daily Total (in)
26-Aug-22	0.03	0.70	0.47	0.20	0.16	0.08		0.27	-0.11	0.12	0.05	0.22	0.17	0.08	0.03	0.02	0.00	0.00	0.00	0.00
27-Aug-22	0.03	0.77	0.49	0.21	0.18	0.07		0.60	0.39	0.12	0.06	0.24	0.17	0.06	0.03	0.03	0.00	0.00	0.00	0.00
28-Aug-22	0.03	0.79	0.46	0.25	0.22	0.08		0.79	0.55	0.14	0.07	0.25	0.19	0.07	0.03	0.03	0.00	0.00	0.00	0.00
29-Aug-22	0.02	0.70	0.36	0.25	0.21	0.09		0.76	0.53	0.13	0.05	0.23	0.17	0.07	0.04	0.03	0.00	0.00	0.00	0.00
30-Aug-22	0.02	0.67	0.38	0.22	0.18	0.07		0.63	0.40	0.13	0.06	0.25	0.19	0.07	0.03	0.03	0.00	0.03	0.03	0.01
31-Aug-22	0.03	0.74	0.44	0.25	0.22	0.05		0.56	0.33	0.13	0.06	0.27	0.21	0.07	0.03	0.03	0.00	0.14	0.02	0.03
1-Sep-22	0.03	0.80	0.48	0.27	0.24	0.05		0.56	0.32	0.14	0.06	0.27	0.20	0.08	0.03	0.03	0.00	0.00	0.02	0.01
2-Sep-22	0.03	0.78	0.48	0.24	0.22	0.05		0.52	0.28	0.14	0.07	0.26	0.19	0.08	0.03	0.02	0.00	0.00	0.00	0.00
3-Sep-22	0.04	0.82	0.50	0.26	0.24	0.06		0.54	0.29	0.14	0.07	0.26	0.19	0.08	0.02	0.03	0.00	0.02	0.02	0.01
4-Sep-22	0.04	0.84	0.49	0.29	0.26	0.06		0.51	0.28	0.13	0.06	0.24	0.18	0.07	0.02	0.02	0.00	0.02	0.02	0.01
5-Sep-22	0.03	0.95	0.58	0.30	0.28	0.07		0.53	0.28	0.14	0.07	0.24	0.18	0.07	0.03	0.03	0.00	0.01	0.00	0.00
6-Sep-22	0.03	0.85	0.51	0.28	0.24	0.06		0.56	0.30	0.14	0.06	0.23	0.17	0.09	0.04	0.03	0.00	0.00	0.00	0.00
7-Sep-22	0.03	0.87	0.53	0.27	0.21	0.08		0.58	0.32	0.15	0.06	0.26	0.20	0.09	0.06	0.03	0.00	0.08	0.12	0.05
8-Sep-22	0.04	0.92	0.46	0.37	0.32	0.09		0.57	0.31	0.14	0.07	0.44	0.37	0.10	0.05	0.02	0.00	0.00	0.00	0.00
9-Sep-22	0.03	0.81	0.42	0.24	0.19	0.07	0.15	0.50	0.25	0.14	0.09	0.30	0.22	0.09	0.05	0.02	0.00	0.00	0.00	0.00
10-Sep-22	0.01	0.88	0.46	0.19	0.15	0.08	0.14	0.48	0.25	0.14	0.08	0.28	0.19	0.07	0.04	0.02	0.00	0.00	0.00	0.00
11-Sep-22	0.04	0.97	0.52	0.19	0.15	0.10	0.17	0.48	0.24	0.15	0.07	0.27	0.20	0.07	0.04	0.02	0.00	0.00	0.00	0.00
12-Sep-22	0.03	0.91	0.51	0.16	0.11	0.11	0.14	0.49	0.25	0.14	0.05	0.24	0.19	0.08	0.04	0.02	0.00	0.00	0.00	0.00
13-Sep-22	0.04	0.87	0.46	0.17	0.12	0.10	0.14	0.41	0.19	0.13	0.06	0.22	0.16	0.08	0.05	0.02	0.00	0.00	0.00	0.00
14-Sep-22	0.03	0.76	0.30	0.22	0.16	0.10	0.14	0.42	0.18	0.13	0.05	0.22	0.17	0.09	0.06	0.02	0.00	0.00	0.00	0.00
15-Sep-22	0.03	0.80	0.32	0.22	0.18	0.10	0.15	0.39	0.16	0.13	0.05	0.21	0.16	0.08	0.05	0.02	0.00	0.00	0.00	0.00
16-Sep-22	0.04	0.81	0.32	0.22	0.17	0.10	0.16	0.44	0.20	0.14	0.05	0.21	0.16	0.08	0.05	0.02	0.00	0.00	0.00	0.00
17-Sep-22	0.04	0.91	0.38	0.24	0.19	0.10	0.18	0.44	0.16	0.15	0.07	0.24	0.17	0.09	0.05	0.03	0.00	0.00	0.00	0.00
18-Sep-22	0.04	0.96	0.38	0.26	0.21	0.10	0.21	0.40	0.16	0.16	0.08	0.25	0.17	0.07	0.05	0.02	0.00	0.00	0.00	0.00
19-Sep-22	0.04	0.87	0.36	0.24	0.19	0.08	0.18	0.41	0.15	0.15	0.06	0.23	0.17	0.09	0.06	0.02	0.00	0.00	0.00	0.00
20-Sep-22	0.04	0.86	0.36	0.23	0.16	0.08	0.18	0.40	0.14	0.16	0.06	0.22	0.16	0.08	0.07	0.02	0.00	0.00	0.00	0.00
21-Sep-22	0.04	0.84	0.36	0.22	0.17	0.08	0.18	0.40	0.14	0.16	0.07	0.23	0.17	0.08	0.05	0.02	0.00	0.00	0.00	0.00
22-Sep-22	0.05	0.84	0.37	0.21	0.16	0.09	0.18	0.41	0.16	0.15	0.06	0.23	0.17	0.08	0.05	0.02	0.00	0.00	0.00	0.00
23-Sep-22	0.04	0.83	0.35	0.22	0.17	0.08	0.18	0.37	0.11	0.16	0.06	0.22	0.16	0.08	0.05	0.02	0.00	0.00	0.00	0.00
24-Sep-22	0.04	0.85	0.40	0.15	0.09	0.09	0.21	0.37	0.11	0.17	0.06	0.24	0.18	0.07	0.06	0.02	0.00	0.00	0.00	0.00
25-Sep-22	0.04	0.93	0.22	0.39	0.32	0.10	0.23	0.39	0.12	0.17	0.01	0.26	0.24	0.07	0.06	0.02	0.00	0.00	0.00	0.00
26-Sep-22	0.03	0.90	0.30	0.32	0.26	0.09	0.19	0.39	0.13	0.16	0.01	0.24	0.23	0.08	0.06	0.02	0.00	0.00	0.00	0.00
27-Sep-22	0.03	0.76	0.31	0.22	0.16	0.09	0.14	0.39	0.14	0.15	0.01	0.23	0.22	0.07	0.05	0.02	0.00	0.00	0.00	0.00
28-Sep-22	0.04	0.70	0.27	0.21	0.15	0.07	0.15	0.39	0.15	0.16	0.04	0.23	0.19	0.07	0.06	0.02	0.00	0.00	0.00	0.00
29-Sep-22	0.04	0.80	0.37	0.18	0.12	0.06	0.19	0.37	0.13	0.15	0.06	0.23	0.17	0.07	0.06	0.02	0.00	0.00	0.00	0.00
30-Sep-22	0.05	0.86	0.48	0.13	0.06	0.06	0.19	0.39	0.13	0.16	0.06	0.23	0.16	0.07	0.07	0.02	0.00	0.00	0.00	0.00
1-Oct-22	0.04	0.92	0.44	0.21	0.15	0.06	0.21	0.37	0.10	0.18	0.06	0.24	0.18	0.05	0.06	0.03	0.00	0.00	0.00	0.00
2-Oct-22	0.05	0.91	0.37	0.24	0.16	0.07	0.23	0.40	0.12	0.20	0.07	0.26	0.20	0.06	0.08	0.03	0.00	0.00	0.00	0.00
3-Oct-22	0.06	0.92	0.47	0.18	0.12	0.07	0.21	0.42	0.14	0.19	0.05	0.24	0.19	0.06	0.06	0.03	0.00	0.00	0.00	0.00
4-Oct-22	0.08	0.74	0.28	0.20	0.14	0.06	0.20	0.38	0.13	0.16	0.06	0.24	0.18	0.07	0.06	0.03	0.00	0.00	0.00	0.00
5-Oct-22	0.09	0.76	0.28	0.22	0.15	0.06	0.20	0.38	0.12	0.16	0.05	0.24	0.19	0.06	0.07	0.03	0.00	0.00	0.00	0.00
6-Oct-22	0.08	0.75	0.27	0.22	0.16	0.06	0.20	0.30	0.06	0.15	0.06	0.24	0.18	0.06	0.06	0.03	0.00	0.00	0.00	0.00
7-Oct-22	0.08	0.80	0.32	0.22	0.16	0.06	0.21	0.43	0.18	0.16	0.06	0.22	0.16	0.06	0.06	0.03	0.00	0.00	0.00	0.00
8-Oct-22	0.08	0.87	0.36	0.23	0.17	0.06	0.22	0.40	0.14	0.18	0.05	0.23	0.18	0.06	0.07	0.03	0.00	0.00	0.00	0.00
9-Oct-22	0.07	0.87	0.31	0.25	0.18	0.06	0.25	0.36	0.09	0.17	0.06	0.23	0.17	0.06	0.08	0.03	0.00	0.00	0.00	0.00
10-Oct-22	0.05	0.84	0.28	0.25	0.17	0.06	0.25	0.41	0.13	0.19	0.06	0.25	0.19	0.06	0.07	0.03	0.00	0.00	0.00	0.00
11-Oct-22	0.05	0.83	0.33	0.22	0.15	0.06	0.22	0.33	0.04	0.18	0.05	0.24	0.19	0.08	0.08	0.03	0.00	0.00	0.00	0.00
12-Oct-22	0.05	0.77	0.32	0.18	0.13	0.06	0.21	0.33	0.05	0.18	0.05	0.24	0.19	0.08	0.05	0.03	0.00	0.00	0.00	0.00
13-Oct-22	0.05	0.78	0.34	0.19	0.13	0.06	0.20	0.38	0.10	0.18	0.05	0.23	0.18	0.07	0.05	0.03	0.00	0.00	0.00	0.00
14-Oct-22	0.05	0.75	0.31	0.19	0.12	0.06	0.20	0.35	0.08	0.17	0.05	0.23	0.18	0.08	0.07	0.03	0.00	0.00	0.00	0.00
15-Oct-22	0.05	0.83	0.31	0.23	0.16	0.06	0.22	0.28	0.00	0.18	0.06	0.26	0.20	0.07	0.07	0.03	0.00	0.00	0.00	0.00
16-Oct-22	0.04	0.89	0.31	0.25	0.19	0.07	0.26	0.34	0.06	0.19	0.08	0.26	0.18	0.07	0.06	0.03	0.00	0.03	0.07	0.03
17-Oct-22	0.05	1.00	0.33	0.29	0.19	0.08	0.30	0.51	0.11	0.21	0.10	0.49	0.40	0.11	0.10	0.08	0.07	0.05	0.07	0.05
18-Oct-22	0.04	0.94	0.38	0.26	0.20	0.06	0.24	0.34	0.07	0.16	0.09	0.36	0.27	0.08	0.06	0.03	0.00	0.00	0.00	0.00
19-Oct-22	0.05	0.83	0.27	0.28	0.22	0.06	0.22	0.34	0.08	0.17	0.08	0.28	0.20	0.06	0.06	0.03	0.00	0.00	0.00	0.00
20-Oct-22	0.04	0.81	0.28	0.25	0.19	0.06	0.23	0.35	0.10	0.17	0.08	0.27	0.19	0.06	0.06	0.03	0.00	0.00	0.00	0.00
21-Oct-22	0.06	0.79	0.29	0.23	0.19	0.06	0.21	0.33	0.05	0.17	0.08	0.26	0.18	0.08	0.04	0.03	0.00	0.00	0.00	0.00

Table 2-4 - Mass Balance – All Meters (Cont'd)

Date	Site 1 - Cumulative Flow Volume (MG)	Site 2 - Cumulative Flow Volume (MG)	Site 2 - Subsystem Flow Volume (MG)	Site 2A - Cumulative Flow Volume (MG)	Site 2A - Subsystem Flow Volume (MG)	Site 2B- Cumulative Flow Volume (MG)	Site 2C- Cumulative Flow Volume (MG)	Site 3 - Cumulative Flow Volume (MG)	Site 3 - Subsystem Flow Volume (MG)	Site 4 - Cumulative Flow Volume (MG)	Site 6 - Cumulative Flow Volume (MG)	Site 7 - Cumulative Flow Volume (MG)	Site 7 - Subsystem Flow Volume (MG)	Site 8 - Cumulative Flow Volume (MG)	Site 10 - Cumulative Flow Volume (MG)	Site 13 - Cumulative Flow Volume (MG)	RG 1 Daily Total (in)	RG 2 Daily Total (in)	RG 3 Daily Total (in)	Average Rain Daily Total (in)
22-Oct-22	0.06	0.87	0.34	0.25	0.18	0.06	0.22	0.33	0.07	0.17	0.08	0.27	0.19	0.06	0.06	0.03	0.00	0.00	0.00	0.00
23-Oct-22	0.07	0.94	0.39	0.24	0.17	0.07	0.24	0.36	0.09	0.17	0.10	0.30	0.20	0.07	0.07	0.03	0.00	0.00	0.00	0.00
24-Oct-22	0.07	0.89	0.36	0.24	0.18	0.06	0.23	0.47	0.18	0.17	0.08	0.28	0.20	0.08	0.07	0.04	0.00	0.06	0.09	0.05
25-Oct-22	0.05	0.90	0.36	0.27	0.19	0.06	0.22	0.43	0.14	0.17	0.08	0.31	0.24	0.08	0.08	0.04	0.82	0.00	0.00	0.27
26-Oct-22	0.06	0.88	0.32	0.28	0.22	0.06	0.22	0.38	0.12	0.16	0.08	0.29	0.20	0.08	0.06	0.03	0.00	0.00	0.00	0.00
27-Oct-22	0.06	0.86	0.33	0.26	0.20	0.06	0.21	0.34	0.09	0.16	0.08	0.26	0.19	0.06	0.06	0.03	0.00	0.00	0.00	0.00
28-Oct-22	0.07	0.95	0.34	0.29	0.23	0.06	0.25	0.44	0.14	0.16	0.09	0.38	0.30	0.08	0.06	0.06	0.04	0.04	0.03	0.03
29-Oct-22	0.07	0.98	0.36	0.30	0.26	0.06	0.26	0.37	0.11	0.16	0.11	0.40	0.29	0.06	0.05	0.03	0.01	0.00	0.00	0.00
30-Oct-22	0.06	0.98	0.36	0.28	0.19	0.07	0.27	0.37	0.12	0.16	0.11	0.34	0.23	0.06	0.09	0.03	0.00	0.00	0.00	0.00
31-Oct-22	0.06	0.85	0.30	0.25	0.16	0.06	0.23	0.35	0.10	0.15	0.09	0.29	0.20	0.07	0.09	0.03	0.00	0.00	0.00	0.00
1-Nov-22	0.06	0.84	0.31	0.24	0.16	0.06	0.23	0.29	0.05	0.15	0.08	0.23	0.15	0.06	0.07	0.02	0.03	0.01	0.02	0.01
2-Nov-22	0.06	0.92	0.45	0.21	0.14	0.05	0.21	0.31	0.08	0.15	0.07	0.23	0.16	0.06	0.07	0.02	0.01	0.00	0.00	0.00
3-Nov-22	0.06	0.92	0.44	0.22	0.15	0.06	0.20	0.33	0.08	0.15	0.07	0.28	0.21	0.08	0.07	0.02	0.00	0.00	0.00	0.00
4-Nov-22	0.07	0.90	0.40	0.23	0.15	0.06	0.21	0.39	0.11	0.17	0.08	0.29	0.21	0.07	0.08	0.03	0.00	0.08	0.05	0.04
5-Nov-22	0.06	0.90	0.30	0.29	0.22	0.07	0.25	0.41	0.13	0.18	0.11	0.43	0.33	0.07	0.07	0.04	0.68	0.00	0.00	0.23
6-Nov-22	0.06	0.56	-0.03	0.27	0.19	0.07	0.25	0.39	0.11	0.18	0.11	0.37	0.26	0.07	0.07	0.03	0.00	0.00	0.00	0.00
7-Nov-22	0.07	0.47	-0.18	0.30	0.21	0.07	0.27	0.51	0.17	0.19	0.12	0.47	0.35	0.09	0.10	0.06	0.05	0.07	0.06	0.04
8-Nov-22	0.07	0.65	0.05	0.28	0.20	0.07	0.25	0.44	0.14	0.18	0.13	0.48	0.34	0.08	0.08	0.04	0.00	0.06	0.07	0.03
9-Nov-22	0.08	1.41	0.78	0.28	0.20	0.08	0.27	0.46	0.14	0.19	0.13	0.53	0.40	0.08	0.08	0.05	0.11	0.00	0.00	0.04
10-Nov-22	0.08	1.10	0.57	0.24	0.18	0.06	0.23	0.41	0.12	0.18	0.13	0.41	0.27	0.08	0.06	0.03	0.00	0.00	0.00	0.00
11-Nov-22	0.06	1.06	0.48	0.24	0.17	0.07	0.26	0.54	0.21	0.19	0.12	0.42	0.30	0.08	0.07	0.06	0.03	0.03	0.03	0.02
12-Nov-22	0.08	1.10	0.50	0.24	0.18	0.08	0.28	0.52	0.22	0.18	0.16	0.53	0.37	0.08	0.07	0.04	0.03	0.00	0.00	0.01
13-Nov-22	0.06	0.93	0.35	0.23	0.16	0.07	0.28	0.47	0.19	0.18	0.14	0.39	0.25	0.07	0.07	0.03	0.00	0.00	0.00	0.00
14-Nov-22	0.05	0.47	-0.04	0.20	0.13	0.07	0.23	0.42	0.15	0.17	0.12	0.32	0.20	0.08	0.07	0.03	0.02	0.03	0.05	0.01
15-Nov-22	0.06	0.82	0.33	0.19	0.13	0.06	0.23	0.42	0.12	0.19	0.10	0.30	0.20	0.08	0.07	0.02	0.01	0.00	0.01	0.00
16-Nov-22	0.06	1.01	0.53	0.18	0.11	0.07	0.23	0.36	0.07	0.20	0.10	0.30	0.20	0.07	0.06	0.02	0.00	0.00	0.00	0.00
17-Nov-22	0.06	1.33	0.91	0.17	0.10	0.06	0.22	0.32	0.05	0.17	0.09	0.29	0.20	0.07	0.05	0.02	0.00	0.00	0.00	0.00
18-Nov-22	0.06	1.45	1.17		-0.05	0.06	0.22	0.35	0.11	0.15	0.09	0.29	0.20	0.06	0.05	0.02	0.01	0.01	0.00	0.00
19-Nov-22	0.06	1.59	1.27		-0.06	0.06	0.26	0.39	0.13	0.17	0.09	0.32	0.22	0.06	0.06	0.04	0.01	0.01	0.01	0.01
20-Nov-22	0.05	1.67	1.31		-0.06	0.07	0.28	0.38	0.11	0.17	0.10	0.37	0.27	0.07	0.06	0.03	0.01	0.00	0.01	0.00
21-Nov-22	0.06	1.65	1.32		-0.05	0.06	0.27	0.35	0.08	0.17	0.10	0.37	0.27	0.07	0.05	0.03	0.01	0.01	0.01	0.00
22-Nov-22	0.07	1.65	1.30		-0.06	0.07	0.28	0.38	0.10	0.17	0.11	0.43	0.32	0.06	0.06	0.04	0.00	0.00	0.00	0.00
23-Nov-22	0.06	1.65	1.31		-0.05	0.08	0.27	0.32	0.05	0.18	0.10	0.37	0.26	0.07	0.05	0.03	0.03	0.02	0.02	0.01
24-Nov-22	0.07	2.04	1.52	0.34	0.03	0.10	0.34	0.42	0.07	0.20	0.14	0.51	0.38	0.08	0.05	0.07	0.02	0.03	0.02	0.01
25-Nov-22	0.08	1.79	1.10	0.31	0.26	0.06	0.33	0.34	0.04	0.18	0.15	0.59	0.44	0.07	0.05	0.05	0.03	0.03	0.02	0.01
26-Nov-22	0.29	2.06	1.33	0.49	0.15	0.10	0.41	1.30	0.59	0.36	0.24	0.87	0.63	0.14	0.07	0.21	0.02	0.02	0.02	0.02
27-Nov-22	0.07	1.54	1.20		-0.06	0.05	0.29	0.35	0.06	0.18	0.16	0.58	0.43	0.06	0.06	0.04	0.00	0.00	0.00	0.00
28-Nov-22	0.06	1.33	1.00	0.41	0.00	0.06	0.22	0.42	0.14	0.18	0.12	0.42	0.30	0.07	0.05	0.03	0.00	0.00	0.00	0.00
29-Nov-22	0.05	1.14	0.89		-0.04	0.05	0.19	0.30	-0.74	0.95	0.11	0.35	0.25	0.06	0.04	0.03	0.00	0.00	0.00	0.00
30-Nov-22	0.05	1.20		0.14		0.05	0.16	0.30	0.02	0.19	0.09	0.34	0.25	0.06	0.05	0.02	0.00	0.00	0.00	0.00
1-Dec-22	0.05	1.31	0.97	0.12	0.06	0.05	0.17	0.38	0.15	0.14	0.08	0.33	0.25	0.06	0.06	0.02	0.00	0.00	0.00	0.00
2-Dec-22	0.05	1.48	1.13	0.12	0.06	0.05	0.17	0.36	0.12	0.15	0.07	0.31	0.24	0.06	0.06	0.03	0.01	0.01	0.01	0.00
3-Dec-22	0.08	1.71	1.29	0.17	0.11	0.06	0.19	0.34	0.10	0.16	0.07	0.35	0.29	0.05	0.06	0.03	0.00	0.00	0.00	0.00
4-Dec-22	0.07	1.81	1.34	0.19	-0.08	0.06	0.22	0.36	0.11	0.17	0.08	0.33	0.25	0.05	0.27	0.03	0.00	0.00	0.00	0.00
5-Dec-22	0.06	1.79	1.42	0.12	-0.02	0.06	0.18	0.36	0.12	0.16	0.08	0.32	0.24	0.05	0.14	0.03	0.00	0.00	0.00	0.00
6-Dec-22	0.07	1.84	1.49	0.13	-0.01	0.06	0.17	0.33	0.09	0.15	0.08	0.28	0.21	0.06	0.14	0.03	0.00	0.00	0.00	0.00
7-Dec-22	0.07	1.94	1.54	0.18	0.09	0.06	0.17	0.36	0.14	0.14	0.07	0.30	0.23	0.06	0.09	0.03	0.00	0.00	0.00	0.00
8-Dec-22	0.06	1.89	1.47	0.19	0.15	0.06	0.17	0.37	0.14	0.14	0.08	0.30	0.23	0.06	0.05	0.03	0.00	0.00	0.00	0.00
9-Dec-22	0.07	1.75	1.33	0.19	0.14	0.06	0.17	0.33	0.10	0.14	0.08	0.35	0.27	0.06	0.05	0.03	0.00	0.00	0.00	0.00
10-Dec-22	0.05	1.72	1.27	0.20	0.14	0.06	0.19	0.30	0.07	0.15	0.08	0.35	0.27	0.05	0.06	0.03	0.03	0.03	0.02	0.02
11-Dec-22	0.07	1.75	1.20	0.23	0.17	0.07	0.24	0.38	0.11	0.17	0.09	0.43	0.34	0.06	0.06	0.05	0.03	0.02	0.02	0.02
12-Dec-22	0.06	1.44	0.96	0.22	0.15	0.06	0.20	0.29	0.03	0.16	0.09	0.39	0.31	0.07	0.07	0.03	0.01	0.00	0.00	0.00
13-Dec-22	0.07	1.18	0.72	0.21	0.15	0.06	0.20	0.31	0.04	0.17	0.08	0.33	0.25	0.06	0.06	0.03	0.00	0.00	0.00	0.00
Dry Weather Average[(1)]	**0.05**	**1.04**	**0.57**	**0.23**	**0.14**	**0.07**	**0.22**	**0.42**	**0.14**	**0.17**	**0.08**	**0.31**	**0.23**	**0.07**	**0.06**	**0.03**				
Dry Weather Minimum[(1)]	**0.01**	**0.47**	**-0.32**	**0.12**	**-0.08**	**0.05**	**0.14**	**0.27**	**-0.74**	**0.12**	**0.01**	**0.21**	**0.14**	**0.05**	**0.02**	**0.02**				
Dry Weather Maximum[(1)]	**0.29**	**2.06**	**1.54**	**0.49**	**0.32**	**0.11**	**0.41**	**1.30**	**0.59**	**0.95**	**0.24**	**0.87**	**0.63**	**0.14**	**0.27**	**0.21**				
Wet Weather Average	**0.06**	**1.13**	**0.64**	**0.26**	**0.15**	**0.07**	**0.25**	**0.45**	**0.16**	**0.17**	**0.10**	**0.37**	**0.27**	**0.07**	**0.06**	**0.04**				
Average Negative Imbalance	**0.00**	**0.00**	**-0.12**	**0.00**	**-0.05**	**0.00**	**0.00**	**0.00**	**-0.19**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**				

Notes:
(1) Dry weather days exclude days with over 1/4" of rain and the day after.
Indicates incomplete data
Indicates rain event occurred
Indicates an imbalance in the system

2.3 Surcharge Conditions

Surcharge is the depth of water in a sewer that exceeds the top of the pipe. Surcharge occurred in 8 of the 12 sites during the 2022 flow monitoring period.

Surcharge conditions are less desirable than gravity flow conditions to measure peak flows in sanitary sewer systems. However, many of the recorded surcharge events provided high quality hydrographs and data for I&I volume measurements. A high quality hydrograph is one where direct correlation can be made between rainfall and increased flow in the sewer line that is being monitored. Maximum surcharge depth levels and duration of the surcharge was documented.

For each surcharge event, a backup or pressure flow designation was assigned. The backup designation means that the surcharge elevation is impacted by downstream capacity limitations and is demonstrated by significant slowing of velocities as depths are increasing. Pressure flow is when velocities are increasing as levels are rising. This indicates that downstream conditions are not restricting flow. Table 2-5 shows a comparison of surcharging recorded during the 2021 Flow Monitoring to surcharging during the 2022 Flow Monitoring. Four (4) of the sites monitored in 2022 did not surcharge in 2021 and are indicated by the NA in Table 2-5. A more detailed summary of surcharge recordings for each site for the 2022 Flow Monitoring are provided in Table 2-6 and shown on Figure 2-5.

Most of the surcharging was due to backing up from downstream restrictions. Several sites are just upstream of lift stations. Backups at sites near lift stations were also visually noted during wet weather and dry weather. The maximum dry weather surcharge caused by lift station backup was 85.65 inches at Site 4 This was suspected to be caused by backup at the Wildhorse Creek Lift Station. Site 10 also experienced a large surcharge of 76.72 inches which is suspected to be caused by the Stonewater Lift Station. These lift stations should be reviewed to determine if residents are or could be impacted by possible backup and overflows. The pump stations should also be examined to see if pumps are functioning properly (debris buildup and/or blockages), and that operational set points are correct so that the pipes do not surcharge during normal pump cycles. Other sites that surcharged were Sites 1, 2, 2A, 2C, 3, and 8. Four (4) of these sites (Sites 1, 2, 3, and 10) also surcharged during the 2021 flow monitoring conducted by GBA.

Table 2-5 – 2021 vs 2022 Surcharge Depths

Site	2021 Max Surcharge Depth (in)	2022 Max Surcharge Depth (in)
1-N10-004	42.63	24.76
2-N11-003	21.12	95.67
2A-M12-034	NA*	1.55
2C-M12-013	NA*	3.66
3-O10-027	9.74	16.13
4-P09-034	NA	85.65
8-N09-001	NA	37.38
10-I13-003	12.14	76.72

*Note: Sites not monitored in 2021.

Table 2-6 – 2022 Surcharge Summary

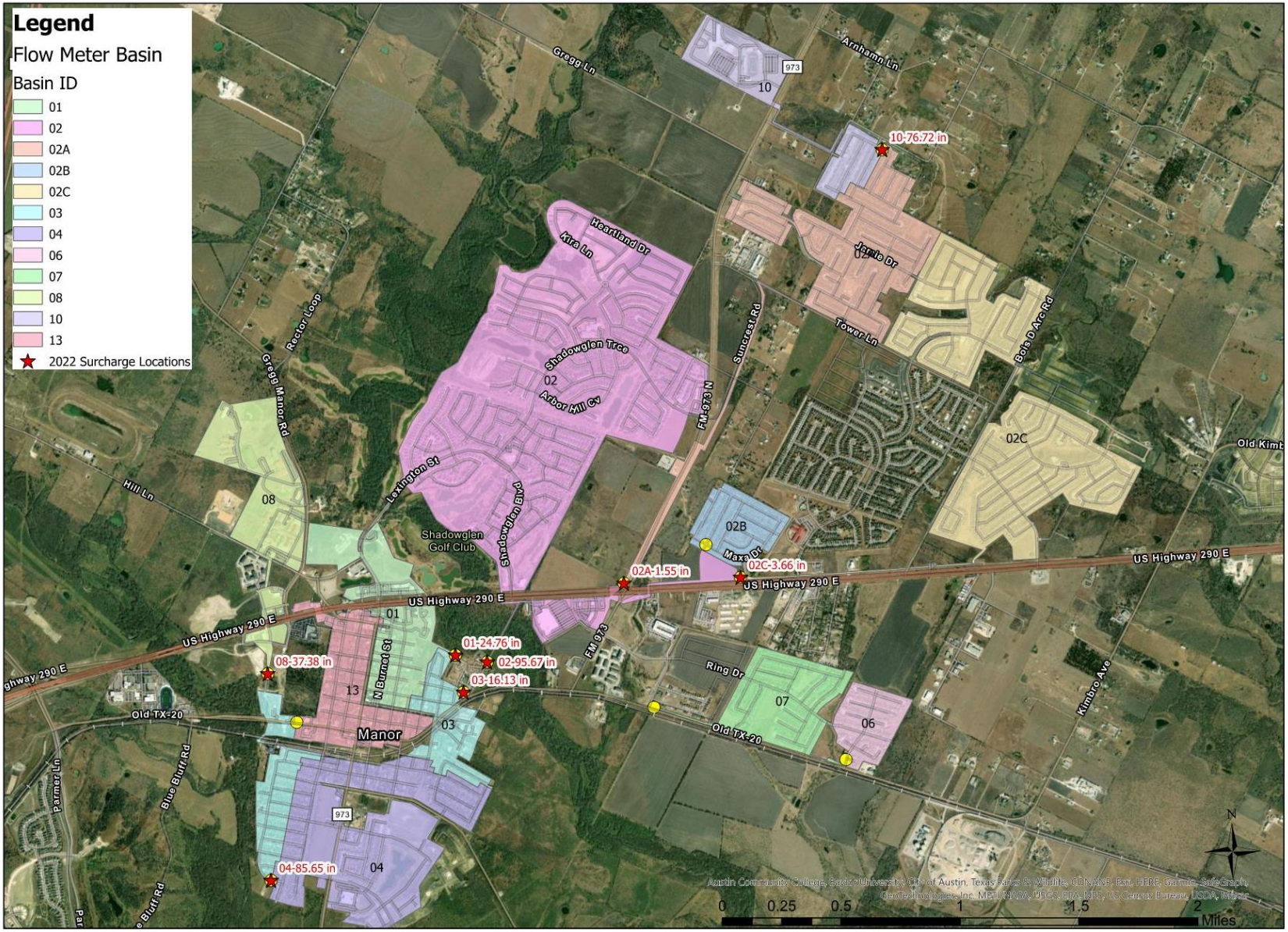
		Date of Storm	9/7/2022	9/17/2022	9/28/2022	11/7/2022	11/11/2023	11/25/2022	11/29/2023	12/4/2022
		Total Storm Rainfall (in.)	0.81	Dry Weather	Dry Weather	0.91	0.72	1.61	Dry Weather	Dry Weather
Site	Dia. (in.)	Storm Duration (hr)	3.42			2.00	11.17	15.17		
1-N10-004	15	Max Depth Value from Invert (in.)	-	-	-	-	-	39.76 (B)	-	-
		Level of Surcharge (in.)	-	-	-	-	-	24.76	-	-
		Surcharge Duration (hrs)	-	-	-	-	-	3.25	-	-
2-N11-003	24	Max Depth Value from Invert (in.)	-	-	-	24.37 (B)	-	119.67 (B)	-	-
		Level of Surcharge (in.)	-	-	-	0.37	-	95.67	-	-
		Surcharge Duration (hrs)	-	-	-	0.083	-	8.25	-	-
2A-M12-034	15	Max Depth Value from Invert (in.)	-	-	-	-	-	-	-	16.55 (P)
		Level of Surcharge (in.)	-	-	-	-	-	-	-	1.55
		Surcharge Duration (hrs)	-	-	-	-	-	-	-	0.083
2C-M12-013	15	Max Depth Value from Invert (in.)	-	-	18.66 (P)	-	-	-	-	-
		Level of Surcharge (in.)	-	-	3.66	-	-	-	-	-
		Surcharge Duration (hrs)	-	-	0.25	-	-	-	-	-
3-O10-027	15	Max Depth Value from Invert (in.)	-	-	-	15.61 (P)	-	31.13 (B)	15.62 (P)	-
		Level of Surcharge (in.)	-	-	-	0.61	-	16.13	0.62	-
		Surcharge Duration (hrs)	-	-	-	0.083	-	6.25	0.083	-
4-P09-034	12	Max Depth Value from Invert (in.)	-	-	-	-	-	-	97.65 (B)	-
		Level of Surcharge (in.)	-	-	-	-	-	-	85.65	-
		Surcharge Duration (hrs)	-	-	-	-	-	-	56.75	-
8-N09-001	12	Max Depth Value from Invert (in.)	-	49.38 (B)	-	-	19.52 (B)	-	-	-
		Level of Surcharge (in.)	-	37.38	-	-	7.52	-	-	-
		Surcharge Duration (hrs)	-	2.92	-	-	0.33	-	-	-
10-I13-003	12	Max Depth Value from Invert (in.)	17.48 (B)	-	-	-	-	-	-	88.72 (B)
		Level of Surcharge (in.)	5.48	-	-	-	-	-	-	76.72
		Surcharge Duration (hrs)	0.17	-	-	-	-	-	-	69.17

Notes:

(P) Denotes pressurized flow caused by lack of capacity (flow velocities generally increase as flow depths increase)

(B) Denotes flow backup caused by downstream restriction (flow velocities generally decrease as flow depths increase)

Figure 2-5 – 2022 Surcharging Summary



2.4 Flow and Rainfall Monitoring Data Analysis

This Fall 2022 flow monitoring collected data from 12 flow meter sites to isolate subsystems contributing sanitary sewer flow within the City of Manor, TX. The information gathered was used to:

- Analyze flow and rainfall monitoring data.
- Determine Average Daily Dry Weather Flow (ADDF).
- Determine high groundwater infiltration.
- Determine inflow.
- Conduct a volumetric analysis.

Detailed results for each flow monitoring site are provided in Appendix A.

2.4.1 Selection of Data for Analysis

The collected flow and rainfall data was reviewed for each monitoring site and representative days were selected for investigation of average dry weather flow (ADDF) periods, high groundwater infiltration flow periods, and peak storm inflow periods. Storms chosen for detailed flow analysis were selected based on high rainfall depths throughout the sub-systems. A number of factors were considered when selecting storm events for detailed analysis. These factors included:

- Total measured rainfall (typically greater than 0.20 in. but preferably at least 0.4 in.).
- Peak rainfall intensity (typically greater 0.30 in/hr).
- Consistent base flow before and after storm events (typically a period of three days before and after a storm).
- Flow monitoring data showed a measurable reaction (typically a peak flow measuring at least twice where the base flow would be).
- Interval between storm events (typically at least three days or enough time to allow flows to return to base flow levels).

2.4.2 Analysis of Rainfall Data

Historical rainfall data provided by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service was used as a point of comparison. The total annual average rainfall for the City of Manor is 36.33 inches. NOAA Atlas 14 Point Precipitation Frequency Estimates were referenced as well. A summary of the probability that a storm event with a particular recurrence interval will not be equaled or exceeded during a specified period is presented with historical data on average monthly rainfall amounts, total annual rainfall, and normal expected rainfall. Table 2-7 shows the historical rainfall depth-duration-frequency relationships.

Table 2-7 – Rainfall Depth-Duration-Frequency Relationship for City of Manor

Return Period (years)	Total Rainfall (in) for Duration Indicated					
	30 min	1 hr	2 hr	6 hr	12 hr	24 hr
1	1.3	1.6	2.0	2.5	2.8	3.2
2	1.5	2.0	2.4	3.2	3.6	4.1
5	1.9	2.5	3.1	4.1	4.7	5.4
10	2.2	2.9	3.7	5.1	5.8	6.7
25	2.6	3.5	4.6	6.5	7.5	8.6
50	3.0	4.0	5.4	7.7	8.9	10.2
100	3.4	4.6	6.2	9.1	10.6	12.1

Rainfall data for this project was collected from 3 rain gauge sites that were installed by GBA field crews. These gauges are considered representative of the project area and its basin tributary areas. Rain gauges 1 and 2 were averaged together to create a representative rain gauge that could be used to analyze sites 1-8 and 13. Site 10 was analyzed using the data from rain gauge 3. Table 2-8 shows the delineation of the percentages for each rain gauge per meter site.

Tables 2-9 and 2-10 provide summaries of the recorded storm events during the monitoring period at the rain gauges. The average total depth of rainfall recorded at the rain gauge sites during the monitoring period was 11.62 inches which is just slightly higher than to the expected average in the area of 11.52 inches for the monitored period based on the U.S. Climate Data and NOAA historical rainfall data. Monthly rain gauge totals are compared with expected monthly averages on Figure 2-6.

Table 2-8 – Weighted Rain Gauge Delineation

RG ID / Meter Basin ID	RG 1	RG 2	RG 3
1	50%	50%	
2	50%	50%	
2A	50%	50%	
2B	50%	50%	
2C	50%	50%	
3	50%	50%	
4	50%	50%	
6	50%	50%	
7	50%	50%	
8	50%	50%	
10			100%
13	50%	50%	

Table 2-9 – Rain Gauge 1 & 2 – Rainfall Summary

RG1 & RG2 - 13220 Old Hwy. 20/13220 Old Hwy. 20							
Date	Storm Time Start	Storm Duration (hr)	Time of Peak Rainfall	Total Storm Rainfall (in)	15 min Storm Intensity (in/hr) (1)	60 min Storm Intensity (in/hr) (1)	Return Interval (years)
8/30/22	8/30/22 10:25	7.58	8/30/22 10:40	0.32	0.48	0.26	< 1
8/31/22	8/31/22 17:40	0.25	8/31/22 17:45	0.55	1.96	0.55	< 1
9/3/22	9/3/22 15:40	1.58	9/3/22 15:50	0.24	0.48	0.20	< 1
9/4/22	9/4/22 23:00	4.00	9/5/22 3:00	0.03	0.08	0.02	< 1
9/7/22	9/7/22 19:00	3.42	9/7/22 19:10	0.81	2.20	0.74	< 1
10/16/22	10/16/22 23:05	11.92	10/17/22 0:20	2.30	1.36	0.98	< 1
10/24/22	10/24/22 21:40	2.33	10/25/22 0:00	0.68	1.64	0.41	< 1
10/28/22	10/28/22 0:00	11.08	10/28/22 8:40	0.86	1.36	0.71	< 1
10/29/22	10/29/22 0:00	0.00	10/29/22 11:55	0.01	0.02	0.01	< 1
11/1/22	11/1/22 0:00	1.08	11/1/22 1:05	0.05	0.06	0.03	< 1
11/2/22	11/2/22 12:00	0.00	11/2/22 23:55	0.01	0.02	0.01	< 1
11/4/22	11/4/22 15:00	9.00	11/5/22 0:00	0.69	1.36	0.35	< 1
11/7/22	11/7/22 8:50	2.00	11/7/22 9:35	0.91	1.60	0.82	< 1
11/8/22	11/8/22 20:00	16.00	11/9/22 0:00	0.31	0.66	0.19	< 1
11/11/22	11/11/22 12:50	11.17	11/11/22 16:30	0.72	0.74	0.33	< 1
11/14/22	11/14/22 13:00	11.00	11/14/22 15:00	0.17	0.18	0.08	< 1
11/18/22	11/18/22 20:10	0.25	11/18/22 20:25	0.01	0.02	0.01	< 1
11/19/22	11/19/22 9:10	9.67	11/19/22 13:10	0.34	0.16	0.10	< 1
11/20/22	11/20/22 22:50	23.00	11/21/22 16:50	0.26	0.08	0.05	< 1
11/23/22	11/23/22 22:45	21.00	11/24/22 16:30	0.66	0.64	0.34	< 1
11/25/22	11/25/22 16:00	15.17	11/25/22 23:55	1.61	1.42	0.64	< 1
12/2/22	12/2/22 0:25	6.92	12/2/22 7:20	0.08	0.04	0.02	< 1
12/10/22	12/10/22 7:55	17.00	12/10/22 23:35	0.48	0.60	0.35	< 1
12/12/22	12/12/22 3:25	0.00	12/12/22 15:20	0.01	0.02	0.01	< 1
12/14/22	12/14/22 6:10	1.42	12/14/22 7:35	0.02	0.04	0.01	< 1

Note: Red highlighted cells indicate storms with a Total Storm Rainfall greater than 0.4 inches.

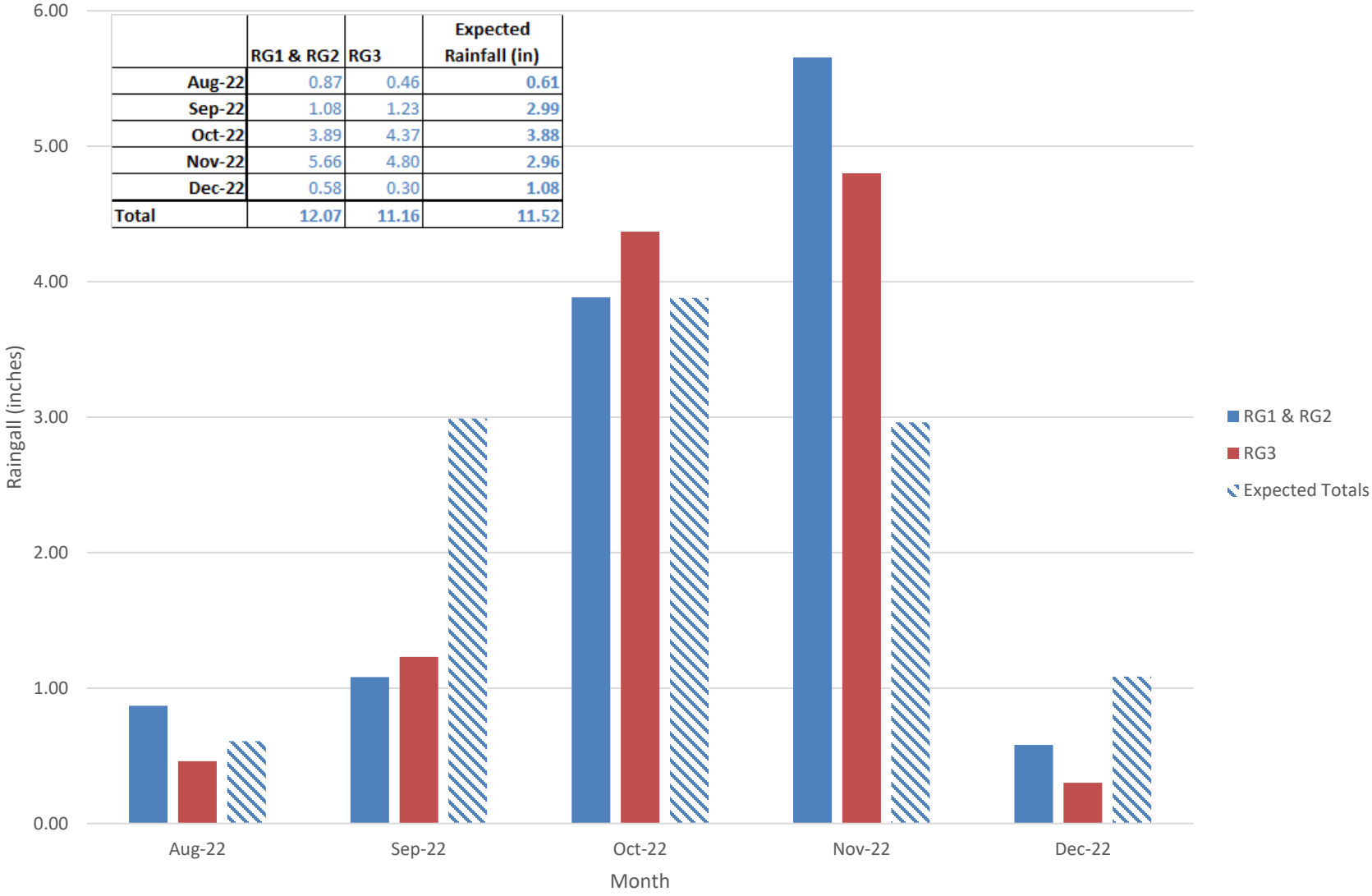
Table 2-10 – Rain Gauge 3 – Rainfall Summary

RG3 - 11957 Johnson Rd.							
Date	Storm Time Start	Storm Duration (hr)	Time of Peak Rainfall	Total Storm Rainfall (in)	15 min Storm Intensity (in/hr) (1)	60 min Storm Intensity (in/hr) (1)	Return Interval (years)
8/30/22	8/30/22 10:30	9.50	8/30/22 11:15	0.33	0.52	0.26	< 1
8/31/22	8/31/22 16:00	2.25	8/31/22 17:50	0.13	0.28	0.12	< 1
9/1/22	9/1/22 20:10	0.25	9/1/22 20:20	0.09	0.32	0.09	< 1
9/3/22	9/3/22 15:35	1.33	9/3/22 15:45	0.22	0.48	0.20	< 1
9/4/22	9/4/22 22:10	0.17	9/4/22 22:20	0.05	0.20	0.05	< 1
9/7/22	9/7/22 18:55	3.42	9/7/22 19:05	0.87	3.12	0.84	< 1
10/16/22	10/16/22 23:20	8.67	10/17/22 8:00	2.71	1.60	1.10	< 1
10/24/22	10/24/22 21:05	1.83	10/24/22 21:55	0.86	2.52	0.82	< 1
10/28/22	10/28/22 4:00	7.08	10/28/22 8:45	0.80	1.16	0.62	< 1
11/1/22	11/1/22 4:00	0.00	11/1/22 15:55	0.02	0.08	0.02	< 1
11/4/22	11/4/22 19:55	0.67	11/4/22 20:10	0.36	0.88	0.36	< 1
11/7/22	11/7/22 9:25	1.00	11/7/22 9:55	0.76	2.08	0.75	< 1
11/8/22	11/8/22 20:30	0.50	11/8/22 20:45	0.49	1.56	0.49	< 1
11/11/22	11/11/22 13:30	6.50	11/11/22 16:30	0.59	0.80	0.31	< 1
11/14/22	11/14/22 13:55	14.08	11/14/22 16:00	0.11	0.24	0.06	< 1
11/19/22	11/19/22 9:10	9.67	11/19/22 13:15	0.29	0.16	0.09	< 1
11/20/22	11/20/22 17:00	4.33	11/20/22 21:20	0.02	0.04	0.01	< 1
11/21/22	11/21/22 10:00	9.67	11/21/22 19:40	0.17	0.12	0.06	< 1
11/23/22	11/23/22 22:50	22.83	11/24/22 16:30	0.60	0.52	0.27	< 1
11/25/22	11/25/22 17:05	12.75	11/26/22 0:00	1.39	1.48	0.66	< 1
12/2/22	12/2/22 0:50	6.58	12/2/22 7:25	0.06	0.04	0.02	< 1
12/10/22	12/10/22 23:25	1.17	12/11/22 0:15	0.22	0.24	0.20	< 1
12/14/22	12/14/22 6:10	0.67	12/14/22 6:50	0.02	0.04	0.02	< 1

Note: Red highlighted cells indicate storms with a Total Storm Rainfall greater than 0.4 inches.

Figure 2-6 – Measured Versus Expected Monthly Average Rainfall

	RG1 & RG2	RG3	Expected Rainfall (in)
Aug-22	0.87	0.46	0.61
Sep-22	1.08	1.23	2.99
Oct-22	3.89	4.37	3.88
Nov-22	5.66	4.80	2.96
Dec-22	0.58	0.30	1.08
Total	12.07	11.16	11.52



Note: The months of August and December are pro-rated to represent partial months of measuring.

2.4.3 Average Daily Dry Weather Flow (ADDF)

Average Daily Dry Weather Flow (ADDF) is defined as the normal wastewater flow generated in the sanitary sewer system during dry weather conditions. This flow includes wastewater production and permanent infiltration naturally present during dry conditions with low groundwater levels. This flow does not include rainfall-induced infiltration and inflow. The ADDF rate can be measured directly during dry weather/low groundwater conditions. The instantaneous ADDF rate varies throughout each day with the highest rates normally observed near 8:00 a.m. and 10:00 p.m.

The ratio of peak instantaneous flow to ADDF is the ADDF peaking factor and is typically determined from representative flow data days. The best way to measure ADDF is in gallons per day per inch-diameter-mile (IDM) which creates an even comparison between basins, regardless of the length or diameters of sewers within them. A summary of ADDF for each subsystem is shown in Table 2-11.

Table 2-11 – ADDF Summary

Site/ Subsystem	Subsystem Area (acres)	Cumulative Area (acres)	Subsystem ADDF (mgd)	Cumulative ADDF (mgd)	Peaking Factor	Cumulative Peak ADDF	Subsystem ADDF Per Acre (gpd/acre)	Cumulative ADDF Per Acre (gpd/acre)	Subsystem ADDF Per IDM (gpd/IDM)	Cumulative ADDF Per IDM (gpd/IDM)
1	118	118	0.03	0.03	1.89	0.06	267	267	1,180	1,180
2	766	1,493	0.36	0.84	1.58	1.33	466	564	1,806	2,189
2A	215	309	0.15	0.20	1.73	0.35	702	657	2,407	2,699
2B	58	58	0.06	0.06	1.64	0.10	1,018	1,018	4,112	4,112
2C	360	360	0.22	0.22	1.74	0.39	620	620	2,289	2,289
3	117	611	0.13	0.35	1.67	0.59	1,149	572	3,760	2,662
4	258	258	0.14	0.14	1.41	0.19	531	531	2,502	2,502
6	50	50	0.06	0.06	1.82	0.11	1,158	1,158	4,287	4,287
7	100	150	0.17	0.22	1.44	0.32	1,670	1,499	5,431	5,082
8	136	136	0.06	0.06	1.43	0.08	411	411	3,096	3,096
10	94	94	0.05	0.05	1.58	0.08	554	554	4,159	4,159
13	100	100	0.02	0.02	1.71	0.04	223	223	979	979

Notes:

(1) Cumulative Peak ADDF is the product of the Cumulative ADDF and the ADDF Peaking Factor.

2.4.4 Infiltration

Infiltration is defined as flows entering the wastewater collection system through defects below ground such as defective pipes, pipe joints, and manholes. The rate of infiltration depends on the depth of groundwater above the defects, as well as the percentage of the collection system below the groundwater table. The variation in groundwater levels and subsequent infiltration is seasonal and weather dependent. Since the groundwater levels are normally a relative constant over periods of several days, the peak infiltration can be considered as the maximum infiltration, which occurs during the maximum groundwater period of the year. To determine high groundwater infiltration, flow data from the day following significant storm events were analyzed.

The hydrographs were examined to verify inflow had subsided. If inflow had not subsided, the flow from the next day was used to determine infiltration. The total flow measured during these infiltration periods included ADDF plus infiltration flow. Infiltration flow was determined by subtracting the ADDF from the total flow measured during the infiltration periods. Night flow readings were used for the analysis since the least temporal variation in base flow occurs during this period. Infiltration is calculated by subtracting the minimum three-hour flow during the ADDF week from the minimum three-hour flow during an infiltration day.

Some common inflow and infiltration source examples are shown on Figure 2-7. The difference between ADDF, inflow, and infiltration is further demonstrated graphically on Figure 2-8.

The infiltration parameters are shown for each subsystem for the flow monitoring period in Table 2-12 and Figure 2-9. Subsystems with excessive infiltration were based on an infiltration rate above 2,500 gpd/IDM. The 2,500 gpd/IDM threshold is based on GBA's historical flow monitoring observations and experience as well as guidelines set forth by the EPA. Two (2) subsystems – Basins 6 and 7 – indicated having excessive infiltration based on an infiltration rate above the 2,500 gpd/IDM for the monitoring period. Coincidentally, these basins also had excessive infiltration rates during the 2021 Fall flow monitoring, and due to this were selected as the "pilot" study areas for this 2022 project.

Figure 2-7 – Inflow and Infiltration Sources

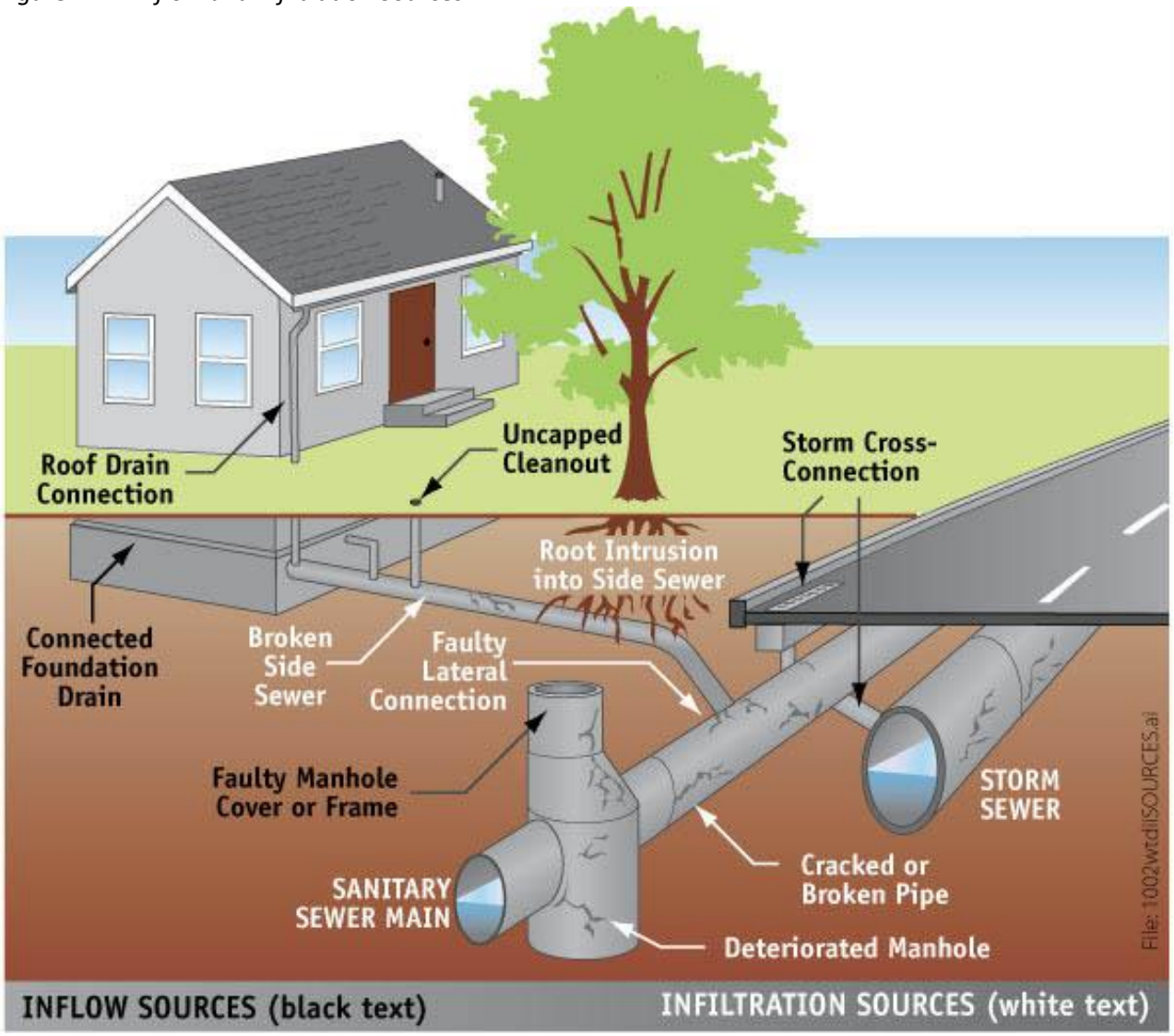


Figure 2-8 – Graphical Illustration of I&I Components

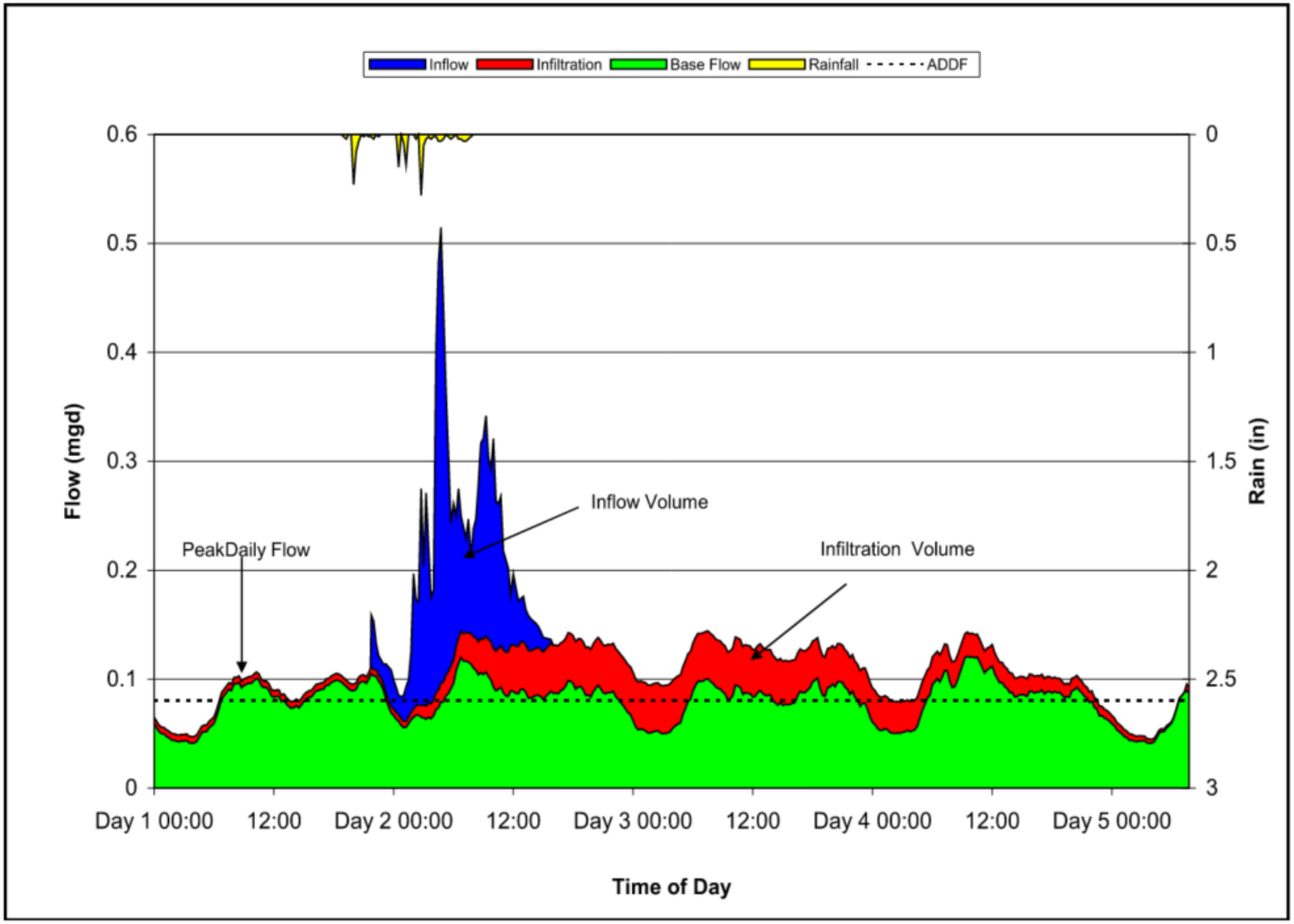


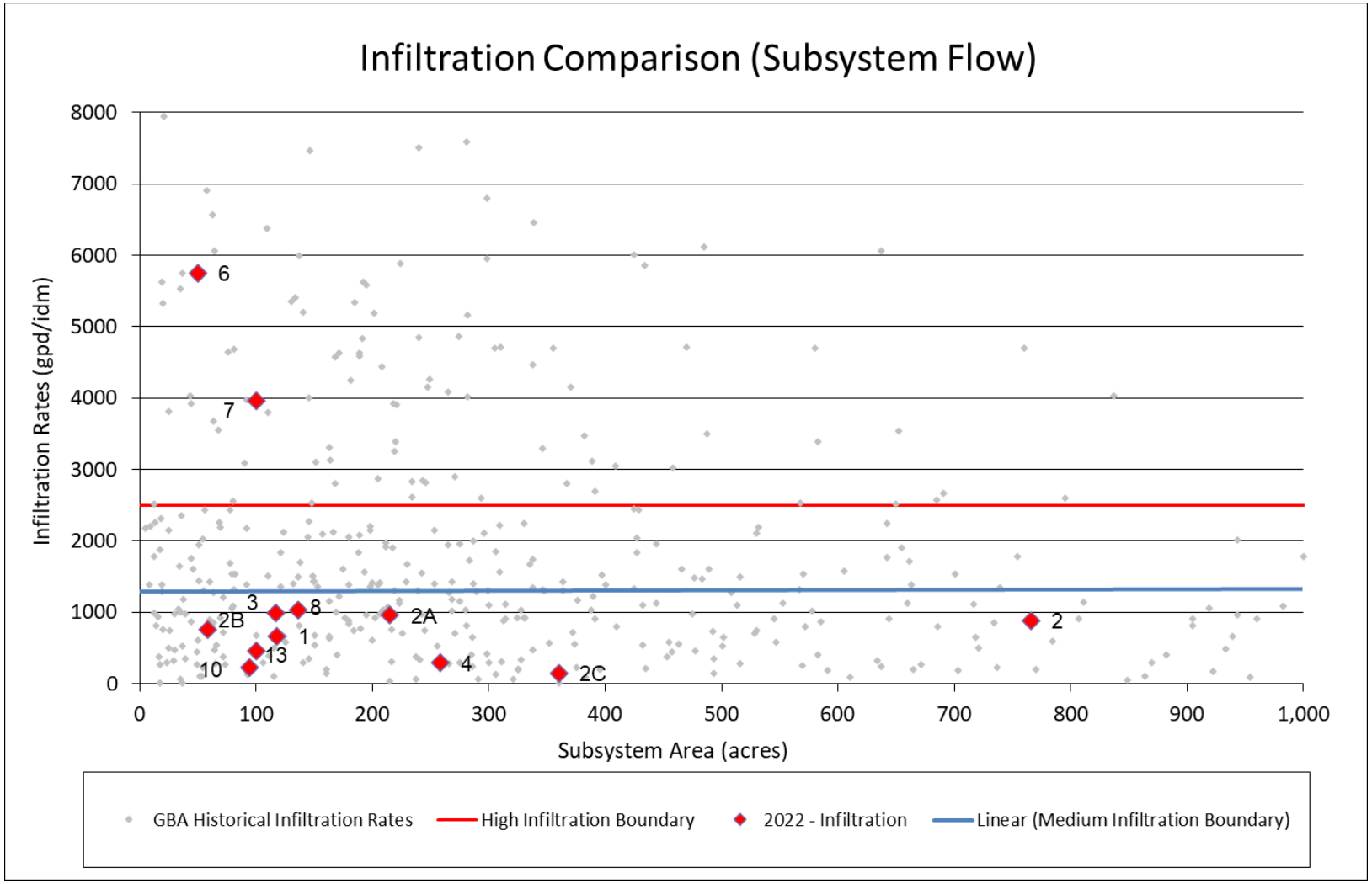
Table 2-12 – Infiltration Summary

Site/ Subsystem	Subsystem Area (acres)	Cumulative Area (acres)	Subsystem IDM	Cumulative IDM	Subsystem Infiltration (mgd)	Cumulative Infiltration (mgd)	Subsystem Infiltration Rate (gpd/IDM)	Cumulative Infiltration Rate (gpd/IDM)	Cumulative Infiltration Per Acre (gpd/acre)	Subsystem Infiltration Ranking
1	118	118	27	27	0.018	0.018	663	663	150	8
2	766	1493	198	385	0.174	0.262	881	681	175	6
2A	215	309	63	75	0.060	0.063	958	835	203	5
2B	58	58	14	14	0.011	0.011	754	754	187	7
2C	360	360	97	97	0.014	0.014	145	145	39	12
3	117	611	36	131	0.036	0.081	995	613	132	4
4	258	258	55	55	0.016	0.016	290	290	61	10
6	50	50	14	14	0.078	0.078	5,751	5,751	1,553	1
7	100	150	31	44	0.122	0.200	3,962	4,508	1,330	2
8	136	136	18	18	0.019	0.019	1,030	1,030	137	3
10	94	94	13	13	0.003	0.003	223	223	30	11
13	100	100	23	23	0.010	0.010	461	461	105	9

Notes:

Excessive Infiltration > 2,500 gpd/IDM

Figure 2-9 – Excessive Infiltration



2.4.5 Inflow

Inflow is defined as rainfall-related water entering the collection system from sources such as private sewer laterals, downspouts, foundation drains, yard and area drains, storm sump pumps, manhole covers, and cross connections from storm drains. Inflow is directly influenced by the intensity and duration of a storm event and therefore is not a fixed quantity.

A value for the design inflow is not directly calculated. Instead, a constant is calculated based on the storm duration, intensity, and the monitored flow. This constant, "K," is then used to predict inflow values for different rainfall return intervals. The "K" coefficient accounts for rainfall that enters the sewer system as inflow.

For each selected storm, the peak rainfall, peak flow, and time from peak rainfall to peak flow (also referred to as Time of Concentration, Toc) were used to calculate the "K" value at the flow monitoring point. Values for ADDF and infiltration were subtracted from the peak flow to determine the peak inflow. Once the peak inflow was determined and rainfall intensity was calculated from the rainfall monitoring data, a "K" value was determined. Several "K" values were averaged to arrive at a "K" value for the basin being monitored.

The inflow coefficient "K" for each storm event at each monitoring point was determined by the following formula:

$$K = \frac{Q}{iA}$$

Where:

K = inflow coefficient
Q = peak inflow (cfs) calculated by subtracting dry-weather base flow from the peak flow for each rain event that is being analyzed
i = rainfall intensity for selected recurrence interval and time of concentration (in/hr)
A = sewered area (acres)

Interior basins are basins with at least one upstream tributary area. Basin inflow coefficients for interior basins were calculated using measured cumulative flow, tributary basin inflow coefficients and tributary areas. The flow generated within an interior basin must be calculated because measured flow includes the dynamic cumulative effect from all tributary basins. System dynamics considers the time of travel through the sewer system. Each interior basin inflow coefficient was determined using the following weighted coefficient formula.

$$Kt = (K1A1 + K2A2 + ... + KiAi) / At$$

Where:

Kt = cumulative inflow coefficient (measured)
Ki = tributary basin inflow coefficient (calculated)
Ai = tributary sewered basin area (acres)
At = total sewered tributary area (acres)
i = Number of tributary basins

Exterior basins are basins in which there is no additional upstream tributary area coming into the basin. The relative accuracy of the "K" coefficient determined for a basin is typically higher for exterior basins that have only one sewer line outlet from the basin monitored. A decrease in the relative accuracy of the "K" coefficient is typical for interior flow basins due to cumulative flow effects. Inflow coefficients may also be skewed in basins that are largely undeveloped or contain pockets of undeveloped area.

A table showing the calculation of inflow for each storm event and calculation of an inflow coefficient at each monitoring location is included in the individual site analysis located in Appendix A. The inflow calculations required determining the sewered acreage tributary to the site and a time of concentration, which in turn was determined after review of storm event time of concentrations. Many storm data dates were available that showed measurable inflow responses, which included a minimum of four events to provide an average value at each metering site.

The 1-year subsystem inflow rates for each basin were calculated by ratio of 1-year subsystem storm inflow (gpd) to the subsystem's sewer footage length per 1,000 feet. Based on GBA's historical data from past flow monitoring projects as well as guidelines set forth by the EPA and other entities, an excessive subsystem inflow rate boundary line was established from the middle third of data. As subsystem area and sewer footage increases, the excessive inflow rate boundary decreases to represent the larger subsystems more accurately.

The excessive inflow rate boundary line is generally greater than or equal to 26,000 gpd/1000 ft for basins less than 300 acres in area. It then gradually decreases from 26,000 gpd/1000 ft to 8,000 gpd/1000 ft for areas between 300 and 900 acres. Finally inflow is considered excessive above 8,000 gpd/1000 ft for areas greater than 900 acres. This is also demonstrated in Table 2-13 below.

Table 2-13 – Excessive Inflow Rate Thresholds

Basin Area (Acres)	Excessive Inflow Rate Threshold
< 300	> 26,000 gpd/1000 ft
300 - 900	26,000 – 8,000 gpd/1000 ft
> 900	> 8,000 gpd/1000 ft

A summary of inflow parameters for each subsystem is shown in Table 2-14.

As shown in Table 2-14 and on Figure 2-10, 11 of the 12 basins exceeded this high inflow rate. Site 3 had the largest subsystem "K" value and highest 1-year inflow rate of 173,260 gpd/1000 ft. This site collects flow from sites 4, 8, and 13, in addition to its own, and of those three subsystems, Site 13 has the highest subsystem inflow rate of 60,947 gpd/1000 ft.

The only site that did not have excessive inflow was Site 2A. Since Site 2 was further divided into 2A, 2B, and 2C for this year's flow monitoring to attempt to isolate sources of excessive I&I, it can be concluded that basins 2B and 2C should be the primary focus of any further investigations.

Table 2-14 – Inflow Summary

Site/ Subsystem	Subsyst. Area (acres)	Cumul. Area (acres)	Subsyst. Sewer (ft)	Cumul. Sewer (ft)	Time of Concentration Subsystem (min)	Time of Concentration Cumulative (min)	Inflow Coefficient Subsystem K	Inflow Coefficient Cumulative K	1-Year Storm Inflow		1-Year Subsystem Inflow Rate (gpd/1000 ft)	1-Year Cumulative Inflow Rate (gpd/1000 ft)	10-Year Storm Inflow		Subsystem Infilow Ranking [4]
									Subsyst. (mgd)	Cumul. (mgd)			Subsyst. (mgd)	Cumul. (mgd)	
1	118	118	16,668	16,668	75	75	0.0047	0.0047	0.53	0.53	31,668	31,668	0.94	0.94	8
2	766	1,493	103,846	215,660	90	105	0.0033	0.0040	2.14	4.50	20,565	20,857	3.87	8.29	12
2A	215	309	36,064	43,430	90	105	0.0048	0.0059	0.88	1.37	24,459	31,551	1.60	2.52	10
2B	58	58	9,396	9,396	45	45	0.0064	0.0064	0.50	0.50	53,235	53,235	0.88	0.88	5
2C	360	360	58,988	58,988	60	60	0.0037	0.0037	1.41	1.41	23,855	23,855	2.49	2.49	11
3	117	611	22,230	87,886	90	90	0.0386	0.0120	3.85	6.26	173,260	71,238	6.98	11.34	1
4	258	258	37,396	37,396	60	60	0.0037	0.0037	1.02	1.02	27,281	27,281	1.80	1.80	9
6	50	50	8,913	8,913	45	45	0.0056	0.0056	0.38	0.38	42,300	42,300	0.66	0.66	6
7	100	150	17,328	26,241	90	210	0.0324	0.0235	2.76	1.50	159,536	57,029	5.01	2.95	2
8	136	136	10,672	10,672	135	135	0.0045	0.0045	0.36	0.36	34,128	34,128	0.69	0.69	7
10	94	94	7,366	7,366	90	90	0.0085	0.0085	0.68	0.68	92,973	92,973	1.24	1.24	3
13	100	100	17,588	17,588	90	105	0.0126	0.0126	1.07	0.94	60,947	53,300	1.94	1.73	4

Notes:

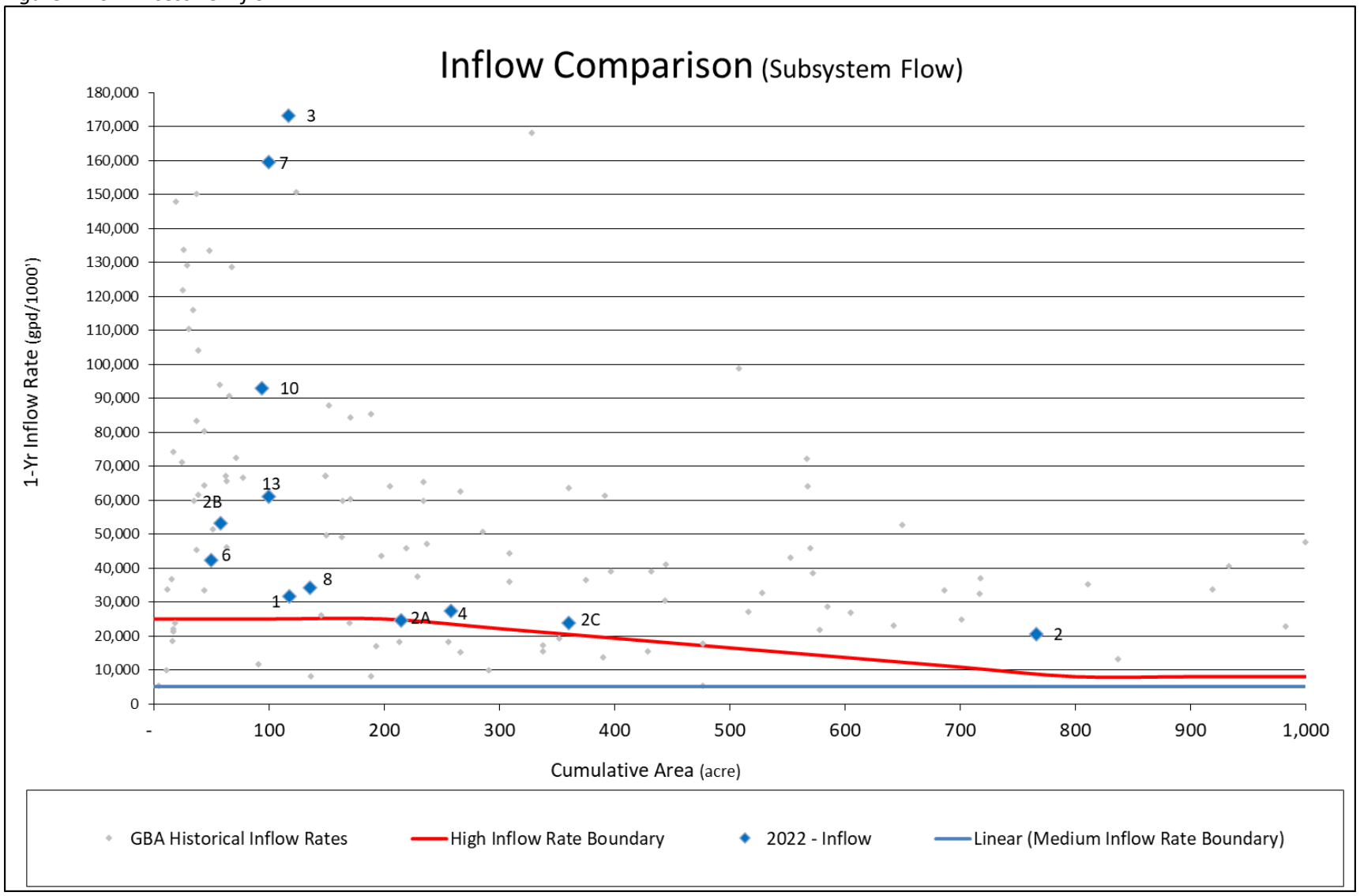
(1) Excessive Inflow is > 25,000 gpd/1000ft for less than 300 acre area, between 25,000 and 8,000 gpd/1000ft for areas between 300 and 900 acres, or > 8,000 gpd/1000ft

(2) Time of concentrationis calculated by averaging the time from peak rainfall to peak inflow for selected storms.

(3) 1 year storm and 10 year storm inflow are based on the following formula: Q=KiA*0.6463 (conversion factor from CFS to MGD)

(4) Ranking based on 1-Year Inflow Rate (gpd/1000 ft).

Figure 2-10 – Excessive Inflow



2.4.6 Peak System Flow Rates

The sewer system capacity at the flow monitoring sites was compared to peak flows with various recurrence intervals. The sewer capacities were calculated using measured pipe diameters and the calibrated energy gradient determined from Manning's equation and flow meter data. These capacities may not represent the capacity of sewers upstream or downstream of the monitoring locations. The approximate level of protection at each of the flow monitoring points was estimated by comparing the cumulative peak flows for various return periods with the existing capacity. A summary of peak subsystem flow rates and known capacities is shown in Table 2-15.

The lowest level of protection was estimated as flows from greater than a 1-year storm but less than a 2-year storm at Sites 2C, 3, and 13. The next lowest protection was estimated as flows from greater than a 2-year storm but less than a 5-year storm at Sites 7 and 8.

Table 2-15 – Calculated Capacity vs Peak Flows

Site/ Subsystem	Pipe Diam (in)	Existing Capacity[(1)] (mgd)	Average Dry-Weather Flow (mgd)	Maximum Recorded Flowrate (mgd)	Peak-to-ADDF Ratio	Cumulative Peak Flows (mgd)							Approximate Level of Protection[(2)]
						1 Year	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	
1	15	3.5591	0.0315	2.5700	81.6:1	0.61	0.71	0.88	1.02	1.23	1.40	1.58	Greater than 100 Year
2	24	9.5038	0.8417	6.8970	8.2:1	6.09	7.07	8.54	9.88	11.81	13.42	15.16	Between 5 and 10 Year
2A	15	2.7138	0.2029	2.1500	10.6:1	1.79	2.09	2.53	2.94	3.53	4.02	4.55	Between 5 and 10 Year
2B	10	0.8436	0.0590	0.3630	6.1:1	0.61	0.70	0.85	0.98	1.17	1.32	1.48	Between 2 and 5 Year
2C	15	1.9569	0.2230	1.6000	7.2:1	1.81	2.08	2.51	2.89	3.42	3.85	4.32	Between 1 and 2 Year
3	15	8.0504	0.3496	6.7000	19.2:1	6.93	8.24	10.22	12.01	14.56	16.66	18.93	Between 1 and 2 Year
4	12	4.2335	0.1369	2.2038	16.1:1	1.23	1.43	1.74	2.01	2.40	2.71	3.05	Greater than 100 Year
6	8	1.4359	0.0579	0.3800	6.6:1	0.56	0.63	0.75	0.84	0.98	1.09	1.21	Greater than 100 Year
7	15	2.9728	0.2249	1.5600	6.9:1	2.02	2.40	2.96	3.48	4.26	4.93	5.67	Between 5 and 10 Year
8	12	0.7333	0.0559	0.4900	8.8:1	0.46	0.55	0.67	0.79	0.96	1.11	1.26	Between 5 and 10 Year
10	12	3.2792	0.0520	1.8425	35.4:1	0.77	0.91	1.13	1.33	1.61	1.83	2.08	Greater than 100 Year
13	12	1.1594	0.0223	0.6940	31.1:1	0.99	1.19	1.50	1.78	2.18	2.51	2.88	Between 1 and 2 Year

(1) Existing Capacity is calculated using the pipe diameter and calibrated energy gradient determined from modified Mannings equation.

(2) Level of protection = storm recurrence interval which will surcharge the metered location.

2.4.7 Volumetric Analysis

Utilizing significant storm events, the amount of rainfall (I&I volume, or percent rain to sewer) entering the sanitary sewer system was calculated. Using the meter data for each storm, the I&I volume was determined by creating an I&I hydrograph, which is the difference between an adjusted dry weather flow period and the storm's wet weather hydrograph. The adjusted dry weather flow period represents what the predicted dry weather flow would be if the rain event had not occurred. Typically, flows from the day or week before the storm event are used as the adjusted dry weather flow. The total I&I volumes were plotted on a graph against the corresponding 24-hour rainfall total for each event. A linear regression analysis was then used to determine the total I&I volumes for any given amount of rain.

Table 2-16 indicates which subsystems have excessive I&I volumes. A subsystem is considered to have excessive I&I if it averaged 2% or greater total rain volume entering the sanitary sewer. Each subsystem was ranked for excessiveness of I&I volume. Only one of the basins was above the excessive level – Basin 7, which is similar to its excessive ranking during the 2021 flow monitoring project. Individual site percent rain to sewer analyses are detailed in Appendix A.

Table 2-16 – Statistical Analysis of Rain to Sewer Volume

Site/ Subsystem	Average Rain to Sewer Cumulative (%)	Average Rain to Sewer Subsystem[(1)] (%)	Ranking[(2)]	Number of Events Analyzed	10-Year 24-Hour I&I Volume (MG)
1	0.85%	0.85%	7	15	0.34
2	0.53%	0.10%	12	12	1.00
2A	1.28%	1.54%	3	11	0.30
2B	1.13%	1.13%	5	14	0.08
2C	0.72%	0.72%	8	11	0.28
3	0.81%	0.98%	6	14	1.46
4	0.50%	0.50%	11	15	0.31
6	1.41%	1.41%	4	15	0.12
7	5.60%	8.40%	1	15	1.41
8	0.63%	0.63%	10	15	0.31
10	0.67%	0.67%	9	11	0.12
13	1.68%	1.68%	2	15	0.34

(1) Highlight excessive I/I which is I/I greater than 2% subsystem, based on historical analysis.

(2) Ranking based on Subsystem average

2.5 Flow and Rainfall Monitoring Results Summary

The 2022 Fall flow monitoring in Manor, TX showed several sub-basins with excessive I&I characteristics. Table 2-17 shows a summary of the flow monitoring sub-basins and the I&I characteristics each basin had including capacity issue indicators such as wet-weather surcharging. Table 2-17 demonstrates that nine (9) of the thirteen (13) flow meter sub-basins had at least one excessive I&I characteristic. The only sub-basin that did not have any I&I indicators is 2A, however the inflow rate for this sub-basin is 2% away from the excessive threshold of 25,000 gpd/1000ft. Overall, inflow seems to be a significant issue in the City's sanitary sewer system and should be further investigated to determine the sources of inflow.

Table 2-17 – Flow Monitoring Results Summary

	Excessive Parameters			Capacity Issue Indicator	
Site/ Subsystem	Subsystem Infiltration Rate (gpd/IDM)	1-Year Subsystem Inflow Rate (gpd/1000 ft)	Average Percent Rain to Sewer Subsystem (%)	Wet Weather Surcharge	Dry Weather Surcharge
1	663	31,668	0.85%	Yes	No
2	881	20,565	0.10%	Yes	No
2A	958	24,459	1.54%	No	Yes
2B	754	53,235	1.13%	No	No
2C	145	23,855	0.72%	No	Yes
3	995	173,260	0.98%	Yes	Yes
4	290	27,281	0.50%	No	Yes
6	5,751	42,300	1.41%	No	No
7	3,962	159,536	8.40%	No	No
8	1,030	34,128	0.63%	Yes	Yes
10	223	92,973	0.67%	Yes	Yes
13	461	60,947	1.68%	No	No

Indicates excessive characteristics
All three parameters are excessive
Two of three parameters are excessive
One parameter is excessive

3 Manhole Condition Assessments

3.1 Inspection Background

The 2021 Fall flow monitoring project indicated several basins with excessive I&I characteristics. Two of those basins - Sites 6 and 7 – were selected as a "pilot" study area. Detailed SSES investigations would be completed in these basins to collect further I&I data. The next three chapters will present the findings of these investigations.

Manhole Condition Assessments were performed on 137 manholes within the Pilot Area to assess the structural condition of the manholes and to gather information regarding the presence and degree of I&I. Simple manhole inspections were performed and logged using a GIS Application called Field Maps. If a manhole was suspected to have a defect that was not clearly visible from the surface, or if better measurements and pictures were required, an internal inspection could be completed. Manholes in the project area on which an inspection was attempted by GBA are shown on Figure 3-1.

After a primary investigation, it was determined that only simple surface inspections were necessary. No defects were found that indicated the necessity of an internal inspection. A Simple Surface inspection gathers general upper manhole condition information from the surface, as well as basic information about lower manhole conditions that can be observed and measured from the surface without entering the manhole. The accuracy of a simple surface inspection with regard to pipe sizes and lower manhole condition is lower than an internal inspection. An internal inspection gathers the highest level of measurement and condition information primarily used as part of a comprehensive condition analysis. An internal inspection includes a manned entry into the structure to collect all pipe measurements, lamping defects, and pictures.

A scoring guide to the Simple Inspections which were performed is included on Figure 3-2.

3.2 Inspection Results

There were 137 attempted simple surface inspections, of which six (6) were not able to be fully inspected. Of the incomplete inspections three (3) manholes were located behind fences and could not be accessed, two (2) were not found, and one (1) had a locked cover that the crews could not open. All of these manholes are listed in Table 3-1. The locations of the incomplete inspections are shown on Figure 3-3.

Additionally, two (2) new manholes were found during inspections. These are listed in Table 3-2 and shown on Figure 3-4.

Figure 3-1 – Manhole Condition Assessments Map

Figure 3-2 – Manhole Condition Assessments Scoring Guide

MH Score	Defect	Definition	Photo Required
0	No defects found		Topside, Vicinity & Channel
1	Cracks-(Small)	Crack less than 3/8"	Topside, Vicinity & Channel
	Inflow or Infilitration-(Light)	Staining and/or weeping observed	
	Debris-(Light)	<1 gallon	
	Offset of any manhole part	1-2" (measuring the greatest offset distance)	
2	Cracks-(Medium)	3/8" to 3/4"	Topside, Vicinity & Channel
	Inflow or Infilitration-(Light)	Trickle and/or dripping (1-3 gallons per minute)	
	Debris-(Moderate)	1-3 gallons	
	Offset of any manhole part	2-3" (measuring the greatest offset distance)	
	Surcharge Evidence	Greater than pipe height	
	Mortar or Joint	Material Missing	
3	Cracks-(Large)	3/4" to 1"	Topside, Vicinity & Channel
	Inflow or Infilitration-(Medium)	Streaming or running (3-10 gallons per minute)	
	Debris-(Heavy)	3-5 gallons	
	Offset of any manhole part	3-4" (measuring the greatest offset distance)	
	Surcharge Evidence	Within 5 ft of the MH rim	
	Chimney/Chamber material	Missing/Deteriorated	
	Bench/Channel	Missing material/ Poor hydraulics	
	Flowline Obstruction	Any un-removable object obstructing less than 50% of flow	
	Flow	Greater than 50% of pipe but less than top of pipe	
4	Voids Visible	Manhole Material Loss and or Cracks >1" with material loss	Topside, Vicinity & Channel
	Inflow or Infilitration-(Heavy)	Gusher (>10 gallons per minute)	
	Debris-(Extremely Heavy)	>5 gallons	
	Offset of any manhole part	>4" (measuring the greatest offset distance)	
	Surcharge Evidence	Evidence to the rim or overflow (comment: "Possible SSO")	
	Bench/Channel	Material mostly missing/Slow stagnant hydraulics	
	Flowline Obstruction	Any un-removable object obstructing greater than 50% of flow	
	Flow	Greater than top of pipe	
5	Unable to Inspect	REQUIRED TO POPULATE "Reason Not Inspected" FIELD If possible locate with metal detector and mark with paint	Vicinty

Table 3-1 – Manholes Not Inspected

MH ID	Condition	Reason Not Inspected
O13-001	Unable to Inspect	Could Not Open, Bolted Cover
O13-002	Unable to Inspect	Could Not Access, In Private Yard
O13-004	Unable to Inspect	Could Not Find
O13-021	Unable to Inspect	Could Not Access, In Private Yard
O13-012	Unable to Inspect	Could Not Find
O13-025	Unable to Inspect	Could Not Access, In Private Yard

Table 3-2 – New Manholes Found

MH ID	Condition	Upstream Manhole	Downstream Manhole	Address
UMH-1	0	O13-056	O13-047	13012 Ship Bell Drive
UMH-2	4	O13-057	O13-046	13012 Tinker Street

Figure 3-3 – Incomplete Manhole Inspections

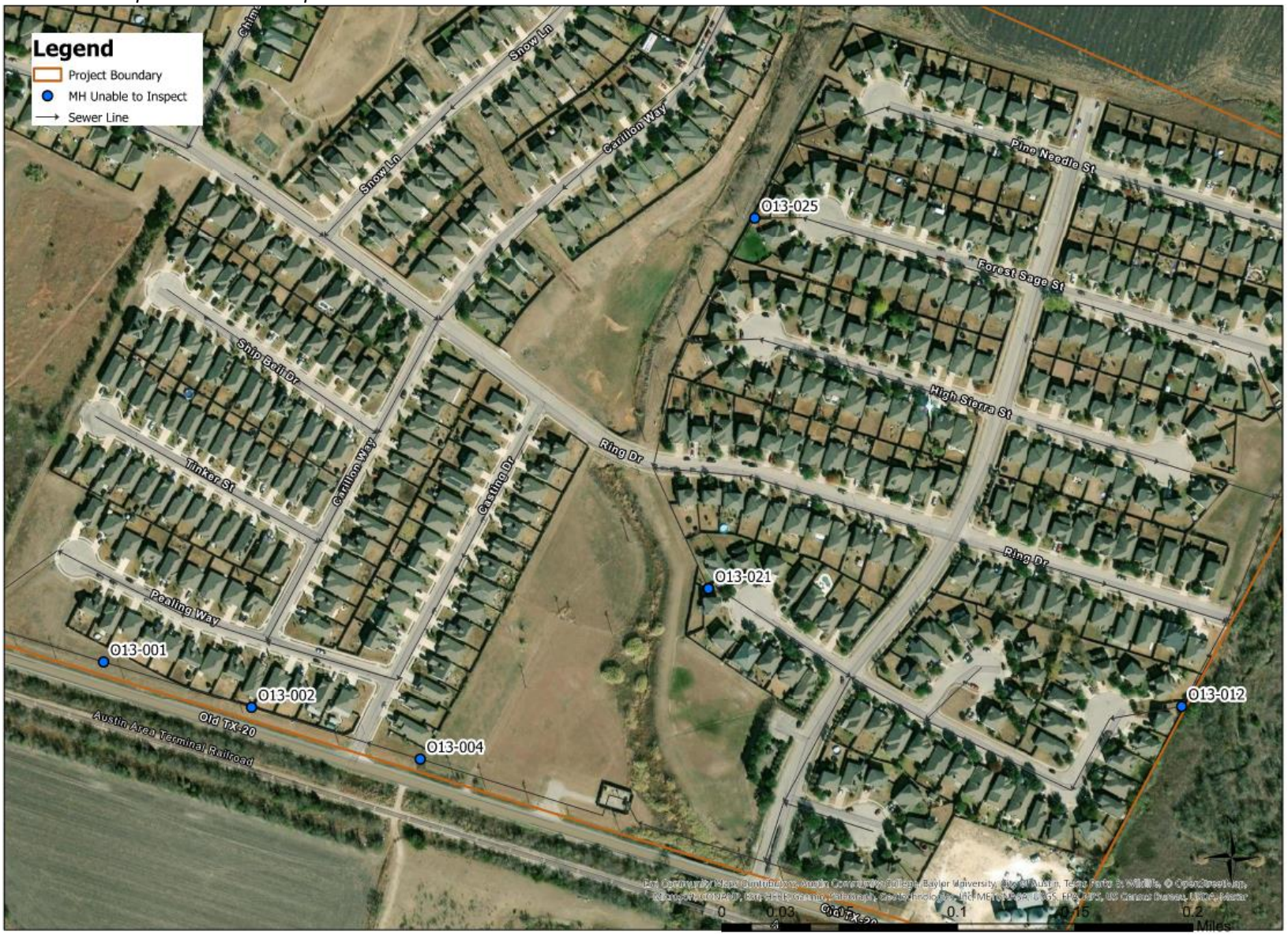


Figure 3-4 – New Manholes Found

3.2.1 Structural Condition Summary

Of the 131 manholes successfully inspected, 19 were rated 4 on the condition rating. This is the most severe rating available and is given when significant I&I or structural defects are found. Table 3-3 lists the manholes which were rated 4 as well as the reason for this rating. It is recommended that the City perform rehabilitation on these 19 manholes first to ensure the continued functionality of its system. As shown in Table 3-3, most of the defects are related to liner failures throughout the manholes. If large chunks of liner are allowed to break off, they can get stuck in a sewer line and cause severe back-ups upstream in the system.

Table 3-3 – Manholes Rated 4

MH ID	COVER TYPE	MH MATERIAL	MH DEPTH (ft)	RATING	REASON FOR RATING [1]
O12-003	Bolt Down	CONCRETE	19.6	4	Liner peeling around grade ring and around pipes (3), manhole offset at grade ring (4).
O12-004	Bolt Down	CONCRETE	18.25	4	Lining peeling off at bottom of chamber (2), manhole joint separating at chamber (3), infiltration at chamber (4).
O12-006	Bolt Down	CONCRETE	16.05	4	Liner is peeling at the chamber (3), manhole separation at midpoint (4).
O12-007	Standard	CONCRETE	N/A [2]	4	Liner bubbles in chamber (4), flow line obstruction in north in pipe (3).
O12-008	Standard	PVC	13.4	4	Total liner failure in chamber (4),south in pipe (dry) full of debris (2), debris on bench (2).
O12-010	Standard	PVC	6.15	4	A chunk of PVC pipe is in the mouth of the in pipe (4).
O13-058	Standard	CONCRETE	7.59	4	Crack surrounding chimney with liner failure (4), crack surrounding half of the chamber with bubbling (4).
O12-021	Bolt Down	CONCRETE	12.32	4	Lining around grade ring is peeling all around (3), cracks around concrete base (3), major infiltration point at bench of manhole (4).
O13-006	Standard	CONCRETE	18.37 to grease [3]	4	Grease surcharge flowline obstruction and debris (4), liner failure at mouth of chimney (3).
O13-041	Standard	CONCRETE	7.03	4	Crack surrounding chimney (4)
O13-038	Standard	CONCRETE	6.2	4	Large crack all the way around and I&I staining.
O13-037	Standard	CONCRETE	7.62	4	Large crack all the way around chimney, quarter inch in width.
O13-023	Standard	CONCRETE	8.2	4	Manhole lid broken.
O13-013	Standard	CONCRETE	10.04	4	Crack surrounding grade ring (3), asphalt surrounding manhole cover is broken (4), roots growing through crack in chimney.
O13-017	Standard	CONCRETE	7.83	4	No lining, large crack all the way around chimney.
O13-035	Standard	CONCRETE	5.7	4	Cracked all the way around and no lining.
O13-036	Standard	CONCRETE	6.25	4	Cracked all the way around chamber and no lining.
O13-005	Bolt Down	CONCRETE	19.16	4	Manhole surcharged (4).
UMH-2	Standard	CONCRETE	9.26	4	Manhole between O13-057 and O13-046, large crack surround chimney with void visible (4).

Notes

1. Numbers in parenthesis in the Reason for Rating column indicate the severity rating given to each defect found, if multiple significant defects were found.
2. Manhole was too deep to get a depth measurement with the level rod.
3. There was a grease plug partway up the chamber that blocked crew access to manhole invert.

Structural manhole defects allow certain amounts of I&I to enter the sanitary system. Based on studies by both GBA and other entities, average inflow rates have been assigned to certain defects. Table 3-4 details these estimates:

Table 3-4 – Inflow Rates for Manhole Defects

Manhole Defect	Average Inflow Rate (gpm)
Ponding Manhole	3
Rim Seal	1-5
Corbel Lead or Cracked Frame Base Seal (FBS)	0.5-1.5
Chimney Cracks	1-2
Broken Frame	1-2

*Flow rate is per hole and assuming 2" head of rainfall accumulation

Using the inflow rates from Table 3-4, a total of approximately 46 gpm can be potentially removed if the indicated rehabilitation is performed.

In addition to the 19 manholes rated 4, there were 22 manholes rated 3. Typically in an I&I rehabilitation project it would be recommended to fix manholes rated 3 and 4 together, as both can allow significant amounts of I&I to enter the system. These manholes are listed in Appendix B.

The manholes that are recommended for further rehabilitation work are listed in Table 3-5. It is important to keep in mind that I&I rehabilitation has the potential to push the I&I to a different point on the manhole or line where it could thus still enter the sanitary system. Sanitary sewer rehabilitation will not completely remove all I&I and create a water-tight system. The goal of any rehabilitation should be instead to reduce I&I while also increasing the functional life cycle of the collection system.

Table 3-5 – Manholes in Need of Rehabilitation

		Location of defect							Recommended Rehabilitation/Maintenance							
Manhole ID	**Inspection Rating**	**Frame**	**FBS**	**Grade Ring**	**Chimney**	**Chamber**	**Channel**	**Other**	**Reset MH part**	**Install FBS**	**Line MH**	**Cleaning**	**Point Repair**	**Pipe Seals**	**Other**	**Comments**
O12-003	4			✔		✔			✔	✔				✔		Liner peeling around grade ring and around pipes, manhole offset at grade ring.
O12-004	4					✔					✔					Lining peeling off at bottom of chamber, manhole joint separating at chamber, infiltration at chamber.
O12-006	4					✔			✔		✔					Liner is peeling at the chamber, manhole separation at midpoint.
O12-007	4					✔	✔				✔	✔				Liner bubbles in chamber, flow line obstruction in north in pipe.
O12-008	4					✔	✔				✔	✔				Total liner failure in chamber, south in pipe (dry) full of debris, debris on bench.
O12-010	4						✔					✔				A chunk of PVC pipe is in the mouth of the in pipe .
O12-021	4		✔	✔		✔				✔	✔					Lining around grade ring is peeling all around , cracks around concrete frame surround, major infiltration point at bench of manhole.
O13-005	4							Surcharge				✔				Manhole surcharged, most likely due to back-up from lift station.
O13-006	4				✔		✔				✔	✔				Grease surcharge flowline obstruction and debris, liner failure at mouth of chimney.
O13-013	4		✔	✔	✔					✔	✔	✔			Re-pave surrounding asphalt	Crack surrounding grade ring, asphalt surrounding manhole is broken, roots growing through crack in chimney.
O13-017	4				✔						✔					No lining, large crack all the way around chimney.
O13-023	4							Broken lid							New MH lid	Manhole lid broken.
O13-035	4					✔					✔					Chamber seal is missing, no lining.
O13-036	4					✔					✔					Cracked all the way around chamber and no lining.
O13-037	4		✔		✔					✔			✔			Large crack all the way around chimney, quarter inch in width. I&I staining from under the frame.
O13-038	4		✔		✔					✔			✔			Large crack all the way around and I&I staining.
O13-041	4				✔								✔			Crack surrounding chimney.
O13-058	4				✔	✔					✔					Crack surrounding chimney with liner failure, crack surrounding half of the chamber with bubbling.
UMH-2	4		✔		✔					✔	✔					Manhole between O13-057 and O13-046, large crack surround chimney with void visible. Heavy staining from under frame.

FBS = Frame Base Seal

4 CCTV Inspections

4.1 Inspection Background

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc. attempted CCTV inspections in 2022 on 107 line segments for a total of 30,386 linear feet. All CCTV inspections attempted are shown on Figure 4-1 and the statistics are listed in Table 4-1.

Table 4-1 – CCTV Summary

Project Area	Pipe Size	LF Scoped	LF Inspected
Basins 6 & 7	8”	26,108	26,907
	12”	1,428	1,641
	15"	2,759	2,791
	Total	**30,295**	**30,386**

All of the lines scoped for this project were successfully inspected. There were no major issues with tree roots in the system however debris was present in many line segments. Section 4.2 will discuss the heavy cleaning that was completed for this project.

Additionally, two new manholes were found during CCTV (and noted again during manhole inspections) which were labeled UMH-1 and UMH-2. These are discussed in more detail in Section 3.2.

4.2 Heavy Cleaning

A total of 48.5 hours was spent on heavy cleaning in this targeted Project Area. Most of this time was spent cleaning the 12”-15” lines along Old TX-20. These lines were found to be at least 50% full of silt, rock, and other debris at the time of inspections. It is suspected that the two lift stations located along this trunk line are at least partially responsible for the debris accumulation. The lift station operation cycles were not perfectly calibrated so flows were not always pumped out at the correct intervals and this caused flows to back-up into the sewer lines and debris to settle out.

Additionally, the 8” lines along St Mary Drive had heavy gravel-type debris that needed heavy cleaning. It is unclear where the debris originated, but it is suspected to have been introduced into the lines during the construction taking place northwest of St Mary Drive.

It was also noted that the two (2) lift stations along Old Hwy 20 (Carriage Hills and Bell Farms Lift Stations) should be cleaned as a follow-up to the work completed during this project. Since not every bit of debris is able to be vacuumed out of the lines at the time of heavy cleaning, it is probably that some debris made its way into the lift stations. Heavy cleaning of the stations will ensure that similar backing up into the system as has been seen before does not happen again.

The lines on which heavy cleaning was performed are shown on Figure 4-2.

Figure 4-1 – CCTV Completed

Figure 4-2 – Heavy Cleaning Lines

4.3 Structural Condition Summary

Water level sags were the most noted defect within this project area identified during CCTV inspections. As can be seen in Table 4-2, three (3) lines experienced sagging severe enough to be rated a 4, and one (1) line had an infiltration defect rated 4. Sagging can occur when pipe joints separate and pipe bedding settles below the line. Over time, sags can worsen and lead to pipe failures, but CIPP lining can reinforce the structural strength of the line segment and keep it from failing.

There were additionally seven (7) lines identified that had a defect rating of 3 which are listed in Table 4-3. Figure 4-2 shows the locations of lines identified to have defects.

The reports produced by the CCTV contractor are included in Appendix C.

Table 4-2 – CCTV Lines with a Highest Defect Rating of 4

Pipe ID	USMH	DSMH	Diam	Matl	PAPC Score	Defect	Defect Ft DS	Comment
O12-009 - O12-008	O12-009	O12-008	8	PVC	4G34	MWLS	50.1, 26.2-196.8	MSA at 50.1 ft D. due to debris. Rated 3423D, reversal was rated 4G00. Sag rated 3/4 for 30.1U-196.8U
O13-001 - O13-021	O13-001	O13-021	12	PVC	4100	IR	272.3	Infiltration Runner rated 4 at 272.3ft DS
O13-010 - O13-009	O13-010	O13-009	8	PVC	4A37	MWLS	175.2-200.1, 227.3-243.2, 315.3	Multiple significant sags in line. 175.2-200.1, 227.3-243.2, 315.3-335.1
O13-016 - O13-015	O13-016	O13-015	8	PVC	4135	MWLS	39.6-66.0	Sag rated 3 from 39.6-66.0 ft DS. MCU rated 4 at 46.5

Table 4-3 – Lines with a Highest Defect Rating of 3

Pipe ID	USMH	DSMH	Diam	Matl	PAPC Score	Defect	Defect Ft DS	Comment
N12-009 - O12-019	N12-009	O12-019	8	PVC	3700	MWLS	230-265	Sag rated 3 from 230-265Ft DS
N13-012 - N12-009	N13-012	N12-009	8	PVC	3112	FL	503	Flow Level rated 3 at 503 ft DS most likely due to a sag
O12-008 - O12-007	O12-008	O12-007	8	PVC	3424	MWLS	8-23.9, 237.2	Sag rated 3 at 8-23.9ft D and at 237.2ft D. Other minor sags in line rated 2.
O12-019 - O12-018	O12-019	O12-018	8	PVC	382A	MWLS	29-125, 289-361	Sag rated 3 from 29-125 DS and 289-361 DS sags rated 2 also in line
O13-012 - O13-011	O13-012	O13-011	8	PVC	3900	MWLS	190-251, 377-558	Sag rated 3 from 190-251, and 377-558 ft DS
O13-044 - O13-043	O13-044	O13-043	8	PVC	372C	MWLS	126.4-184.5	Sag rated 3 from 126.4-184.5 ft DS. MSA due to debris. Line had significant amount of debris which had to be cleaned. Line rated 3A22 DS initially, rated 372C upon redo. Redo was 241.5D, first pass was 184.6D.
O13-046 - O13-045	O13-046	O13-045	8	PVC	3A25	MWLS	4.5-55.8, 237.8-250.8	Sag rated 3 from 4.5-55.8 DS and again at 237.8-250.8 DS. Sags rated 2 also in line.

Figure 4-3 – CCTV Lines with Major Defects

5 Smoke Testing

Smoke testing is typically performed on sewer segments by introducing a non-toxic heated liquid smoke into the collection system. The smoke is forced through the system with a gas-powered blower. The smoke exits the system at locations where rainfall or groundwater can enter. A three-person crew visually inspects areas tributary to the line segment. Typical I&I sources identified during smoke testing are shown on Figure 5-1.

Careful planning preceded the smoke testing to reduce public inconvenience. Due to the potential public concern resulting from smoke in and near buildings, the public and the fire department were notified prior to testing. Smoke testing notices were delivered to every residence in the area a minimum of 48 hours prior to testing. Instructions were included on the notices for ensuring each building's p-traps were full of standing water ahead of the smoke testing. This would prevent smoke from entering a building through the lateral connection to the sanitary sewer. Daily contact was made with the fire and police department dispatch to inform them of specific areas being tested.

Smoke testing was conducted on approximately 37,500 feet of sanitary sewer lines in the project area. The testing observations were recorded in a GIS database created by GBA and approved by the City.

A source was considered positive if the smoke was observed in the area tributary to the line segment being tested. Suspect sources, which are sources that are potentially connected to the system but did not smoke during the tests, were also identified. Clogs, sags, collapsed pipes, or water traps may prevent a suspect source from smoking. A negative source was used if a house plumbing vent did not smoke when the line segment the house was assumed to be connected to was tested. It is possible that the house lateral was full of water or roots, and that prevented smoke from traveling up and out of the vent stack. GBA documented these negative sources as back-up information for the City if a homeowner calls about a problem with their sewer lateral.

A total of 280 positive, 12 negative, and 1 suspect sources were identified during this process. Figures 5-2 and 5-3 show the lines smoke tested and the locations of the smoke sources identified during testing, respectively. All smoke testing sources are also included in a Table in Appendix B.

There were twelve (12) houses that had negative plumbing vent smoke sources. It is suspected that clogs or sags in the laterals were the cause of the smoke not exiting the vent stacks. Table 5-1 shows the properties where vent smoke was not observed.

There were 237 properties with uncapped, broken, or defective cleanouts that should be rehabilitated, out of the 259 total properties with cleanouts present. Although uncapped cleanouts are small in diameter and do not typically introduce a lot of rainfall into the sewer system, they can still pose problems to the system. Foreign objects are often lodged into the cleanouts, and if the top of the cleanout is flush with the surface, it can create a sump scenario that can pool rainfall flow and increase I&I in the system. Appendix D contains the complete list of the 237 defective clean-outs along with recommendations for next steps.

A summary of the types of smoke testing sources and their respective I&I flow rates is shown in Table 5-2. The defects highlighted in gray should be first priority for removal or rehabilitation as they are the most cost-effective sources of I&I that can be removed. More in-depth cost analysis should be performed during the design phase to ensure the most viable solutions are reached.

Figure 5-1 – Typical Smoke Testing Sources

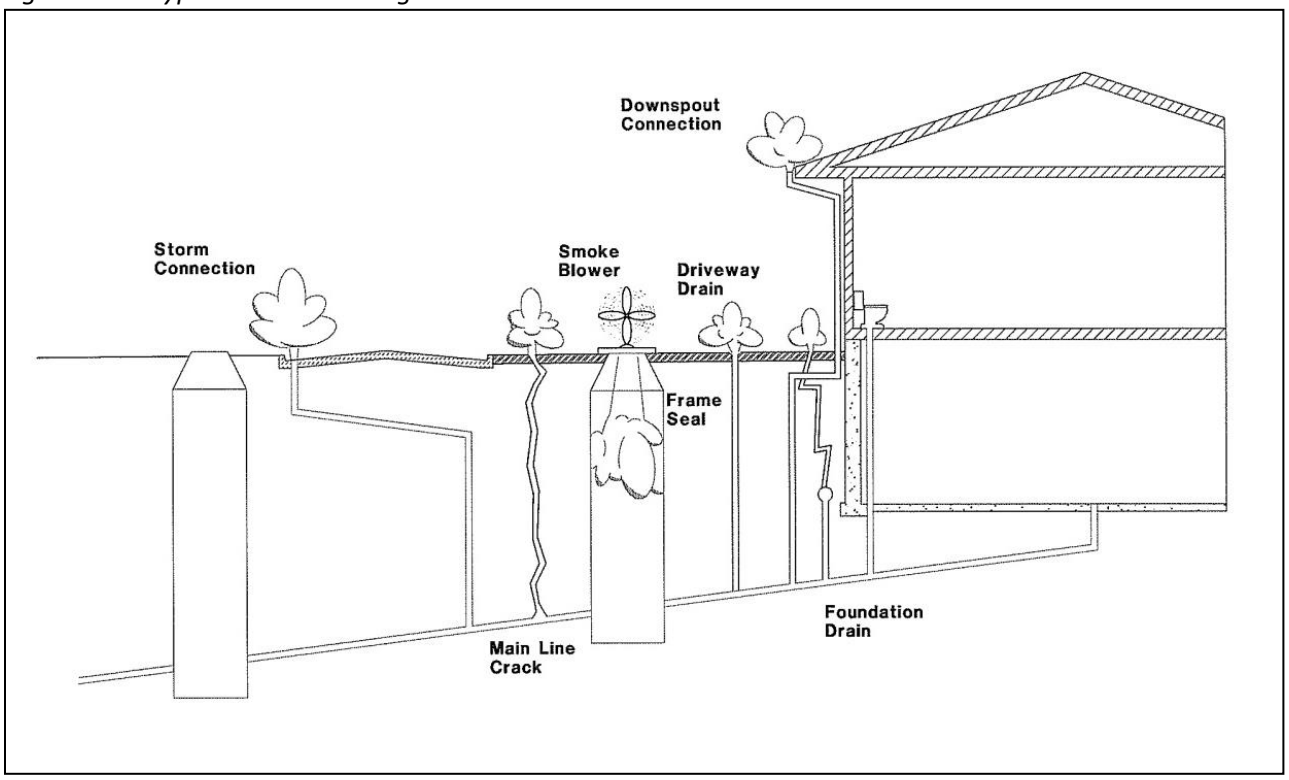


Table 5-1 – Houses with No Vent Smoke

Defect Type	Smoke Intensity	Address	Public/Private	Smoke Result	Blower MH
Vent Stack	None	12916 Wedding Drive	Private	Negative	N13-005
Vent Stack	None	12701 Carillon Way	Private	Negative	O13-046
Vent Stack	None	12925 Carillon Way	Private	Negative	O13-055
Vent Stack	None	12805 Wedding Drive	Private	Negative	N13-006
Vent Stack	None	12721 Wedding Drive	Private	Negative	N13-006
Vent Stack	None	12725 Wedding Drive	Private	Negative	N13-006
Vent Stack	None	12812 St Mary Drive	Private	Negative	N12-010
Vent Stack	None	12753 Bella Parkway	Private	Negative	O13-058
Vent Stack	None	12737 Bella Parkway	Private	Negative	O13-058
Vent Stack	None	12549 Ostrich Trail	Private	Negative	O12-006
Vent Stack	None	13300 Prairie Sage Cove	Private	Negative	O13-042
Vent Stack	None	13333 Indian Oak Bend	Private	Negative	O13-009

Table 5-2 – Smoke Testing Results

Source	Units	Estimated Potential 1-Year Storm Inflow[1] (gpm)	Total Potential 1-Year Storm Inflow (gpm)
Positive Sources			
Cleanout	259	0.25	64.75
Foundation Drain	1	3.0	3.0
Indirect Storm Inlets/Lines	0	0.5	0
Plumbing Defect	1	0.25	0.25
Sanitary Manholes	15	1.0	15.0
Service Laterals	4	0.5	2.0
Stairwell Drain	0	3.0	0
Total	**280**	**-**	**85.0**
Negative Sources			
Plumbing Vent or Inside Building	12	0	0
Total	**12**	**0**	**0**
Suspect Sources			
Inconclusive/Suspect Sources[2]	1	0	0
Total	**1**	**-**	**0**
[1] Estimates for unit flows are based on average values used in previous studies by GBA and other entities.			
[2] This source is a line segment that did not smoke during testing. It could have been due to blockages in the pipe. CCTV did not show any evidence of a blockage, so suspect this was just a momentary issue.			
The defects highlighted in blue should be first priority for removal or rehabilitation as they are the most cost effective sources of I&I that can be removed.			

Figure 5-2 – Smoke Testing Lines

Figure 5-3 – Smoke Testing Results

6 GIS Updates

Table 6-1 lists the necessary GIS updates that should be done. All necessary updates are highlighted in yellow :

Table 6-1 – Updates Needed in GIS

USMH	DSMH	Pipe ID	Diam	Material	Length	Comment
N12-001	O12-012	N12-001_O12-012	8	PVC	343	Original length was 338.88
N13-002	N13-001	N13-002_N13-001	8	PVC	218.7	Original length was 199.12
N13-013	O13-050	N13-013_O13-050	8	PVC	394.8	Original length was 371.6
O12-008	O12-007	O12-008_O12-007	8	PVC	240.5	Original length was 288.81
O12-012	O12-002	O12-012_O12-002	12	PVC	146.31	Line appears to be 12”, not 8”
O13-017	O13-016	O13-017_O13-016	8	PVC	269.6	Original length was 308.43
O13-020	O13-008	O13-020_O13-008	8	PVC	294.7	Original length was 321.85
O13-021	O13-020	O13-021_O13-020	8	PVC	73.4	Original length was 54.77
O13-023	O13-022	O13-023_O13-022	8	PVC	206.1	Original length was 229.47
O13-024	O13-023	O13-024_O13-023	8	PVC	84.6	Original length was 64.34
O13-026	O13-025	O13-026_O13-025	8	PVC	213.1	Original length was 198.06
O13-035	O13-025	O13-035_O13-025	8	PVC	158.7	Original length was 107.5
O13-036	O13-035	O13-036_O13-035	8	PVC	418.3	Original length was 458.59
O13-040	O13-039	O13-040_O13-039	8	PVC	415.3	Original length was 392.31
O13-043	O12-021	O13-043_O12-021	8	PVC	315.4	Original length was 292.5
O13-044	O13-043	O13-044_O13-043	8	PVC	241.5	Original length was 309.09
O13-045	O13-044	O13-045_O13-044	8	PVC	177.4	Original length was 202.54
O13-056	UMH1	O13-056_ UMH1	8	PVC	379.2	New MH labeled UMH1
UMH1	O13-047	UMH1_O13-047	8	PVC	199.2	New MH labeled UMH1
O13-057	UMH2	O13-057_ UMH2	8	PVC	368.2	New MH labeled UMH2
UMH2	O13-046	UMH2_O13-046	8	PVC	192.2	New MH labeled UMH2
O13-002	O13-001	O13-002_O13-001	12	PVC	403.9	Original length was 346.96
O13-001	O13-021	O13-001_O13-021	12	PVC	272.3	Original length was 330.88
O12-021	O12-020	O12-021_O12-020	15	PVC	294.5	Original length was 382.66
O12-021	O12-020	O12-021_O12-020	15	PVC	415.4	Original length was 382.66
O12-006	O12-005	O12-006_O12-005	15	PVC	503.3	Original length was 434.11
O12-005	O12-004	O12-005_O12-004	15	PVC	505.2	Original length was 362.54
O12-004	O12-003	O12-004_O12-003	15	PVC	284.2	Original length was 499.1
O12-003	O10-002	O12-003_O10-002	15	PVC	188.9	Original length was 150.46

The locations of unknown manholes O13-046A and O13-047A were shown previously in Figure 3-4 and were the same unknown manholes identified during manhole inspections.

7 Conclusions and Recommendations

7.1 Conclusions

The objectives of this project were:

1. Check for pipe connectivity, structural defects, and potential sources of I&I in existing manholes and sanitary sewer lines within the specific neighborhoods selected to be investigated.
2. Collect flow and rainfall data and perform I&I analysis on the separated sanitary sewers in the City of Manor.
3. Use the data collection to update the City's GIS and ensure accurate routing is documented.

All objectives were met through the completion of manhole inspections, smoke testing, CCTV, and flow monitoring in this Project Area. Several areas of GIS updates have been identified and were discussed in Chapter 6. Many sources of I&I were discovered throughout the completion of the field inspections and can be addressed with a rehabilitation program.

The conclusions for this project area are:

- The sanitary sewer lines appear to be in good shape and only approximately 10.2% of the 107 lines inspected have significant structural defects that should be fixed.
- The manhole structures are in slightly worse condition, with approximately 31% needing some level of rehabilitation.
- Smoke testing identified 237 clean-outs that have broken, missing, or leaking lids that could be addressed to reduce storm inflow into the system.

7.2 Recommendations

7.2.1 Maintenance Items

Flow Monitoring Items

Based on the 2022 Fall flow monitoring results, seven (7) of the twelve (12) basins showed evidence of inflow sources. Inflow is most often associated with system surcharging because it is the result of sources directly tied into the system and causes rain-induced flows to enter the system much quicker than through infiltration sources.

The best way to detect infiltration sources is by performing sanitary sewer smoke testing. GBA recommends that the City adopt a multi-year inflow-reduction program, similar to what is shown below in Table 7-1, to identify, design, and rehabilitate I&I sources in the leakiest basins. Smoke testing would be the first round of inspections to be completed, and the results of the smoke testing would indicate more specific locations for additional investigations in the form of CCTV and manhole inspections. It is anticipated that approximately 30% of the system will need to be televised, and 25% of the manholes will need further inspection. Once sources and conditions are identified, rehabilitation design documents can be created and construction of repairs accomplished.

Based on the aforementioned quantities, the recommended City annual budget amounts for the investigations should follow the schedule shown below:

- 2023: $68,225
- 2024: $104,390
- 2025: $84,088
- 2026: $113,745

The basins listed in Table 7-1 were ranked in order from highest to lowest inflow rates as the leakiest basins should be addressed first. These costs also include the estimated costs of Administration, Analysis, and Reporting.

To ensure the most effective discovery, analysis, design, and rehabilitation of I&I sources, a schedule similar to one shown in Table 7-2 is recommended. This schedule is broken up into three phases for each problem area:

1. Field work or Preliminary Engineering – the investigation and analysis of specific basins with a focus on I&I sources. This task will also include post-construction flow monitoring to help determine if I&I was successfully reduced.

2. Design or Final Engineering – the preparation of construction documents, plans, and specifications for competitive sealed bidding.

3. Construction and Observation – the periodic observation of the rehabilitation of defects identified and designed in Phases 1 and 2. Construction observation is crucial at this phase because it will ensure the construction is done correctly and future construction-related failures such as sagging of pipes will be minimized.

The rate of these phases will depend on City budgets and staff availability to work with consultant on the various phases. GBA has seen great success of programs like this in other similarly-sized clients.

Manhole Inspection Items

Inspection attempts were made at all manholes assigned to this project to confirm pipe connectivity. Out of the 136 structures selected for inspections and analysis, 6 were not able to be inspected.

- It is recommended that the City locate and inspect the three (3) manholes located in private back-yards: O13-002, O13-021, and O13-025.

- It is recommended that the City uncover the two (2) buried manholes and raise them to grade: O13-004 and O13-012.

- The lift stations along Old Hwy 20 – Carriage Hills and Bell Farms – should be heavily cleaned and calibrated to ensure they are operating with correct levels. The systems upstream of these lift stations showed signs of flow backing up and being held in the lines which leads to deposition of debris, the formation of grease plugs (as was seen in manhole O13-006), and potential back-ups into residents' homes.

CCTV Items

The lines identified in Table 7-3 that have sagging in them should be placed on a routine maintenance and inspection schedule. It is recommended that the lines are televised at a minimum every 5 years and

cleaned as needed. If a sag is not cleaned periodically, sump conditions will cause debris to collect, eventually filling the pipe and stopping flow.

Table 7-1 – Inflow Reduction Program for the City of Manor

Focus of Investigations Year Basin Location	Inflow 2024 Basin 3	Inflow 2024 Basin 10	Inflow 2024 Basin 13	Inflow 2025 Basin 2B	Inflow 2025 Basin 8	Inflow 2025 Basin 1	Inflow 2026 Basin 4
Total LF of sewer	22,230	7,366	17,588	9,396	10,672	16,668	37,396
Manholes	91	23	55	28	58	61	105
Total Smoke Testing (LF)	22,230	7,366	17,588	9,396	10,672	16,668	37,396
Cost of Total Smoke Testing	$ 22,230	$ 7,366	$ 17,588	$ 9,396	$ 10,672	$ 16,668	$ 37,396
Number of Dyed Water Tests	10	4	7	5	5	7	20
Cost of Dyed Water Testing	$ 1,300	$ 520	$ 910	$ 650	$ 650	$ 910	$ 2,600
% of System to CCTV	30%	30%	30%	30%	30%	30%	30%
Cost of CCTV	$ 26,676	$ 8,839	$ 21,106	$ 11,275	$ 12,806	$ 20,002	$ 44,875
% of Manholes to Inspect	25%	25%	25%	25%	25%	25%	25%
Cost of Manhole Inspections	$ 2,275	$ 575	$ 1,375	$ 700	$ 1,450	$ 1,525	$ 2,625
Total Cost of Field Work	$ 52,481	$ 17,300	$ 40,979	$ 22,021	$ 25,578	$ 39,105	$ 87,496
Administration, Analysis, and Reporting	$ 15,744	$ 5,190	$ 12,294	$ 6,606	$ 7,674	$ 11,731	$ 26,249
Total Cost of Investigations	**$ 68,225**	**$ 22,490**	**$ 53,272**	**$ 28,628**	**$ 33,252**	**$ 50,836**	**$ 113,745**

Table 7-2 – Inflow Reduction Program Schedule for the City of Manor

	2024	2025				2026				2027				2028			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Basin 3 Investigations Basin 10 Investigations Basin 13 Investigations	Field Work ("Preliminary Engineering")		Design ("Final Engineering")			Construction/Observation			Post-Construction Flow Monitoring								
Basin 2B Investigations Basin 8 Investigations Basin 1 Investigations			Field Work ("Preliminary Engineering")			Design ("Final Engineering")			Construction/Observation			Post-Construction Flow Monitoring					
Basin 4 Investigations							Field Work ("Preliminary Engineering")			Design ("Final Engineering")			Construction/Observation			Post-Construction Flow Monitoring	

Table 7-3 – CCTV Major Defects

Pipe ID	USMH	DSMH	Diam	Matl	PAPC Score	Defect	Defect Dist. From USMH	Comment
O12-009 - O12-008	O12-009	O12-008	8	PVC	4G34	MWLS	50.1, 26.2-196.8	MSA at 50.1 ft DS. due to debris. Rated 3423D, reversal was rated 4G00. Sag rated 3/4 for 30.1 US-196.8 US
O13-010 - O13-009	O13-010	O13-009	8	PVC	4A37	MWLS	175.2-200.1, 227.3-243.2, 315.3	Multiple significant sags in line. 175.2-200.1, 227.3-243.2, 315.3-335.1
O13-016 - O13-015	O13-016	O13-015	8	PVC	4135	MWLS	39.6-66.0	Sag rated 3 from 39.6-66.0 ft DS. MCU rated 4 at 46.5
O13-001 - O13-021	O13-001	O13-021	12	PVC	4100	IR	272.3	Infiltration Runner rated 4 at 272.3ft DS
N12-009 - O12-019	N12-009	O12-019	8	PVC	3700	MWLS	230-265	Sag rated 3 from 230-265Ft DS
N13-012 - N12-009	N13-012	N12-009	8	PVC	3112	FL	503	Flow Level rated 3 at 503 ft DS
O12-008 - O12-007	O12-008	O12-007	8	PVC	3424	MWLS	8-23.9, 237.2	Sag rated 3 at 8-23.9ft D and at 237.2ft D. Other minor sags in line rated 2.
O12-019 - O12-018	O12-019	O12-018	8	PVC	382A	MWLS	29-125, 289-361	Sag rated 3 from 29-125 DS and 289-361 DS sags rated 2 also in line
O13-012 - O13-011	O13-012	O13-011	8	PVC	3900	MWLS	190-251, 377-558	Sag rated 3 from 190-251, and 377-558 ft DS
O13-044 - O13-043	O13-044	O13-043	8	PVC	372C	MWLS	126.4-184.5	Sag rated 3 from 126.4-184.5 ft DS. MSA due to debris. Line had significant amount of debris which had to be cleaned. Line rated 3A22 DS initially, rated 372C upon redo. Redo was 241.5D, first pass was 184.6D.
O13-046 - O13-045	O13-046	O13-045	8	PVC	3A25	MWLS	4.5-55.8, 237.8-250.8	Sag rated 3 from 4.5-55.8 DS and again at 237.8-250.8 DS. Sags rated 2 also in line.

7.2.2 Construction Items

Based on structural condition assessments of the 127 successfully inspected manholes, it is recommended that the City perform rehabilitation on the 19 manholes with the worst rating. The manholes in need of rehabilitation, as well as the type of rehabilitation recommended, are listed in Table 7-4.

Smoke testing exposed several areas of storm water inflow into the sanitary system that should be addressed.

- It is recommended that the City address the following private I&I sources:
    - Work with homeowner to disconnect the foundation drain at 12828 Doorbell Drive.
    - Check and fix broken caps or replace missing caps on 237 cleanouts listed in Appendix D.

Based on the flow monitoring analysis and the SSES work completed as part of this project, the drainage areas to meter sites 6 and 7 had an excessive infiltration rate, inflow rate, and rain to sewer percentage. The rehabilitation recommendations listed in Tables 7-3 and 7-4 should decrease these I&I rates.

- It is recommended that the City perform post-rehabilitation flow monitoring to see if a reduction in I&I can be measured.

7.2.3 Administrative Items

The SSES investigations completed showed that the City's GIS network is lacking correct information on line size and material for several segments.

- It is recommended the City consider performing a system-wide update to incorporate CCTV data and manhole inspection data into their GIS databases. The lines with the necessary changes are listed in Table 7-5.

Table 7-4 – Manholes in Need of Rehabilitation

		Location of defect							Recommended Rehabilitation/Maintenance							
Manhole ID	**Inspection Rating**	**Frame**	**FBS**	**Grade Ring**	**Chimney**	**Chamber**	**Channel**	**Other**	**Reset MH part**	**Install FBS**	**Line MH**	**Cleaning**	**Point Repair**	**Pipe Seals**	**Other**	**Comments**
O12-003	4			✔		✔			✔	✔				✔		Liner peeling around grade ring and around pipes, manhole offset at grade ring.
O12-004	4					✔					✔					Lining peeling off at bottom of chamber, manhole joint separating at chamber, infiltration at chamber.
O12-006	4					✔			✔		✔					Liner is peeling at the chamber, manhole separation at midpoint.
O12-007	4					✔	✔				✔	✔				Liner bubbles in chamber, flow line obstruction in north in pipe.
O12-008	4					✔	✔				✔	✔				Total liner failure in chamber, south in pipe (dry) full of debris, debris on bench.
O12-010	4						✔					✔				A chunk of PVC pipe is in the mouth of the in pipe .
O12-021	4		✔	✔		✔				✔	✔					Lining around grade ring is peeling all around , cracks around concrete frame surround, major infiltration point at bench of manhole.
O13-005	4							Surcharge				✔				Manhole surcharged, most likely due to back-up from lift station.
O13-006	4				✔		✔				✔	✔				Grease surcharge flowline obstruction and debris, liner failure at mouth of chimney.
O13-013	4		✔	✔	✔			Broken lid		✔	✔	✔			New MH lid	Crack surrounding grade ring, asphalt surrounding manhole cover is broken, roots growing through crack in chimney.
O13-017	4				✔						✔					No lining, large crack all the way around chimney.
O13-023	4							Broken lid							New MH lid	Manhole lid broken.
O13-035	4					✔					✔					Chamber seal is missing, no lining.
O13-036	4					✔					✔					Cracked all the way around chamber and no lining.
O13-037	4		✔		✔					✔			✔			Large crack all the way around chimney, quarter inch in width. I&I staining from under the frame.
O13-038	4		✔		✔					✔			✔			Large crack all the way around and I&I staining.
O13-041	4				✔								✔			Crack surrounding chimney.
O13-058	4				✔	✔					✔					Crack surrounding chimney with liner failure, crack surrounding half of the chamber with bubbling.
UMH-2	4		✔		✔					✔	✔					Manhole between O13-057 and O13-046, large crack surround chimney with void visible. Heavy staining from under frame.

FBS = Frame Base Seal

Table 7-5 – GIS Updates Recommended

USMH	DSMH	Pipe ID	Diam	Material	Length	Comment
N12-001	O12-012	N12-001_O12-012	8	PVC	343	Original length was 338.88
N13-002	N13-001	N13-002_N13-001	8	PVC	218.7	Original length was 199.12
N13-013	O13-050	N13-013_O13-050	8	PVC	394.8	Original length was 371.6
O12-008	O12-007	O12-008_O12-007	8	PVC	240.5	Original length was 288.81
O12-012	O12-002	O12-012_O12-002	12	PVC	146.31	Line appears to be 12”, not 8”
O13-017	O13-016	O13-017_O13-016	8	PVC	269.6	Original length was 308.43
O13-020	O13-008	O13-020_O13-008	8	PVC	294.7	Original length was 321.85
O13-021	O13-020	O13-021_O13-020	8	PVC	73.4	Original length was 54.77
O13-023	O13-022	O13-023_O13-022	8	PVC	206.1	Original length was 229.47
O13-024	O13-023	O13-024_O13-023	8	PVC	84.6	Original length was 64.34
O13-026	O13-025	O13-026_O13-025	8	PVC	213.1	Original length was 198.06
O13-035	O13-025	O13-035_O13-025	8	PVC	158.7	Original length was 107.5
O13-036	O13-035	O13-036_O13-035	8	PVC	418.3	Original length was 458.59
O13-040	O13-039	O13-040_O13-039	8	PVC	415.3	Original length was 392.31
O13-043	O12-021	O13-043_O12-021	8	PVC	315.4	Original length was 292.5
O13-044	O13-043	O13-044_O13-043	8	PVC	241.5	Original length was 309.09
O13-045	O13-044	O13-045_O13-044	8	PVC	177.4	Original length was 202.54
O13-056	UMH1	O13-056_ UMH1	8	PVC	379.2	New MH labeled UMH1
UMH1	O13-047	UMH1_O13-047	8	PVC	199.2	New MH labeled UMH1
O13-057	UMH2	O13-057_ UMH2	8	PVC	368.2	New MH labeled UMH2
UMH2	O13-046	UMH2_O13-046	8	PVC	192.2	New MH labeled UMH2
O13-002	O13-001	O13-002_O13-001	12	PVC	403.9	Original length was 346.96
O13-001	O13-021	O13-001_O13-021	12	PVC	272.3	Original length was 330.88
O12-021	O12-020	O12-021_O12-020	15	PVC	294.5	Original length was 382.66
O12-021	O12-020	O12-021_O12-020	15	PVC	415.4	Original length was 382.66
O12-006	O12-005	O12-006_O12-005	15	PVC	503.3	Original length was 434.11
O12-005	O12-004	O12-005_O12-004	15	PVC	505.2	Original length was 362.54
O12-004	O12-003	O12-004_O12-003	15	PVC	284.2	Original length was 499.1
O12-003	O10-002	O12-003_O10-002	15	PVC	188.9	Original length was 150.46

Appendix A – Flow Monitoring Site Data

Due to the size of this Appendix, it will be included as a separate document submitted with this report.

Appendix B – Manhole Inspections Rated 3

MH ID	COVER TYPE	MH MATERIAL	MH DEPTH	RATING	TYPE OF DEFECT	DEFECT LOCATION	COMMENTS
N12-009	Standard	CONC	10.36	3	Maintenance	Bench or Channel	Sanitation debris in invert, grease in invert.
N12-010	Standard	PVC	10.9	3	Structural	Chimney	Liner flaking off with cracks underneath surrounding chimney,grease in channel, manhole cover pick hole is filled with concrete.
N13-010	Standard	CONC	6.59	3	Structural	Frame or Cover	Manhole frame has liner pealing and cracking around it.
O12-005	Bolt Down	CONC	17.4	3	Structural	Grade Ring	Manhole ring offset from grade ring.
O12-009	Standard	CONC	12.61	3	Maintenance and Structural	Bench or Channel	Seems to be heavy debris in invert and on bench, flow obstruction in east in pipe. Liner failure above out pipe in chamber.
O13-008	Standard	CONC	16.19	3	Structural	Grade Ring	Liner bubbling, cracks surrounding reducer.
O13-009	Standard	CONC	16.98	3	Structural	Chimney	Frame deterioration, crack surrounding chimney.
O13-010	Standard	CONC	14.58	3	Structural	Chimney	Cracks surrounding chimney.
O13-011	Standard	CONC	13.85	3	Structural	Grade Ring	Rag obstructing flow, crack surrounding grade ring.
O13-014	Standard	CONC	9.2	3	Structural	Grade Ring	Crack around grade ring.
O13-018	Standard	CONC	8.47	3	Structural	Reducer or Chamber	No lining no cracked all the way around
O13-019	Standard	CONC	6.13	3	Structural	Reducer or Chamber	No liner in manhole, crack all the way around chamber.
O13-020	Standard	CONC	8.26	3	Structural	Grade Ring	Crack surrounding grade ring.
O13-026	Standard	CONC	8.64	3	Structural	Reducer or Chamber	No liner in manhole; crack around manhole chamber.
O13-027	Standard	CONC	6.06	3	Structural	Reducer or Chamber	No liner in manhole,crack around manhole chamber.
O13-028	Standard	CONC	6.13	3	Structural	Reducer or Chamber	No liner around manhole, 2 cracks around manhole chamber.
O13-029	Standard	CONC	8.12	3	Structural	Chimney	Crack all the way around at lower chimney
O13-032	Standard	CONC	6.52	3	Structural	Chimney	Crack along chimney and crying
O13-042	Standard	CONC	6.53	3	Structural	Reducer or Chamber	Crack surrounding chamber.
O13-045	Standard	CONC	12.42	3	Structural	Frame or Cover	Grease in chamber, cracks surround frame liner failing, liner cracks in chamber cracks in liner above north in pipe,
O13-047	Standard	PVC	14.21	3	Structural	Bench or Channel	Bench missing large section of liner, liner cracks on top of both in and out pipe.
O13-057	Standard	CONC	5.27	3	Structural	Chimney	Liner pealing in chimney.

Appendix C – CCTV Results

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
512-581-8669

Project Summary

Manor 9-8-22

Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13046MHO13046AA	9/16/2022	Tinker St	MH O13-046	MH O13-046A	PVC	199.7	199.7
MH012017MH012016A	9/8/2022	Albatross Pass	MH 012-017	MH 012-016	PVC	373.2	373.2
MHN13001MHO13055A	9/15/2022	Carillon Way	MH N13-001	MH O13-055	PVC	402.2	402.2
MHN13013MHO13050A	9/16/2022	Snow Lane	MH N13-013	MH O13-050	PVC	394.8	394.8
MHO13050MHO13049A	9/16/2022	Snow Lane	MH O13-050	MH O13-049	PVC	401.0	401.0
MHO13054MHO13049A	9/16/2022	Ring Dr	MH O13-054	MH O13-049	PVC	246.6	246.6
MHO13049MHO13048A	9/16/2022	Ring Dr	MH O13-049	MH O13-048	PVC	320.8	320.8
MHO13056MHO13047A	9/16/2022	Ship Bell Dr	MH O13-056	MH O13-047	PVC	379.5	379.5
MHO13047MHO13047AA	9/16/2022	Ship Bell Dr	MH O13-047	MH O13-047A	PVC	199.2	199.2

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13055MHO13048A	9/16/2022	Carillon Way	MH O13-055	MH O13-048	PVC	405.2	405.2
MHN13005MHN13002A	9/15/2022	Carillon Way	MH N13-002	MH N13-005	PVC	170.4	170.4
MHO13057MHO13046A	9/16/2022	Manor	MH O13-057	MH O13-046	PVC	368.2	368.2
MHN13003MHN13002A	9/15/2022	Wedding Dr	MH N13-003	MH N13-002	PVC	402.0	402.0
MHO13053MHO13052A	9/21/2022	Casting Dr	MH O13-053	MH O13-052	PVC	324.2	324.2
MHO13052MHO13051A	9/21/2022	Casting Dr	MH O13-052	MH O13-051	PVC	307.3	307.3
MHO13047MHO13046A	9/21/2022	Carillon Way	MH O13-047	MH O13-046	PVC	279.3	279.3
MHO13046MHO13045A	9/21/2022	Carillon Way	MH O13-046	MH O13-045	PVC	250.8	250.8
MHO13051MHO13045A	9/21/2022	Pealing Way	MH O13-051	MH O13-045	PVC	298.3	298.3
MHO13045MHO13044A	9/21/2022	Pealing Way	MH O13-045	MH O13-044	PVC	177.4	177.4
MHO13044MHO13043A	9/21/2022	Pealing Way - Heavy Cleaning	MH O13-044	MH O13-043	PVC	241.7	184.6

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13028MHO13027A	9/21/2022	Pine Needle	MH O13-028	MH O13-027	PVC	358.2	358.1
MHO13036MHO13035A	9/21/2022	Forest Sage	MH O13-036	MH O13-035	PVC	418.3	418.3
MHO13038MHO13037A	9/21/2022	High Sierra St	MH O13-038	MH O13-037	PVC	475.1	475.1
MH O13-048MH O13-047AA	9/16/2022	Carillon Way	MH O13-048	MH O13-047A	PVC	288.7	288.7
MHN13006MHN12011A	9/9/2022	Wedding Dr	MH N13-006	MH N12-011	PVC	403.0	403.0
MHO12016MHO12015A	9/8/2022	Albatross Pass	MH O12-016	MH O12-015	PVC	79.5	79.5
MHO12024MHO12015A	9/8/2022	Woodcock Way	MH O12-024	MH O12-015	PVC	283.1	283.1
MHO12015MHO12014A	9/8/2022	Woodcock Way	MH O12-015	MH O12-014	PVC	396.9	396.9
MHO12014MHO12013A	9/8/2022	Woodcock Way	MH O12-014	MH O12-013	PVC	406.6	406.5
MHO12013MHO12012A	9/8/2022	Woodcock Way	MH O12-013	MH O12-012	PVC	335.4	335.4
MHO12027MHO12026A	9/8/2022	Ostrich Trail	MH O12-027	MH O12-026	PVC	413.5	413.5

Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO12026MHO12025A	9/8/2022	Ostrich Trail	MH O12-026	MH O12-025	PVC	323.5	323.5
MHO12025MHN12001A	9/8/2022	Ostrich Trail	MH O12-025	MH N12-001	PVC	267.0	267.0
CON13P01MHN3008A	9/9/2022	Wedding Dr.	MH N13-008	CO N13-P01	PVC	170.8	170.8
MHN13002MHN13001A	9/15/2022	Carillon Way	MH N13-002	MH N13-001	PVC	218.7	218.7
MHN13007MHN13006A	9/9/2022	Wedding Dr.	MH N13-007	MH N13-006	PVC	404.7	404.7
MHO13037MHO13024A	9/24/2022	High Sierra St	MH O13-037	MH O13-024	PVC	161.7	161.7
MHN12011MHN12010A	9/9/2022	St. Mary Dr	MH N12-011	MH N12-010	PVC	303.6	303.5
MHN12010MHN12009A	9/9/2022	St. Mary Dr	MH N12-010	MH N12-009	PVC	286.5	286.5
MHN12009MHO12019A	9/9/2022	St. Mary Dr	MH N12-009	MH O12-019	PVC	325.7	325.7
MHO12019MHO12018A	9/9/2022	St. Mary Dr	MH O12-019	MH O12-018	PVC	398.5	398.5
MHN13010MHN13009A	9/15/2022	Door Bell Dr	MH N13-010	MH N13-009	PVC	372.8	372.8

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHN13009MHN12010A	9/15/2022	Door Bell Dr	MH N13-009	MH N12-010	PVC	399.0	399.0
MHN13011MHO13058A	9/15/2022	Chime Dr	MH N13-011	MH O13-058	PVC	505.5	505.5
MHO13058MHN13012A	9/15/2022	Ring Dr	MH O13-058	MH N13-012	PVC	376.1	376.1
MHN13012MHN12009A	9/15/2022	Ring Dr	MH N13-012	MH N12-009	PVC	503.9	503.9
MHN13004MHN13003A	9/15/2022	Wedding Dr	MH N13-004	MH N13-003	PVC	331.2	331.2
MHN13008MHN13007A	9/9/2022	Wedding Dr.	MH N13-008	MH N13-007	PVC	231.2	231.2
MHN12003MHN12002A	9/27/2022	Skimmer Run	MH N12-003	MH N12-002	PVC	135.8	135.7
MHO12009MHO12008A	9/25/2022	Bella Prky - reversal	MH O12-009	MH O12-008	PVC	223.0	50.1
MHO12008MHO12007A	9/25/2022	Bella Prky	MH O12-008	MH O12-007	PVC	240.5	240.5
MHO12009MHO12008A	9/25/2022	Bella Prky - reversal	MH O12-008	MH O12-009	PVC	223.0	196.8
MHO13011MHO13010A	9/24/2022	Indian Oak Bend	MH O13-011	MH O13-010	PVC	182.9	182.9

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13012MHO13011A	9/24/2022	Indian Oak Bend	MH O13-011	MH O13-012	PVC	167.6	167.6
MHO13010MHO13009A	9/24/2022	Indian Oak Bend	MH O13-010	MH O13-009	PVC	365.0	365.0
MHO13009MHO13008A	9/24/2022	Indian Oak Bend	MH O13-009	MH O13-008	PVC	202.9	202.9
MHO13041MHO13009A	9/24/2022	Camellia Cove	MH O13-041	MH O13-009	PVC	165.1	165.1
MHO13008MHO13007A	9/24/2022	Carriage Hills Dr	MH O13-008	MH O13-007	PVC	327.5	327.5
MHO13019MHO13018A	9/21/2022	Pine Needle	MH O13-019	MH O13-018	PVC	284.8	284.8
MH N12-004MH N12-003	9/27/2022	Skimmer Run	MH N12-004	MH N12-003	PVC	140.0	140.0
MHO13044MHO13043A	9/25/2022	Pealing Way - Heavy Cleaning	MH O13-044	MH O13-043	PVC	241.7	241.5
MHN12002MHN12001A	9/27/2022	Skimmer Run	MH N12-002	MH N12-001	PVC	187.0	187.0
MHN12007MHN12006A	9/27/2022	Skimmer Run	MH N12-006	MH N12-007	PVC	64.4	64.4
MHN12008MHN12006A	9/27/2022	Skimmer Run	MH N12-006	MH N12-008	PVC	50.8	50.8

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO12018MHO12009A	9/27/2022	St Mary Dr	MH O12-018	MH O12-009	PVC	325.2	325.2
MHO13029MHO13015A	9/25/2022	Forest Sage	MH O13-029	MH O13-015	PVC	269.5	269.5
MHO13035MHO13025A	9/25/2022	Manor Forest Sage	MH O13-035	MH O13-025	PVC	158.7	158.7
MHO13043MHO12021A	9/25/2022	Pealing Way	MH O13-043	MH O12-021	PVC	315.4	315.4
MHN12001MHO12012A	9/25/2022	Skimmer Run	MH N12-001	MH O12-012	PVC	343.3	343.0
MHO12012MHO12002A	9/25/2022	Manor Skimmer Run	MH O12-012	MH O12-002	PVC	143.6	143.6
MHN12006MHN12005A	9/27/2022	Skimmer Run	MH N12-006	MH N12-005	PVC	64.9	64.9
MHO13007MHO13006A	9/24/2022	Carriage Hills Dr	MH O13-007	MH O13-006	PVC	138.6	138.6
MHO13015MHO13014A	9/24/2022	Ring Dr	MH O13-014	MH O13-015	PVC	89.1	89.1
MHN12005MHN12004A	9/27/2022	Skimmer Run	MH N12-005	MH N12-004	PVC	91.6	91.4
MHO13023MHO13022A	9/24/2022	Ring Dr	MH O13-022	MH O13-023	PVC	206.1	206.1

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13024MHO13023A	9/24/2022	Ring Dr	MH O13-023	MH O13-024	PVC	84.6	84.6
MHO13025MHO13024A	9/24/2022	Ring Dr	MH O13-024	MH O13-025	PVC	305.4	305.4
MHO13026MHO13025A	9/24/2022	Ring Dr	MH O13-025	MH O13-026	PVC	213.1	213.1
MHO13022MHO13021A	9/24/2022	Ring Dr	MH O13-022	MH O13-021	PVC	309.6	309.6
MHO13020MHO13008A	9/24/2022	Pecan Hill Cove	MH O13-020	MH O13-008	PVC	294.7	294.7
MHO13021MHO13020A	9/24/2022	Pecan Hill Cove	MH O13-020	MH O13-021	PVC	73.4	73.4
MHO13031MHO13014A	9/24/2022	High Sierra St	MH O13-031	MH O13-014	PVC	276.6	276.6
MHO13017MHO13016A	9/24/2022	Pine Needle	MH O13-017	MH O13-016	PVC	269.6	269.5
MHO12010MHO12009A	9/25/2022	Bella Prky	MH O12-010	MH O12-009	PVC	402.2	402.2
MHO13014MHO13013A	9/24/2022	Ring Dr	MH O13-013	MH O13-014	PVC	298.9	298.9
MHO12011HO12010A	9/25/2022	Bella Prky	MH O12-011	H O12-010	PVC	202.2	202.2

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13016MHO13015A	9/24/2022	Ring Dr	MH O13-015	MH O13-016	PVC	204.8	204.8
MHO13018MHO13017A	9/21/2022	Manor	MH O13-018	MH O13-017	PVC	258.9	258.9
MH O13-030MH O13-029	9/21/2022	Forest Sage St	MH O13-030	MH O13-029	PVC	403.7	403.7
MHO13032MHO13031A	9/21/2022	High Sierra St	MH O13-032	MH O13-031	PVC	281.9	281.9
MHO13040MHO13039A	9/21/2022	Ring Dr	MH O13-040	MH O13-039	PVC	415.3	415.3
MHO13039MHO13022A	9/21/2022	Ring Dr	MH O13-039	MH O13-022	PVC	205.7	205.7
MHO13034MHO13033A	9/21/2022	Ring Dr	MH O13-034	MH O13-033	PVC	283.5	283.5
MHO13033MHO13013A	9/21/2022	Ring Dr	MH O13-033	MH O13-013	PVC	277.2	277.2
MHO13042MHO13007A	9/25/2022	Prairie Sage Cove	MH O13-042	MH O13-007	PVC	200.5	200.5
MHO13027MHO13026A	9/24/2022	Pine Needle	MH O13-027	MH O13-026	PVC	213.8	213.8
MHO13013HO13012A	9/24/2022	Ring Dr	MH O13-013	MH O13-012	PVC	212.5	212.5

Number of inspections: 97

Subtotal **26,616.6 ft** **26,359.2 ft**

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
512-581-8669

Project Summary

Manor - Heavy cleaning & CCTV 12-28-22 thru 1-30-23

Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO12-002_MHO12-001A	1/30/2023	Skimmer Run - Old Tx-20 Hwy Easement	MH O12-002	MH O12-001	PVC	81.2	81.1
MHO12-003_MHO12-002A	1/27/2023	Old Tx-20 Hwy Easement	MH O12-003	MH O12-002	PVC	188.9	188.9
MHO12004_MHO12003A	1/27/2023	Old TX 20 Hwy Easement	MH O12-004	MH O12-003	PVC	284.2	284.2
MHO12-005_MHO12-004A	1/18/2023	Old Tx-20 Hwy Easement	MH O12-005	MH O12-004	PVC	505.2	505.2
MHO12-006_MHO12-005A	1/18/2023	Old Tx-20 Hwy Easement	MH O12-006	MH O12-005	PVC	503.3	503.3
MHO12-007_MHO12-006A	1/18/2023	Old Tx-20 Easement	Drive MH O12-007	MH O12-006	PVC	504.9	504.9
MHO12-020_MHO12-007A	1/17/2023	Old Tx-20 Easement	MH O12-020	MH O12-007	PVC	294.5	294.5
MHO12-021_MHO12-020A	1/17/2023	Old Tx-20 Easement	MH O12-021	MH O12-020	PVC	415.4	415.4
MHO13-003_MHO13-002A	12/29/2022	Casting Dr-Old Tx-20 Hwy Easement	MH O13-003	MH O13-002	PVC	263.6	263.6

Tunnel Vision Pipeline Cleaning and Video Inspection, Inc.
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Main ID	Date	Address	Start MH	Finish MH	Pipe	Asset length	Surveyed Length
MHO13-002_MHO13-001	12/29/2022	Old Tx-20 Hwy Easement	MH O13-002	MH O13-001	PVC	403.9	403.9
MHO13-001_MHO12-021A	12/29/2022	Old Tx-20 Hwy Easement	MH O13-001	MH O12-021	PVC	272.3	272.3
MHO13-004_MHO13-003A	12/28/2022	Old Tx-20 Hwy Easement	MH O13-003	MH O13-004	PVC	139.4	139.4
MHO13-005_LS05A	12/28/2022	Old Tx-20 Hwy Easement	MH O13-005	LS05	PVC	58.8	58.8
MHO13-006_MHO13-005A	12/28/2022	Carriage Hills Drive -Old Tx-20 Hwy Easement	MH O13-006	MH O13-005	PVC	302.4	302.3

Number of inspections: 14

Subtotal	**4,218.0 ft**	**4,217.8 ft**
Total	**4,218.0 ft**	**4,217.8 ft**

Appendix D – Defective Clean-out List