



westonandsampson.com

WESTON & SAMPSON ENGINEERS, INC.
55 Walkers Brook Drive, Suite 100
Reading, MA 01867
tel: 978.532.1900

REPORT

September 2023

TOWN OF
Rockland
MASSACHUSETTS

Annual I/I and O&M Program Year 1 –
Flow Metering and I/I Analysis



TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	i
LIST OF FIGURES	ii
LIST OF TABLES	iii
LIST OF APPENDICES	iv
EXECUTIVE SUMMARY	ES-1
1.0 INTRODUCTION	1-1
1.1 Background	1-1
1.2 Project Area	1-1
1.3 Project Objectives	1-1
2.0 FLOW MONITORING RESULTS & FINDINGS	2-1
2.1 Groundwater Monitoring	2-1
2.2 Rainfall Monitoring	2-2
2.3 Flow Metering	2-2
2.3.1 Infiltration	2-4
2.3.2 Inflow	2-5
2.3.3 Design Storm RDII Volume	2-7
3.0 CONCLUSIONS & RECOMMENDATIONS	3-1
3.1 Conclusions	3-1
3.2 Recommendation	3-2
4.0 REFERENCES	4-1

LIST OF FIGURES

Figure 1Project Area Map

Figure 2Flow Meter Schematic

Figure 3.....Groundwater Level

LIST OF TABLES

Table 1	Project Area Sewer System Summary
Table 2.....	Rainfall Monitoring Data
Table 3	Wastewater Summary
Table 4	Infiltration Summary
Table 5.....	Inflow Summary
Table 6	Design Storm RDII Summary
Table 7	Priority Ranking

LIST OF APPENDICES

Appendix AMeter Installation Logs

Appendix BHydrographs

Appendix CPeak Net I/I Regression Plots

Appendix D.....Total Event Net RDII Volume Regression Plots

EXECUTIVE SUMMARY

The Town of Rockland retained Weston & Sampson to conduct the Year 1 of the Annual Infiltration/Inflow (I/I) and Operation & Maintenance (O&M) Program in Rockland, Massachusetts. This report summarizes the results of flow metering and provides recommendations for next steps. Flow metering, groundwater, and rainfall monitoring was conducted by Weston & Sampson's subconsultant from April 24 through July 6, 2023. An estimation of the Town's I/I quantity was developed by analyzing the data collected during the flow metering program. The Department of Environmental Protection (DEP) *Guidelines for Performing Infiltration/Inflow Analyses and Sewer System Evaluation Survey* were used as the basis for the flow data analysis.

The project area in the flow metering program consists of approximately 300,000 linear feet (lf) of sewers ranging in size from 8- to 33-inches in diameter. A total of fifteen (15) flow meters were installed in manholes within the project area. Groundwater gauges were installed at three (3) of the flow meter locations and one (1) rain gauge was installed on the roof of the Town's Wastewater Treatment Plant building.

To perform the I/I analysis, Weston & Sampson utilized a computer I/I analytics software program, to extract and estimate I/I within the project area.

Infiltration and Inflow

Infiltration

The flow metering program found an estimated total base infiltration of approximately 915,000 gallons per day (gpd) entering the sewer system. Typically, the "average" base daily infiltration rate is approximately 75% of the peak infiltration rate. Using this assumption, approximately 1,220,000 gpd of peak infiltration enters the Town's collection system during high groundwater periods.

Due to the varying sizes of the metered areas and the different lengths and diameters of the sewer, the estimated infiltration rate was calculated for each metered area in gpd and then again in gallons per day per inch-mile (gpdim). In accordance with DEP Guidelines, peak infiltration rates greater than or equal to 4,000 gpdim are considered "excessive" and should be prioritized for further investigation. Four (4) of the metered subareas, 6, 9, 11, and 13, had peak infiltration rates of over 4,000 gpdim. Overall, the peak infiltration of the entire town's collection system was approximately 1,600 gpdim.

Inflow

Inflow is defined as any extraneous storm water that enters the sewer collection system through either direct or indirect sources, including but not limited to surface drains, roof leaders, sump pumps and cross connections from other drainage systems.

The peak design storm inflow was obtained by subtracting the base infiltration rate from the peak design storm rainfall derived infiltration and inflow (RDII) value. The DEP Guidelines recommend estimating inflow for the peak design storm which refers to the standard 5-year, 24-hour storm event and utilizes a peak hourly rainfall intensity of 0.73 inches per hour and approximately 4.61 inches of rain. The results of the flow metering program estimated the peak design storm inflow for the project area at approximately 1.89 million gallon per day (mgd).

The estimated peak design storm inflow for each meter was used to determine which areas contributed the most inflow into the Town's wastewater collection system. Based on DEP Guidelines, areas contributing greater than 80% of the total peak design storm inflow should be considered excessive. Seven (7) out of the fifteen (15) metered areas, 3, 5, 6, 10, 11, 12, and 15, accounted for approximately 80.1% of the total peak design storm inflow with a combined peak inflow of approximately 1.52 mgd.

Conclusions and Recommendations

The flow metering program was performed in order to quantify the amount of I/I entering the Town's wastewater collection system. The results of the I/I analysis were used to recommend and prioritize subareas for further investigation, which will identify potential sources of I/I and allow repairs to be made to the collection system to reduce I/I.

Based on the results from the I/I analysis, Weston & Sampson recommends prioritizing subareas 6 and 11 for further investigation in Year 2 of Annual I/I Program, followed by subareas 9 and 10 in Year 3, and subareas 13 and 14 in Year 4. This schedule is based on the I/I Control Plan but can be expediated if the Town prefers. Infiltration and Inflow investigations will be performed in all subareas, which include manhole inspection, closed-circuit television (CCTV) inspection, smoke testing, dye water testing and flooding of sewers that are identified during smoke testing and building inspection.

.....

1.0 INTRODUCTION

1.1 Background

In accordance with our March 22, 2023 Agreement, Weston & Sampson is pleased to submit this summary report for the Year 1 of the Annual Infiltration/Inflow (I/I) and Operation and Maintenance (O&M) Program – Flow Metering and I/I Analysis. In addition to flow metering, groundwater and rainfall monitoring were also conducted over the same metering period. This report presents an analysis of the flow metering results, provides estimates of peak infiltration/inflow (I/I) and identifies areas that appear to contribute excessive I/I. This I/I analysis is conducted in accordance with the Department of Environmental Protection's (DEP) *Guidelines for Performing Infiltration/Inflow Analyses and Sewer System Evaluation Survey*.

1.2 Project Area

The municipal sanitary sewer system in the Town of Rockland is comprised of approximately 300,000 linear feet of sanitary sewers, ranging in size from 8- to 33-inches in diameter. Figure 1 provides a layout of the Town's sewer system and the location of the flow meters. A summary of sewer pipelines is included in Table 1. Figure 2 provides a flow schematic to supplement the flow meters shown in Figure 1 and to show how the flow meters interact with each other.

1.3 Project Objectives

The primary objectives of this project were to gain a better understanding of the existing wastewater flows, identify the areas with excessive I/I, and prepare an analysis and recommendations for prioritizing sewer subareas for investigation. For this flow monitoring program, fifteen (15) flow meters, one (1) rain gauge, and three (3) groundwater gauges were installed throughout the Town's wastewater collection system for a 10-week period. Under the direction of Weston & Sampson, the flow meters, rain gauge, and groundwater gauges were installed, calibrated, and maintained by Weston & Sampson's subconsultant for the duration of the project.

2.0 FLOW MONITORING RESULTS & FINDINGS

2.1 Groundwater Monitoring

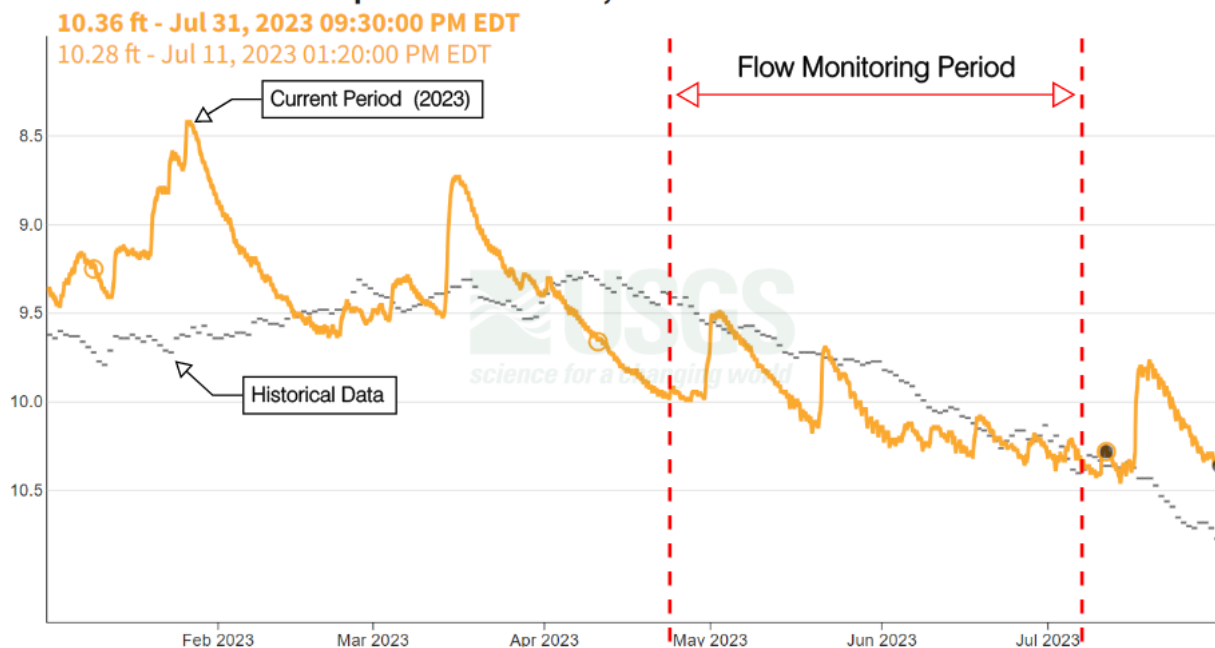
Temporary groundwater gauges were installed in the manholes where flow meters M-7, M-10, and M-15 were installed. This was done to monitor groundwater levels for the duration of the flow metering period. Of the three (3) groundwater gauges, two (2) gauges, M-10 and M-15, recorded groundwater levels. The groundwater gauge data from the two (2) gauges showed groundwater levels maintained at a steady level from May to July, with minimal fluctuation. A summary of the groundwater levels is shown in Figure 3.

A permanent USGS groundwater gauge located in Duxbury, Massachusetts monitors groundwater levels. Data from this groundwater gauge serves to indicate the general groundwater trends of the region. It should be noted that this USGS gauge is located over 10 miles away from the Town and is not necessarily an accurate representation of the groundwater levels in the project area. A graph representing the groundwater readings recorded during the metering period and the historical average during the same time frame from the USGS gauge is shown below. As shown in the figure below, the groundwater levels during the metering period (from April 24 to July 6) were generally lower than the median daily statistics for the last fifteen (15) years. This would suggest that the estimated I/I in this analysis may be lower than what would have been observed in prior years.

MA-D4W 79R Duxbury, MA - 420316070433501

January 1, 2023 - July 31, 2023

Depth to water level, feet below land surface



USGS Groundwater Gauge – Duxbury, MA

2.2 Rainfall Monitoring

Rainfall data was collected every 15 minutes during the monitoring period by a tipping-bucket style rain gauge. The rain gauge was installed on the roof of the Town's Wastewater Treatment Plant building. Storm events were selected if the event created more than 0.5 inches of rainfall in a period of time without a break of more than five (5) hours. Under this criterion, five (5) storm events were used in the data analysis and are summarized in Table 2.

According to the National Weather Service, the months of May and June 2023 showed below average precipitation for the City of Boston, Massachusetts, approximately 1.4 inches below the average historical precipitation amount. The average historical precipitation is approximately 7.1 inches during the months of May and June; while in 2023, the precipitation was 5.7 inches during the same timeframe. As shown in Table 2, only five (5) storm events were selected based on the criterion discussed above and four (4) of the five (5) storms accumulated more than 1-inch of total rainfall. The April 29 storm accumulated the most rainfall with 2.02-inches in a 24-hour period. The storm with the highest intensity occurred on June 17, with a peak hour intensity of 0.85 inches in a 1-hour period. As a comparison, the 5-year, 24-hour storm event produces 4.61 inches of rainfall with a peak intensity of 0.73 inches per hour. Therefore, the storm events that occurred during this study period were not as significant as past storm events in terms of precipitation.

2.3 Flow Metering

The flow metering program was conducted to obtain current information regarding sewer flows for use in quantifying I/I rates for the Town. Fifteen (15) flow meters were installed at various locations in the Town and their locations are shown in Figure 1. The Town's wastewater collection system is divided into fifteen (15) sewer subareas as a result. DEP Guidelines suggests one flow meter to be installed per approximately 20,000 linear feet of sewers.

Each meter recorded the flow rate, depth, and velocity of the flow inside its respective pipe in 5-minute intervals for the duration of the project. The meter installation logs with photographs of all meters are included in Appendix A. The list below provides a brief description for each meter and its locations:

- **Meter M-1** was placed inside manhole S141 on Beech Street and measured wastewater flow from sewer subarea 1. Flows from this subarea are tributary to sewer subarea 2.
- **Meter M-2** was placed inside manhole S253 on Summer Street. Flows from subarea 2 and tributary flows from subarea 1 are included at this meter. Flows recorded from this meter are tributary to subarea 15.
- **Meter M-3** was placed inside manhole W12 on Brookside Road and measured flows from subarea 3. Flows from this subarea are tributary to subarea 10.
- **Meter M-4** was placed inside manhole N81 on Forest Street. Flows from subarea discharge into Forest Street Pump Station and are tributary to subarea 7.
- **Meter M-5** was placed inside manhole N196 on Hingham Street. Flows from this subarea are tributary to subarea 6.

- **Meter M-6** was placed inside manhole L52 on Webster Street. Flows from subarea 6 and tributary flows from subarea 5 are included at this meter. Flows recorded from this meter are tributary to subarea 12.
- **Meter M-7** was placed inside manhole L17 on Webster Street. Flows from subarea 7 and tributary flows from subarea 4 are included at this meter. Flows recorded from this meter are tributary to subarea 12.
- **Meter M-8** was placed inside manhole D1 on North Avenue and measured flows from subarea 8. Flows from this subarea are tributary to subarea 9.
- **Meter M-9** was placed inside manhole E9 on Lower Reed Street. Flows from subarea 9 and tributary flows from subarea 8 are included at this meter. Flows recorded from this meter are tributary to subarea 10.
- **Meter M-10** was placed inside manhole M97 near Studley/Reed's Pond Road. Flows from subarea 10 and tributary flows from subareas 3, 8, and 9 are included at this meter. Flows recorded from this meter are tributary to subarea 11.
- **Meter M-11** was placed inside manhole M1 on John A Dunn Memorial Drive. Flows from subarea 11 and tributary flows from subareas 3, 8, 9, and 10 are included at this meter. Flows recorded from this meter are tributary to subarea 15.
- **Meter M-12** was placed inside manhole C36 on Market Street. Flows from subarea 12 and tributary flows from subareas 4 to 7 are included at this meter. Flows recorded from this meter are tributary to subarea 15.
- **Meter M-13** was placed inside manhole C8 on Howard Street and measured flows from subarea 13. Flows from this subarea are tributary to subarea 15.
- **Meter M-14** was placed inside manhole J2 on Linwood Terrace and measured flows from subarea 14. Flows from this subarea are tributary to subarea 15.
- **Meter M-15** was placed inside manhole 422 near the Town's WWTF. Flows from subarea 15 and tributary flows from all other subareas are included at this meter.

As described above, some of the meter data included flow from tributary meters, making it necessary to subtract data from any direct upstream meter to obtain individual net area data. The flow meter schematic is provided in Figure 2.

The data collected by each meter was analyzed to determine flow trends and overall quality of the data. To perform the I/I analysis, Weston & Sampson utilized a computer I/I analytics software program, to extract and quantify I/I within the project area. Hydrographs were generated in Slicer to show the diurnal flows for each meter. These hydrographs are included in Appendix B.

Overall, the metering data showed an average daily flow of approximately 2.28 million gallon per day (mgd) for the Town during the metering period. It should be noted that the average daily flows were

.....

taken from days without rain events, or dry days. The definition of dry days will be explained further below. The average daily flow stated above included infiltration, which will be discussed and quantified later in this report.

A summary of the wastewater flows is included as Table 3. The average daily flows for each meter are taken from dry days throughout the metering period, which is a combination of sanitary flow and infiltration. The estimated peak design storm inflow is also included in the table.

2.3.1 Infiltration

Infiltration is any extraneous groundwater that enters the sewer system through defects in pipes, pipe joints and manhole walls. Commonly, peak Infiltration is estimated as the nighttime flow rates, typically observed between the hours of 12:00 a.m. and 6:00 a.m., over a period of several dry days, during a period of high groundwater conditions. This method can be considered crude since it assumes infiltration is the minimum daily flow (MDF) during dry conditions. Empirical methods are often used to quantify and estimate infiltration based on metering sewer flow data. In this analysis, the Stevens-Schutzbach method was used, as opposed to the Wastewater Production and Minimum Flow Factor Method. According to a whitepaper published by ADS, the Stevens-Schutzbach equation “provides a more accurate estimate of BI (base infiltration) in basins yielding flows comprised of more than 20% BI.” (Mitchell, Stevens, & Nazaroff, 2007). The Stevens-Schutzbach equation is as followed:

$$BI = \frac{0.4 * (MDF)}{1 - 0.6 * \left(\frac{MDF}{ADF}\right)^{ADF^{0.7}}}$$

Where,

BI = Base Infiltration
ADF = Average Daily Flow (mgd)
MDF = Minimum Daily Flow (mgd)

Basin infiltration is calculated using the average and minimum daily flow observed over a period of several dry days, during a period of high groundwater conditions; typically, this is measured during the spring. A day can be considered as a dry day if it meets the following conditions:

- One (1) day after the occurrence of a rain event if the event has a cumulative rainfall of greater than or equal to 0.1 inches, but less than 0.4 inches
- Three (3) days after the occurrence of a rain event if the event has a cumulative rainfall of greater than or equal to 0.4 inches, but less than 1 inch.
- Five (5) days after the occurrence of a rain event if the event has a cumulative rainfall of greater than or equal to 1 inch.

Under the above conditions, dry days were selected in the period of mid- to late-May and late-June, where groundwater levels were still relatively high compared to winter and summer seasons, in order to provide an accurate estimate of infiltration into the sewer system. A summary of the estimated base infiltration rates for each subarea is provided in Table 4. As presented in Table 4, approximately 915,000 gpd of base infiltration was observed on dry days during the flow metering program. This base infiltration figure should be considered as average daily infiltration since groundwater level was not at its highest (or “peak”) conditions (see page 2-1), which usually occur in early spring after snow melt and/or soil

thaw. The average daily infiltration is approximately 75% of the peak infiltration, therefore, the total peak infiltration is estimated at approximately 1.22 mgd, or 1,220,000 gpd.

Due to the varying sizes of the subareas and the different lengths and diameters of the sewer throughout the Town, the estimated infiltration rate was calculated for each subarea in gpd and then again in gallons per day per inch-mile (gpdim). The “gpdim” value for infiltration was calculated by dividing the gpd of base infiltration by the size of the respective subarea in inch-miles (i.e. diameter of the pipe (in inches) multiplied by the length of pipe (in miles) for each subarea). The gpdim value is used to produce a normalized value for comparison of flows from pipes of different diameters and for subareas with different pipe length.

In accordance with DEP Guidelines, peak infiltration rates greater than or equal to 4,000 gpdim are considered “excessive” and should be prioritized for further evaluation. Table 4 shows that four (4) of the subareas, 6, 9, 11, and 13, have a peak infiltration rate of greater than the 4,000 gpdim threshold limit, and therefore are considered “excessive”. An excerpt of Table 4 is shown below.

Excerpt from Table 4 – Infiltration Summary
(only included subareas with over 4,000 gpdim of peak infiltration)

Subarea	Total Length (ft)	Total Inch-Miles (in-mi)	Base Infiltration (gpd)	Estimated Peak Infiltration (gpd)	Estimated Peak Infiltration (gpdim)
9	20,348	33.08	130,714	174,286	5,269
6	21,514	39.10	144,800	193,067	4,938
11	18,090	35.43	112,000	149,333	4,215
13	20,083	34.01	106,500	142,000	4,175

2.3.2 Inflow

Inflow is any extraneous rainwater that enters the sewer system through either direct or indirect sources. These sources include, but are not limited to, cross connections from catch basins or surface drains, roof leaders, sump pumps and holes in manhole covers, among many other direct and indirect sources.

In the I/I computer program, infiltration and inflow were not calculated separately during storm events and were combined into one parameter – rainfall derived infiltration and inflow (RDII). For the purpose of this analysis, base infiltration, which was discussed earlier in this report, was subtracted from the RDII value to determine and evaluate inflow separately.

Rainfall data was collected during the flow monitoring program in order to track the storm events that occurred and provided a quantity for rainfall intensity. This data was used to relate variations in sewer flow during rainfall events to rainfall intensity, total volume and duration for each storm event in order to identify RDII introduced into the sewer system. RDII can be quantified by comparing flow rates observed during a storm event to flow rates observed during dry days and same time of the day as the storm event. This comparison was necessary to ensure that any flow variations observed in the data were influenced by inflow and not normal diurnal flow conditions.

Per DEP Guidelines, peak design storm inflow was calculated by estimating the inflow volume associated with the 5-year, 24-hour storm event, also referred to as the “design storm.” Peak design storm inflow was taken as the volume of inflow that was observed during the 5-year, 24-hour storm event at a peak intensity of 0.73 inches of rain per hour. The total rainfall for this design storm was 4.61 inches.

In accordance with DEP guidelines, it is also recommended that inflow be estimated using storm events with an average rainfall intensity of 0.20 inches per hour.

As discussed earlier in this report, five (5) storm events were used in this I/I analysis. The flow meter data during these storm events were compared to the flow meter data on similar dry days during the same time period. The five (5) storm events had lower peak intensities and rainfall totals than typically used for inflow analysis, except for one (1) storm event, where the peak intensity (0.85 in/hr.) is greater than the design storm (0.73 in/hr.).

The amount of RDII was calculated for each flow meter during the ten storm events in order to provide data points for development of a linear regression analysis. RDII for each storm was calculated as the difference between flow during the storm event and flow during an average same dry day time period. This analysis plotted peak RDII against the peak hourly rainfall intensity observed during the storm event. A best fit regression line was placed with the data points and then used to determine the peak design storm RDII relative to the rainfall intensity. Using the 0.73 inches per hour rainfall intensity as the basis, the peak design storm RDII for each meter was obtained from the regression line formula. The peak design storm inflow was then obtained by subtracting the base infiltration rate from the peak design storm RDII value. A summary of the peak inflows is provided in Table 5 and regression plots for each meter are provided in Appendix C.

In accordance with the DEP Guidelines, areas that contribute at least 80% of the total peak inflow identified during flow monitoring are considered “excessive”. Based on our analysis, peak design storm inflow was approximately 1.89 mgd or 1,890,000 gpd. This peak design storm inflow represented the peak amount of inflow that would be introduced into the Town’s collection system only during the 5-year, 24-hour storm event.

Seven (7) out of the fifteen (15) subareas were considered “excessive” and accounted for approximately 80% of the total inflow identified during the flow metering program was found in approximately 47% of the Town. The combined estimated inflow for subareas 3, 5, 6, 10, 11, 12, and 15 accounted for approximately 1.52 mgd of the peak design storm inflow. Subarea 6 had the highest inflow total with an estimated 375,200 gpd of peak design storm inflow. This subarea alone counted for approximately 20% of the total inflow identified.

Excerpt from Table 5 – Inflow Summary
(only included subareas cumulatively accounted for 80% of the total inflow)

Subarea	Total Length (ft)	Total Inch-Miles (in-mi)	Estimated Peak Design Storm Inflow (gpd)	Estimated Peak Design Storm Inflow (gpdim)	Percentage of Inflow (%)	Cumulative Percentage
6	21,514	39.1	375,200	9,596	19.80%	19.80%
15	18,159	62.71	360,882	5,755	19.05%	38.85%
11	18,090	35.43	198,000	5,588	10.45%	49.30%
10	25,887	51.41	187,727	3,652	9.91%	59.21%
5	22,347	35.8	133,769	3,737	7.06%	66.27%
3	18,800	34.72	132,529	3,817	7.00%	73.27%
12	15,284	38.3	129,260	3,371	6.82%	80.09%
Total	140,081		1,517,368	35,516		

Inflow entering the sewer system during wet weather events can cause large increases of flow over a short period of time. The main goal in removing inflow from the sewer system is to eliminate the sudden increase in flow in the sewer system and avoid overflows or backups.

2.3.3 *Design Storm RDII Volume*

Another matrix in evaluating and prioritizing areas for additional investigation is to compare the total volume of RDII as a result of the design 5-year, 24-hour storm event. In Section 2.3.1 and 2.3.2, Infiltration and Inflow are reviewed and quantified separately; in this section, they are considered as one (1) static indicator.

The design storm RDII volume is estimated similarly to how peak inflow was calculated; however, instead of using the 0.73 inches per hour rainfall intensity as the basis, the total rainfall of 4.61 inches was utilized. This analysis plotted total RDII against the storm event rainfall total observed during the storm event. A best fit regression line was placed with the data points and then used to determine the design storm RDII volume relative to the total rainfall. The design storm RDII volume does not differentiate infiltration and inflow; rather, it considers infiltration and inflow as a whole and provides a complete picture of how much extraneous flows enter the sanitary sewer system during and directly after the design storm. A summary of the design storm RDII is provided in Table 6 and regression plots for each meter are provided in Appendix D.

Based on the analysis and regression plots, the estimated design storm RDII volume is approximately 3.57 million gallons (MG) or 3,570,000 gallons (gal). This figure represented the total amount of I/I that would be introduced into the Town's collection system during the 5-year, 24-hour storm event and the subsequent recovery period, which begins immediately after the end of the storm event and ends after approximately 48 hours. Combining the average daily flow (2.28 mgd) with the estimated design storm RDII volume, the WWTP could potentially receive up to 5.85 mgd of flow during a 5-year, 24-hour storm event. In comparison, the WWTP has seen excessive flow totaling over 6 mgd.

.....

3.0 CONCLUSIONS & RECOMMENDATIONS

3.1 Conclusions

Flow metering was performed in order to quantify wastewater flows and estimate the amount of I/I entering the Town's sewer system. The results of the flow metering program were used to develop recommendations and prioritize the sewer subareas for further I/I investigations.

Table 4 presents the infiltration results from the flow metering program and was sorted highest to lowest based on gpdim. An estimated 1.22 mgd of total peak infiltration was identified in the sewer system. Subareas 6, 9, 11, and 13 had peak infiltration rates above the 4,000 gpdim DEP threshold, which is considered excessive and should be prioritized for additional investigations.

Table 5 presents a summary of the inflow results from the flow metering program and was sorted based on the percentage of inflow from that subarea that is contributed to the total inflow. Peak design storm inflow for the 5-year, 24-hour storm was calculated to be approximately 1.89 mgd. In accordance with the DEP Guidelines, inflow reduction programs are recommended for areas that contribute at least 80% of the total inflow. Subareas 3, 5, 6, 10, 11, 12, and 15 accounted for approximately 80% of the total peak net inflow in the project area. The sewers associated with these seven (7) meters contributed approximately 1.52 mgd of peak inflow into the Town's sewer system during the 5-year, 24-hour design storm event. Meter M-6 showed the highest inflow rate compared to the other meters and accounted for almost 20% of the total estimated peak design storm inflow.

Table 6 presents a summary of the design storm RDII results and was sorted highest to lowest based on gpdim. Approximately 3.57 MG of rainfall derived infiltration and inflow enter the sanitary sewer system during and directly following the 5-year, 24-hour design storm. The DEP Guidelines do not have a threshold or limit for volume of RDII; however, this statical indicator would be used to prioritize areas for additional investigation.

The metering program results revealed a base infiltration of approximately 915,000 gpd. Applying a factor of 1.25, a peak infiltration of 1.22 mgd is estimated, which alone accounts for over half of the Town's average daily flow (2.28 mgd). In addition, during and immediately following a 5-year, 24-hour storm event, rainfall derived I/I (3.57 MG) will be approximately 2.6 times the Town's average daily sanitary flow (1.36 MG).

Based on the information presented in Table 4, 5, and 6, the Town's sewer system subareas were ranked from highest to lowest based on their infiltration rates, estimated inflow, and design storm RDII. The individual ranking scores for infiltration and inflow were then combined for a total score per sewer subarea. The sewer subarea with the lowest combined score was considered the area with the most excessive I/I. Table 7 presents the overall final priority ranking of all fifteen (15) sewer subareas. A Sanitary Sewer Evaluation Surveys (SSES) is then performed to follow up, locate, and identify specific I/I sources in the sewer system. A SSEE program would include groundwater monitoring, rainfall monitoring, television inspection for infiltration, extensive manhole inspection, smoke testing, dyed water testing, dyed water flooding in conjunction with television inspection, building inspection, and cost-effectiveness analysis.

.....

3.2 Recommendation

Weston & Sampson recommends that the Town considers a CMOM (Capacity, Management, operation, and Maintenance Program) approach to evaluate its sewer system. Through this approach, the Town may elect to develop a multiyear evaluation and rehabilitation plan designed to investigate, evaluate, and rehabilitate the sanitary sewers system over a period of years in accordance with the Town's budget. This approach will include infiltration and inflow investigations for all meter areas. It should be noted that flow isolation was performed for approximately 90% of all pipes ranging in size from 8- to 12-inch diameter in 2021 and is not recommended to be repeated in the proposed evaluation program.

Based on the data and results as outlined above, the Town can continue to implement the Annual I/I Control Program submitted the MassDEP. As defined in the I/I control plan, the annual program is broken into three (3) phases. Each phase includes three (3) years of infiltration work (manhole and television inspection) and one (1) year of inflow work (smoke testing, dye testing/flooding, and building inspection). A rehabilitation project is planned to be performed at the end of each phase. This schedule is based on the I/I Control Plan but can be expediated if the Town prefers. Recommendation for the first phase of the annual I/I program is provided below and is based on the ranking system presented in Table 7.

<u>Phase 1 of the Annual I/I Program</u>	<u>Estimated Cost</u>
• Year 2 Infiltration Project – Subareas 6 and 11 ○ Television Inspection of approximately 40,000 linear feet of sewer ○ Approximately 180 manhole inspections	\$165,000
• Year 3 Infiltration Project – Subareas 9 and 10 ○ Television Inspection of approximately 45,000 linear feet of sewer ○ Approximately 240 manhole inspections	\$170,000
• Year 4 infiltration Project – Subareas 13 and 15 ○ Television Inspection of approximately 38,000 linear feet of sewer ○ Approximately 190 manhole inspections	\$175,000
• Year 2 to 4 Inflow Program – Subareas 6, 9, 10, 11, 13, and 15 ○ Smoke testing of approximately 123,000 linear feet of sewer ○ Dye Testing/Flooding with CCTV as necessary ○ Building Inspection	\$200,000

4.0 REFERENCES

Mitchell, P. S., Stevens, P. L., & Nazaroff, A. (2007). *QUANTIFYING BASE INFILTRATION IN SEWERS: A Comparison of Methods and a Simple Empirical Solution*. ADS Environmental Services.

FIGURES

Figure 2
Flow Meter Schematic
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

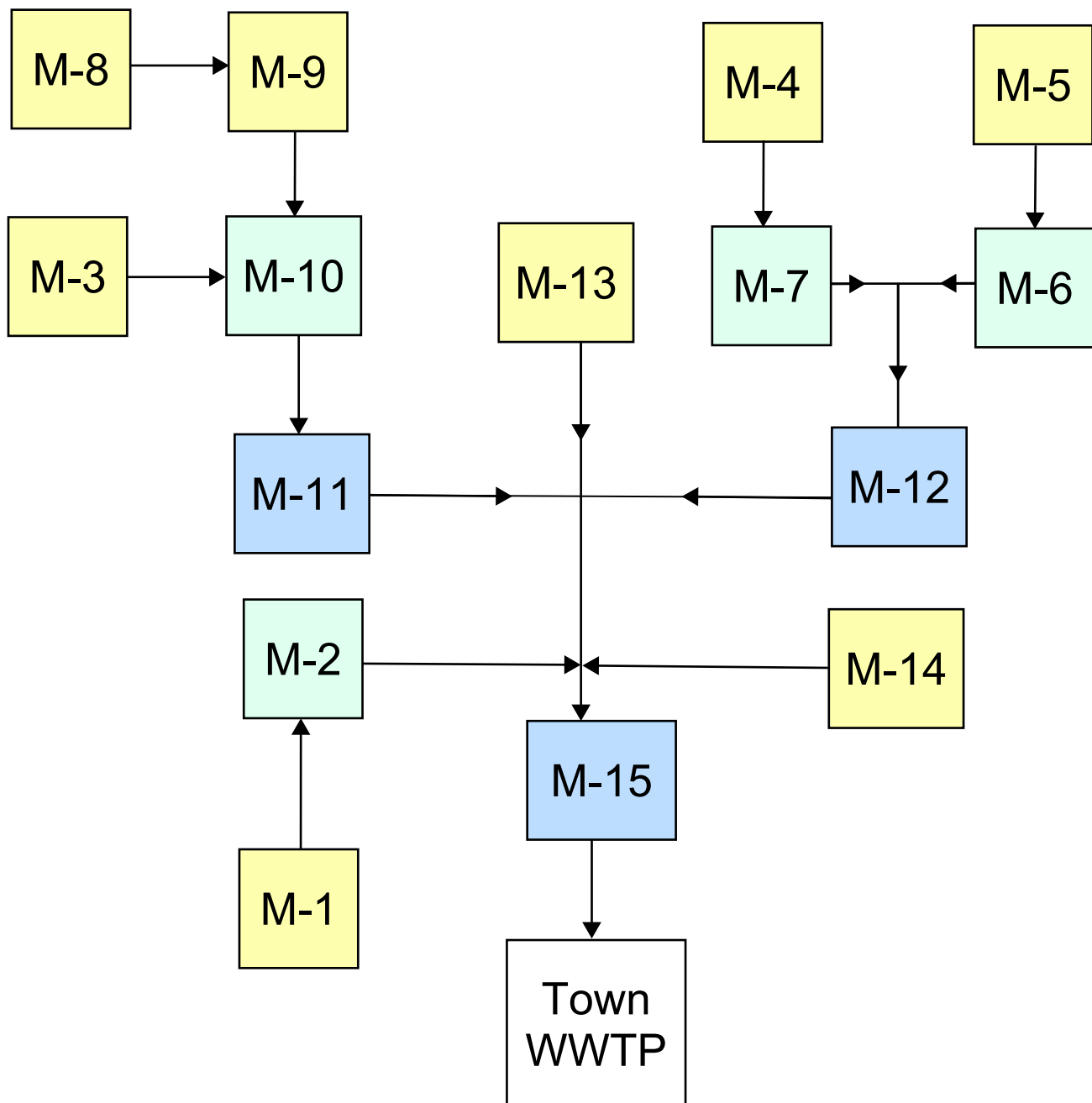
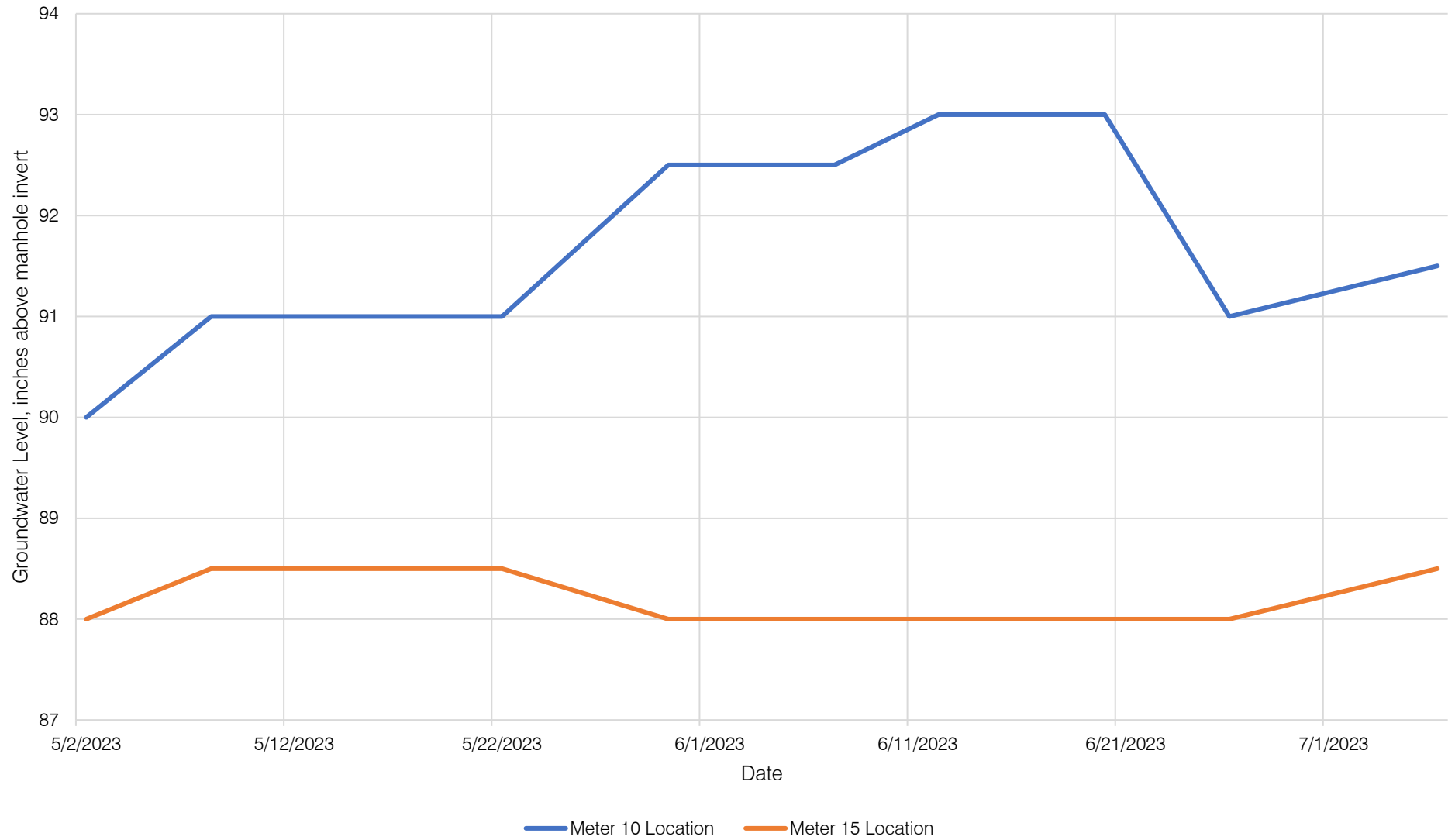


Figure 3
Groundwater Level - 5/2/2023 to 7/6/2023
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland



TABLES

Table 1
Sewer System Summary
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Subarae	8	10	12	15	18	21	24	27	30	33	Total Linear Footage (lf)	Total Inch-Miles (in-mi)
1	17,331	3,082	2,368								22,781	37.48
2	16,955			725							17,680	27.75
3	12,931		2,726	3,143							18,800	34.72
4	12,496	1,319									13,815	21.43
5	17,473	4,810			64						22,347	35.8
6	13,786	1,153	4,664	1,911							21,514	39.1
7	12,154		5,110								17,264	30.03
8	17,409			2,585							19,994	33.72
9	18,395	538		1,111	304						20,348	33.08
10	17,503	2,159		2,094	2,768	1,363					25,887	51.41
11	12,435	2,805	537			805	1,508				18,090	35.43
12	9,807					4,082		1,189	206		15,284	38.34
13	18,317	1,766									20,083	34.01
14	21,015	3,206	243	2,515					433		27,412	45.16
15	8,472				2,646				5,551	1,490	18,159	62.71
Total	226,479	20,838	15,648	14,084	5,782	6,250	1,508	1,189	6,190	1,490	299,458	394.59

Table 2
Rainfall Monitoring Data
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Storm Event	Start			End			Peak Hour Intensity (in/hour)	Total Rainfall (in)
	Date	Day	Time	Date	Day	Time		
1	4/29/2023	Saturday	10:15 PM	5/1/2023	Monday	3:00 AM	0.3	2.02
2	5/20/2023	Saturday	12:15 PM	5/21/2023	Sunday	4:15 AM	0.45	1.68
3	6/9/2023	Friday	4:15 PM	6/10/2023	Saturday	2:45 PM	0.39	0.56
4	6/17/2023	Saturday	9:00 AM	6/18/2023	Sunday	1:00 AM	0.85	1.58
5	6/26/2023	Monday	11:15 PM	6/27/2023	Tuesday	11:30 AM	0.29	1.19
						1-Year, 6-Hour Storm =	0.87	1.72
						1-Year, 24-Hour Storm =	0.72	2.69
						5-Year, 24-Hour Storm =	0.73	4.61

Table 3
Wastewater Summary
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Subarea	Total Length (ft)	Total Inch-Miles (in-mi)	Average Daily Flow* (gpd)	Average Daily Sanitary Flow (gpd)	Base Infiltration (gpd)	Estimated Peak Infiltration (gpd)	Estimated Peak Design Storm I/I (gpd)	Estimated Peak Design Storm Inflow (gpd)	Estimated Design Storm RDII Volume (gal)
1	22,781	37.48	126,667	74,333	52,333	69,778	80,000	27,667	70,000
2	17,680	27.75	14,000	12,667	1,333	1,778	40,000	38,667	20,000
3	18,800	34.72	99,529	82,059	17,471	23,294	150,000	132,529	210,000
4	13,815	21.43	40,667	31,667	9,000	12,000	70,000	61,000	50,000
5	22,347	35.8	123,692	57,462	66,231	88,308	200,000	133,769	100,000
6	21,514	39.1	421,000	276,200	144,800	193,067	520,000	375,200	310,000
7	17,264	30.03	124,800	65,400	59,400	79,200	150,000	90,600	140,000
8	19,994	33.72	130,000	60,500	69,500	92,667	130,000	60,500	210,000
9	20,348	33.08	158,143	27,429	130,714	174,286	180,000	49,286	530,000
10	25,887	51.41	111,000	48,727	62,273	83,030	250,000	187,727	380,000
11	18,090	35.43	368,333	256,333	112,000	149,333	310,000	198,000	440,000
12	15,284	38.34	33,410	22,670	10,740	14,320	140,000	129,260	150,000
13	20,083	34.01	228,400	121,900	106,500	142,000	140,000	33,500	400,000
14	27,412	45.16	114,000	70,000	44,000	58,667	60,000	16,000	200,000
15	18,159	62.71	185,000	155,882	29,118	38,824	390,000	360,882	360,000
Total	299,458	560.17	2,278,641	1,363,229	915,413	1,220,550	2,810,000	1,894,587	3,570,000

*average daily flows taken from days without rain events

Table 4
Infiltration Summary
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Subarea	Total Length (ft)	Total Inch-Miles (in-mi)	Base Infiltration (gpd)	Estimated Peak Infiltration (gpd)	Estimated Peak Infiltration (gpdin)
9	20,348	33.08	130,714	174,286	5,269
6	21,514	39.10	144,800	193,067	4,938
11	18,090	35.43	112,000	149,333	4,215
13	20,083	34.01	106,500	142,000	4,175
8	19,994	33.72	69,500	92,667	2,748
7	17,264	30.03	59,400	79,200	2,637
5	22,347	35.80	66,231	88,308	2,467
1	22,781	37.48	52,333	69,778	1,862
10	25,887	51.41	62,273	83,030	1,615
14	27,412	45.16	44,000	58,667	1,299
3	18,800	34.72	17,471	23,294	671
15	18,159	62.71	29,118	38,824	619
4	13,815	21.43	9,000	12,000	560
12	15,284	38.34	10,740	14,320	374
2	17,680	27.75	1,333	1,778	64
<i>Total</i>	299,458	560.17	915,413	1,220,550	1,634

Table 5
Inflow Summary
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Subarea	Total Length (ft)	Total Inch-Miles (in-mi)	Estimated Peak Design Storm Inflow (gpd)	Estimated Peak Design Storm Inflow (gpdim)	Percentage of Inflow (%)	Cumulative Percentage
6	21,514	39.1	375,200	9,596	19.80%	19.80%
15	18,159	62.71	360,882	5,755	19.05%	38.85%
11	18,090	35.43	198,000	5,588	10.45%	49.30%
10	25,887	51.41	187,727	3,652	9.91%	59.21%
5	22,347	35.8	133,769	3,737	7.06%	66.27%
3	18,800	34.72	132,529	3,817	7.00%	73.27%
12	15,284	38.3	129,260	3,371	6.82%	80.09%
Subtotal	140,081	297.51	1,517,368	35,516		
7	17,264	30.03	90,600	3,017	4.78%	84.87%
4	13,815	21.43	61,000	2,846	3.22%	88.09%
8	19,994	33.72	60,500	1,794	3.19%	91.28%
9	20,348	33.08	49,286	1,490	2.60%	93.89%
2	17,680	27.75	38,667	1,393	2.04%	95.93%
13	20,083	34.01	33,500	985	1.77%	97.70%
1	22,781	37.48	27,667	738	1.46%	99.16%
14	27,412	45	16,000	354	0.84%	100.00%
Total	299,458	560.17	1,894,587	3,382		

Table 6
Design Storm RDII Summary
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Subarea	Total Length (ft)	Total Inch-Miles (in-mi)	Estimated Design Storm RDII Volume (gal)	Estimated Design Storm RDII Volume (gal/im)
9	20,348	33.08	530,000	16,022
13	20,083	34.01	400,000	11,761
11	18,090	35.43	440,000	12,419
6	21,514	39.10	310,000	7,928
10	25,887	51.41	380,000	7,392
15	18,159	62.71	360,000	5,741
8	19,994	33.72	210,000	6,228
3	18,800	34.72	210,000	6,048
7	17,264	30.03	140,000	4,662
14	27,412	45.16	200,000	4,429
12	15,284	38.34	150,000	3,912
5	22,347	35.80	100,000	2,793
4	13,815	21.43	50,000	2,333
1	22,781	37.48	70,000	1,868
2	17,680	27.75	20,000	721
<i>Total</i>	299,458	560.17	3,570,000	6,373

Table 7
Priority Ranking
Annual I/I and O&M Program Year 1 – Flow Metering and I/I Analysis
Rockland, MA

Subarea	Total Length (ft)	Total Inch- Miles (in-mi)	Net Peak Infiltration (gpdim)	Net Peak Inflow (gpdim)	Net Design Storm RDII (gdpim)	Infiltration Ranking	Inflow Ranking	Design Storm RDII Ranking	Total Rank	Priority Ranking
6	21,514	39.10	4,938	9,596	7,928	2	1	4	7	1
11	18,090	35.43	4,215	5,588	12,419	3	3	3	9	2
9	20,348	33.08	5,269	1,490	16,022	1	11	1	13	3
10	25,887	51.41	1,615	3,652	7,392	9	4	5	18	4
13	20,083	34.01	4,175	985	11,761	4	13	2	19	5
15	18,159	62.71	619	5,755	5,741	12	2	6	20	6
8	19,994	33.72	2,748	1,794	6,228	5	10	7	22	7
7	17,264	30.03	2,637	3,017	4,662	6	8	9	23	8
5	22,347	35.80	2,467	3,737	2,793	7	5	12	24	9
3	18,800	34.72	671	3,817	6,048	11	6	8	25	10
12	15,284	38.34	374	3,371	3,912	14	7	11	32	11
4	13,815	21.43	560	2,846	2,333	13	9	13	35	12/13
14	27,412	45.16	1,299	354	4,429	10	15	10	35	12/13
1	22,781	37.48	1,862	738	1,868	8	14	14	36	14
2	17,680	27.75	64	1,393	721	15	12	15	42	15