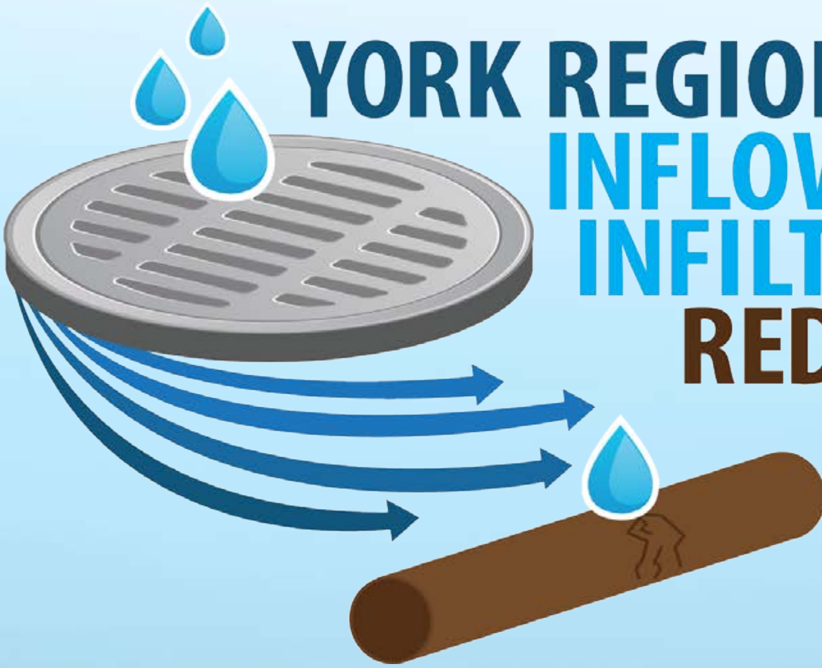
York Region

YORK REGION INFLOW & INFILTRATION REDUCTION STRATEGY



ANNUAL REPORT

MARCH 31, 2018

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The Region and the local municipalities are demonstrating leadership in inflow and infiltration reduction within the water and wastewater industry.

Inflow

Water from rainfall or snow melt that enters the sewage system through direct sources such as yard, roof and downspouts, cross connections with storm drains, foundation drains, and maintenance hole covers.

Infiltration

Groundwater that enters through holes and cracks in maintenance holes, laterals, and sewer pipes.

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1.0 Purpose and Need for the Annual Report

On March 31, 2010, the Ministry of the Environment and Climate Change (MOECC) approved the Southeast Collector Trunk Sewer Individual Environmental Assessment (SEC IEA) subject to 13 conditions (with 74 sub-conditions) including Condition 8 which refers to the Long-Term Water Conservation and Inflow and Infiltration Reduction Monitoring Strategy.

This report is the seventh annual report prepared to address Conditions 8.8 and 8.9 of the SEC IEA Minister's Conditions of Approval. It details the 2017 progress on implementation of the 2011 Inflow and Infiltration Reduction Strategy (Strategy) and 2016 Strategy Update submitted to the Ministry on March 31, 2011 and March 31, 2016 in accordance with Conditions 8.1 and 8.10 of the SEC IEA, respectively.

Requirements under Conditions 8.8 and 8.9 are as follows:

- York Region to submit to the Regional Director an annual report detailing its progress on implementing the Strategy including inflow and infiltration reduction.
- Each annual report prepared shall include at a minimum:
  a) Results of water conservation and efficiency measures
  b) Results of flow monitoring and visual inspections to determine the sources and amount of inflow and infiltration into the Southeast Collector Trunk Sewer within the Regional Municipality of York
  c) Progress in the reduction of inflow and infiltration into the Southeast Collector Trunk Sewer
  d) Details of any remedial work to the sewage system undertaken and the results of the remediation
  e) Results achieved within the Regional Municipality of York with respect to inflow and infiltration reduction measures

Results on water conservation and efficiency measures are submitted in the Long-Term Water Conservation Strategy Annual Report dated March 31, 2018. Progress made towards the implementation of the inflow and infiltration reductions are compiled in this report and include Regional, local municipal and private initiatives. It details the 2017 progress in achieving the Strategy goals and results with respect to inflow and infiltration reduction measures within York Region.

The Region will continue the preparation and submission of the annual reports to the Ministry with support from the Steering Committee and local municipalities until such date as the Regional Director indicates that updates are no longer required.

1.1 Comments and Feedback Received

On May 25, 2017, the Central Region Director of the MOECC notified the Region in writing acknowledging their satisfaction with the Region's 2016 Long Term Water Conservation Strategy and Inflow and Infiltration Reduction Strategy Annual Reports dated March 31, 2017. Comments received expressed that York Region continues to show leadership in achieving its targets.

2.0 2017 Inflow and Infiltration Reduction

A summary of inflow and infiltration reductions achieved in 2017 is presented in Table 1. Further details are provided in the following sections.

Table 1 - Inflow and Infiltration Reductions from 2017 Remediation Activities

Municipality	Reduction Achieved (MLD)	Description
Total of Area Municipalities	0.021	Decommissioning of sanitary sewer laterals and an old clay sanitary line, as well as infiltration sources in the Town of Aurora
	0.262	Disconnection of 85 downspouts in the City of Markham as part of Phase 2 of City-wide Multi Phase Sanitary System Disconnection Program
	0.08	Rehabilitation of 20 sanitary sewer laterals pipes on Prospect Avenue and sanitary sewer mainlines at Queen St and Wilstead Dr by the Town of Newmarket
	0.05*	Rehabilitation of 21 sanitary sewer lateral pipes and 1 gusher through the Dalton Rd and Burke Garret & West Watermain projects in the Town of Georgina
Total of Private Initiatives	0.034	Disconnection of 14 downspouts in the Town of Newmarket
Total of York Region	5.60	Aurora Sewage Pumping Station Outfall Gate Repair
TOTAL	**5.99**	

*Not part of the YDSS (excluded from the Total Reductions)

3.0 2017 Progress in Inflow and Infiltration Reduction in the Southeast Collector Trunk Sewer

Since implementing York Region's 2011 Inflow and Infiltration Reduction Strategy, regular reporting of successes and challenges of the program has been necessary to build on lessons learned and to establish whether targets and goals have been met. The Strategy is meeting all interim goals and is on track toward reaching the overall reduction of 40 MLD by 2031 (Figure 1)

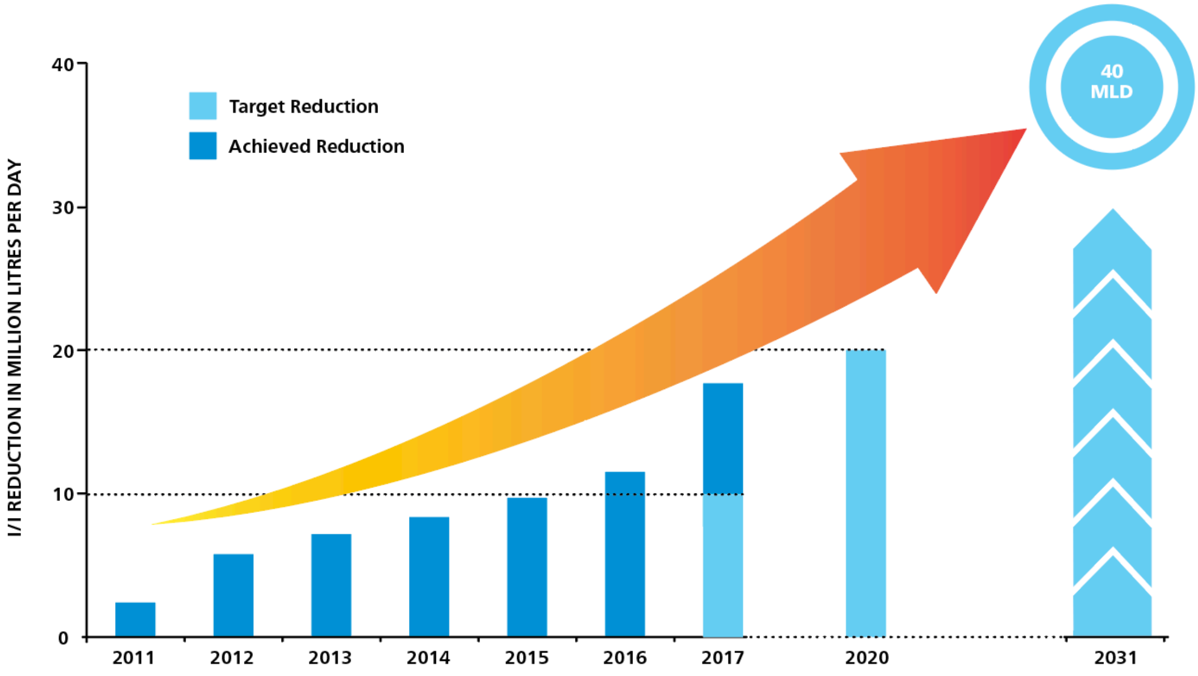


Figure 1: Target and Achieved Inflow and Infiltration Reduction

To date, the Region and local municipalities reduced inflow and infiltration by 17.59 MLD in the York Durham Sewage System (YDSS), representing 44 per cent of the 2031 target reduction of 40 MLD. This achievement exceeds the interim reduction target of 25 per cent (10 MLD) as set in the Strategy for end of 2017. Reduction targets set in the 2016 Strategy Update are shown in Table 2 below.

Table 2 - Inflow and Infiltration Reduction Strategy Update Reduction Targets

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021- 2031
Reduction Targets											
Achieve Up to 25 % of Target Reduction											
Achieve Up to 50 % of Target Reduction											
Achieve 50-100 % of Target Reduction											

The Region and the local municipalities achieved the goals and targets identified in the 2011 Strategy and 2016 Strategy Update. Through the efforts of the Region, local municipalities and private initiatives in 2017, a total inflow and infiltration reduction of 5.99 MLD has been achieved or 15 per cent of the overall 40 MLD target. Reductions achieved each year from 2011 to 2017 are provided in Table 3 below.

Table 3 - Yearly Inflow and Infiltration Reductions Achieved

Year	Inflow an Infiltration Reduction Achieved (MLD)	% Inflow and Infiltration Reduction Achieved
2011	1.01	2.5
2012	4.67	11.7
2013	1.34	3.4
2014	1.40	3.5
2015	1.18	2.9
2016	1.99	5.0
2017	6.00	15.0
TOTAL	**17.59**	**44.0**

These reductions were achieved through operation and maintenance programs, private initiatives and capital rehabilitation projects and were quantified through on-going flow monitoring programs, hydraulic modeling and investigative studies. The Region continued to develop the Strategy's programs in 2017 through pilot projects and implementation of new studies, technologies and guidelines for new and existing infrastructure. The Region in partnership with local municipalities and the Steering Committee will continue their support in maintaining these programs and advancing them to meet Best-In-Class expectations. Progress achieved to date in the eight program areas of the Strategy are summarized in Table 4.

Table 4 – Progress to Date in the 8 Key Program Areas

PROGRAM AREA 1 I/I REDUCTION PROGRAM GOALS AND TARGETS	PROGRAM AREA 2 MONITOR AND ANALYZE FLOWS	PROGRAM AREA 3 INVESTIGATE & REHABILITATE	PROGRAM AREA 4 DESIGN & COMMISSIONING
Establish W&WW Steering Committee	Establish I/I Audit & Flow Monitoring program	Establish mini-basin flow monitoring and analysis	Update design and construction standards
Integrate I/I Reduction with the LTWC strategy	Maintain Region permanent flow metering equipment and rain gauges	Determine condition assessment requirements and SSES inspections	Adopt Sanitary Sewer System Inspection, Testing and Acceptance Guideline by local municipalities
Set target of 40 MLD I/I Reduction by 2031	Develop detailed data QA/QC procedures	Pilot lateral sewer inspection and rehabilitations	Collect post-construction flow monitoring data
Refine audit basin locations and develop I/I audit and flow monitoring program	Analyze data on an ongoing basis	Conduct rehabilitation pilot projects	Implement incentive programs
Hydraulic model development and calibration	Establish thresholds to identify problem areas	Develop standards for maintenance hole and sewer mainlines inspections	Review and Update design and construction standards on a continual basis
Establish wastewater geodatabase	Complete Phase 1 of Region SSES	Develop Sanitary Sewer System Inspection Testing and Acceptance Guideline	Building Permit inspections and conditions
Align I/I Reduction Program with One Water Approach	Achieve I/I Reductions through pilot, local and developer funded projects	Create and maintain database of project costs and benefits	Update Sewer System Inspection, Testing and Acceptance Guideline
Develop Report template for local municipalities	Support ongoing I/I projects in new developments	Deliver proritized capital projects	
Develop and adopt goals for 2011-2015 and 2016-2021	Implement Servicing Incentive Program (SIP)	Assess I/I Reductions achieved	
Develop and adopt goals 2021-2031	Determine improvements to maintain and manage current data needs	Maintain inspection standards and frequency	
Integrate I/I Reduction and Water Conservation into design standards	Integrate monitoring data into data management software	Coordinate and harmonize inspection procedures	
Refine measures for I/I Reductions	Complete internal review of program delivery	Develop private property survey and consent form	
Review technology and tools annually	Complete review of monitoring equipment required and locations	Review standard testing procedures	
	Complete mini-basin and micro-basin monitoring	Establish private property programs with the locals and support of the W&WW Steering Committee	
	Complete quarterly rainfall and flow data analysis		
	Complete annual data analysis technical reports		
	Complete monitoring and analysis of rehabilitation projects and new development areas		
	Partner in pilot projects		
	Review subdivisions for post-construction flow monitoring		

PROGRAM AREA 5

FINANCIAL MANAGEMENT

- Establish Regional and local municipal cost-sharing reserve fund
- Fund I/I control activities including inspection, data collection, and analysis
- Commit to a 20-year funding program
- Establish alternate funding programs through involvement of the development community
- Region and local municipalities manage their own I/I reduction expenditures
- Review roles and responsibilities
- Have Steering Committee assit with determining pilot projects
- Investigate additional short and long-term alternate funding options
- Update implemnetation plan and I/I reduction expenditures allocated for short and long term plans

PROGRAM AREA 6

COMMUNICATION, EDUCATION & ADVOCACY

- Establish interagency communication through W&WW Steering Committee between the local municiplaities and the Region
- Present 2011 I/I Reduction strategy to local and Regional Councils for their endorsement
- Present 2016 I/I Reduction strategy to local and Regional Councils for their endorsement
- Create and maintain a robust website with resources for the public
- Conduct public outreach in pilot study areas
- Post annual report on website
- Begin outreach to development and construction communities
- Report progress to the MOECC annually with performance measures
- Create local municipality coordinator position that is jointly funded by local municipalities and the Region
- Produce I/I information bulletins
- Update website contents
- Create marketing materials for I/I reduction
- Establish industry forums
- Present I/I Reduction Strategy and Program to tthe MOECC
- Establish I/I reduction education and public outreach program
- Establish internal and inter-agency communications
- Establish industry and provincial advocacy protocol

PROGRAM AREA 7

REPORT I/I REDUCTION

- Develop 2011 I/I Reduction Strategy in collaboration with local municipalities
- Update I/I Reduction Strategy 2016
- Report to local municipal and Regional councils
- Report to the MOECC annually
- Complete future strategy updates
- Continue Council reporting
- Complete future annual reports to the MOECC

PROGRAM AREA 8

INNOVATION & ADAPTATION

- Participate in 2011 Climate Change Risk Assessment and Adaptation Strategy
- Refine flow monitoring standards
- Evaluated lessons learned from pilot projects
- Pilot new technologies for public and private property rehabilitation programs
- Refine inspection standards
- Consider climate change impacts
- Refine flow monitoring programs
- Implement rehabilitation standards
- Update municipal bylaws
- Continue with updating the best-in-class review
- Incorporate new tools, technologies and data management systems
- Consider ways of capturing decreases in energy consumption as a result of I/I reduction

Legend:

- Completed
- Ongoing/Annual
- In-Progress
- Not Started

4.0 2017 Summary of York Region Program Activities and Accomplishments

Since implementing the Inflow and Infiltration Reduction Strategy, York Region and its nine local municipalities have developed program components mirrored after best in class applications of inflow and infiltration reduction around the globe.

Over the course of 2017, the Region spent close to $3.1 M as part of the I/I reduction program, on activities such as flow and rainfall monitoring, sanitary sewer evaluation surveys, and rehabilitation projects. The following provides a summary of the Regional, local municipal and private initiatives accomplished in 2017.

4.1 Analysis Work Update

The Region continued with detailed analysis work for both dry and wet weather conditions in 2017. Monitoring areas were prioritized for further investigation and/or rehabilitation based on thresholds developed in previous years. Staff leveraged the unique perspective that long-term monitoring in the same locations provides, studying different parameters and their effects on the prioritization process. Leveraging three to four years of data for each monitoring site, instead of a typical single season, has lead the Region to study the impact of seasonality, antecedent rainfall and moisture conditions on rainfall dependent inflow and infiltration analysis.

One of the key findings is that antecedent rainfall/moisture conditions (the rainfall/moisture conditions preceding a specific storm) should be considered, in addition to the return period intensity of rainfall, when analyzing Rainfall Dependant Inflow and Infiltration (RDII) volume response. This correlation was observed with the wet conditions most catchments experienced in 2017. Examples of this study are provided in Appendix A.

Important analysis work on base infiltration (BI) has also been performed this year. Details of the results of this analysis are provided in section 4.1.1.

4.1.1 Base Infiltration (BI)

Base infiltration is another prioritization parameter that the Region studied in more detail in 2017. Regional staff utilized both the Stevens-Schutzbach and Potable Water Use Methods to estimate BI in the sanitary sewer system, providing a ranking of the meter basins based on severity of BI. The Stevens-Schutzbach Method is an empirical equation that relates the Average Dry Day Flow (ADDF) and the minimum dry day flow to calculate the BI. The Potable Water Use Method compares the water consumption data to the sanitary ADDF to calculate the BI assuming that 100 per cent of the treated potable water is returned back as wastewater. On a Region-wide weighted average basis the BI is approximately 30 per cent of the ADDF. The average BI and RDII for each meter basin in York Region was plotted against various physical characteristics of the meter basins in an attempt to find correlations. For example in Figure 2, the average BI for 2015 and 2016 was plotted against average sewer age in each meter basin.

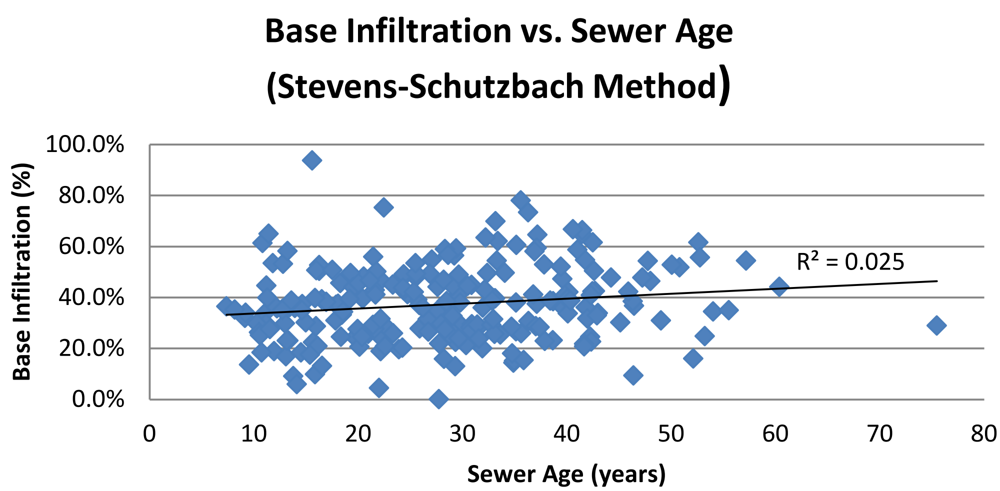


Figure 2: Base Infiltration versus Sewer Age

The trend line indicates higher base infiltration with increasing sewer age, which is what one might expect. However, the correlation coefficient indicates a correlation in the weak to none range and the R-squared value is low. The results are similar for peak RDII plotted against sewer age in Figure 3 below.

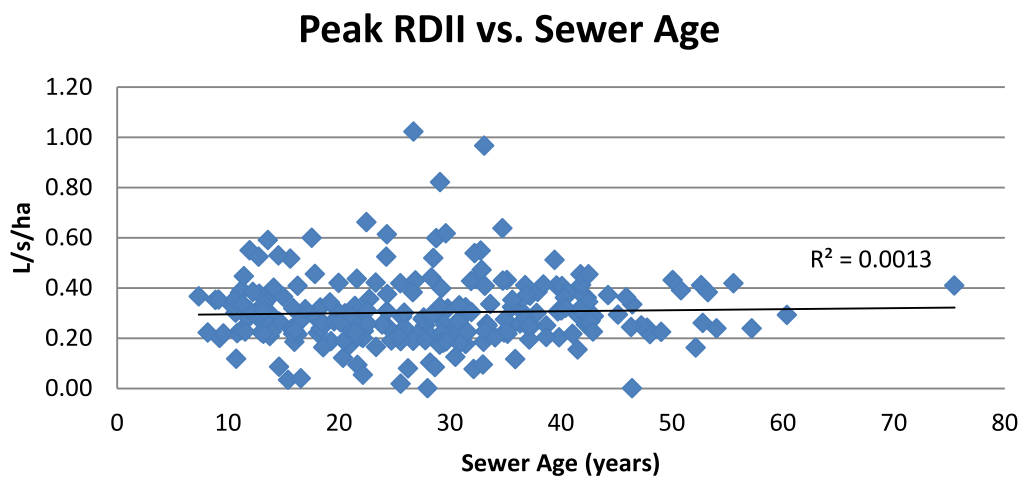


Figure 3: Peak RDII versus Sewer Age

Another interesting observation from Figures 2 and 3 is that inflow and infiltration is a significant problem even in development areas as young as ten years old. Base infiltration above 40 per cent of ADDF is considered elevated and peak RDII above 0.26 L/s/ha is also considered elevated. For this reason the Region has begun a new project to examine the new development design, construction, inspection, and testing and acceptance practices of the nine local municipalities to make recommendations for improvement. More details are provided in Section 4.8.

Finding a correlation between the sewer material in a meter basin and the amount of BI was also attempted this year. The entire Regional and local municipal sewer system is composed of 65 per cent PVC pipe, 28 per cent concrete pipe and 7 per cent other miscellaneous pipe materials. Plots of RDII versus pipe material showed no statistically significant correlations.

A correlation was also sought between the sewer flow temperature and the amount of base infiltration in York Region. Since the groundwater temperature is typically colder than the sewer flow temperature, one would expect to see lower sewage flow temperatures in meter basins with more base infiltration. The average sewer flow temperature in York Region is 16.7°C, whereas the groundwater temperatures near the sewer pipes are generally in the seven to ten Celsius range. Figure 4 below plots base infiltration versus sewer flow temperature.

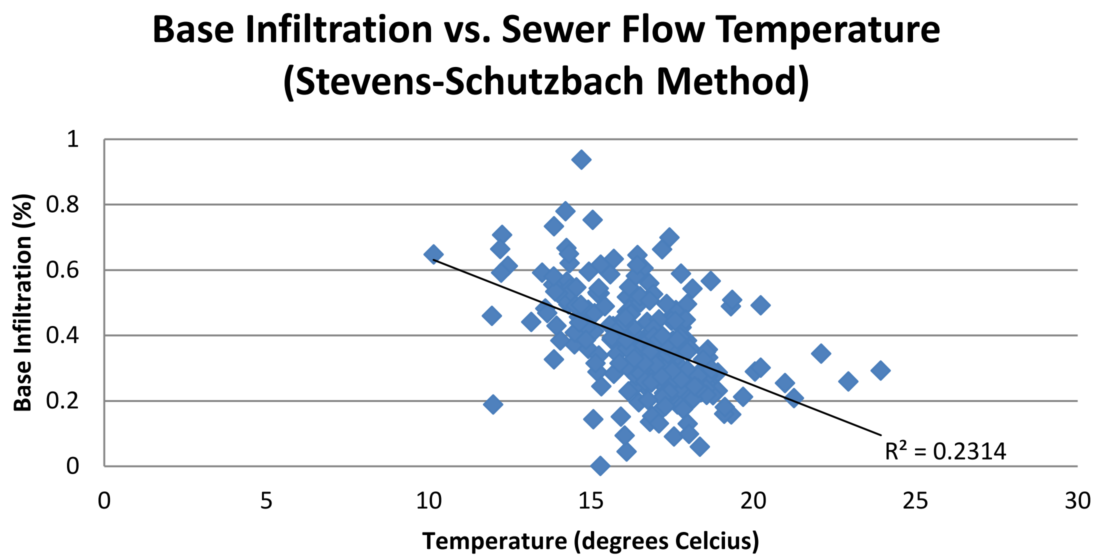


Figure 4: BI versus Average Sewer Flow Temperature in Each Meter Basin

The trend line indicates lower sewage flow temperatures in meter basins with more base infiltration. The correlation coefficient for the data in Figure 4 indicates a correlation in the moderate to weak range.

Those correlations were assessed further and used to inform prioritization decision processes and decision making.

4.2 Inflow and Infiltration Audit and Flow Monitoring Program – Long-Term Flow and Rainfall Monitoring

The Inflow and Infiltration Audit and Flow Monitoring Program (or the Long-Term Flow and Rainfall Monitoring Program) continues to be a key component of the Inflow and Infiltration Reduction Strategy. In 2012, Regional Council approved funding and resources needed for initiating the program which included development, implementation, purchase of equipment and installation, data management, field operation, maintenance and data review for a total of four years.

Subsequently, in 2017 the Region awarded the contract for the continuation of the monitoring program including the installation, operation, and maintenance of the existing and future flow meters and rain gauges as also approved by the Regional Council in 2016.

Collection and data management continue to be one of the largest program areas of the overall I/I Reduction Program. The sanitary sewer flow and rainfall monitoring data collected through the monitoring program is constantly used to:

- **Reveal deficiencies** in local and regional sanitary sewer systems and identify high priority areas
- **Assess levels of inflow and infiltration** during and after a major rainfall event
- **Assess progress** towards meeting interim and ultimate inflow and infiltration reduction targets as mandated by the Ministry
- **Infra-stretch** - adjust capital project timing based on reduced flow in the system realized through inflow and infiltration reductions, and advancing capacity to developers as per the inflow and infiltration reduction pilot project agreements

As shown in Table 5, the Region is currently collecting data from 258 long-term flow monitoring sites in 219 audit basins using 268 flow meters. 14 new flow meters were installed this year to capture the changes in the sanitary sewer system due to growth from new developments and other changes in the system (excluding the ones installed for calibrating the wastewater hydraulic model and micro-monitoring). Figure 8 shows pictures of the monitoring instruments installed as part of the program.

In 2017 an emphasis was put on:

- Enhancing means to identify and monitor areas with extraneous flows and evaluate the system's response to rainfall to identify areas of potential high I/I that may require remediation

- Providing accurate flow and rainfall monitoring to validate the data and ensure accurate, high quality datasets required for analyzing and monitoring performance of audit basins
- Assessing overflows that occurred during large storm events e.g. June 22/23, 2017

Table 5 - Summary of Long-Term and Short-Term Flow Monitoring Sites Installed in the Local Systems in 2017

Municipality	Meters Installed in 2017	Total Number of Meters Installed
Town of Aurora		17
Town of East Gwillimbury	1	6
Town of Georgina		14
Township of King	5	8
City of Markham	1	67
Town of Newmarket		17
Town of Richmond Hill	1	52
City of Vaughan	1	61
Town of Whitchurch-Stouffville	1	6
Mini Basins	1	12
Phase 3 Nobleton		5
Boundary Meters in RH	3	3
TOTAL	**14**	**268**

Figure 5: Pictures showing Area Velocity Meter and Sensor installed as part of the Flow Monitoring Program

On June 23, 2017, the Region experienced significant rainfall ranging from 40 mm to 85 mm within an eight hour period, that primarily affected Schomberg in the Township of King (return period >100 yr), Towns of Newmarket, Aurora and East Gwillimbury (return period <50 yr).

The storm response was significantly higher than the previous record response on June 27, 2015. The June 27, 2015 storm response showed the importance of considering wet conditions and how they affect RDII volume. Although the storm was less than a two year event across the Region, it was consistently higher than almost all other storms in every basin in the Region.

In Newmarket, the wet antecedent conditions from rainfall in May and June of 2015, meant that the June 27 response was even higher than the 50-100 year return period events that were monitored in 2014 and 2016. The June 23, 2017 storm had the perfect conditions for a result of great significance in Newmarket. In relation to June 27, 2015: The preconditions were even wetter, the total storm rainfall volume was 50 per cent higher, and the return period intensity ranged from 10-25 year.

Figure 6 shows the daily cumulative rainfall that fell on one catchment in the Town of Newmarket between April and September demonstrating the high frequency of wet weather events in 2017. Specifically of interest was the impact in the Town of Newmarket, where 53 mm of rain fell within a six hour period. Catchments within the Town of Newmarket were already under saturated soil moisture conditions due to the high frequency of wet weather events present for the previous months.

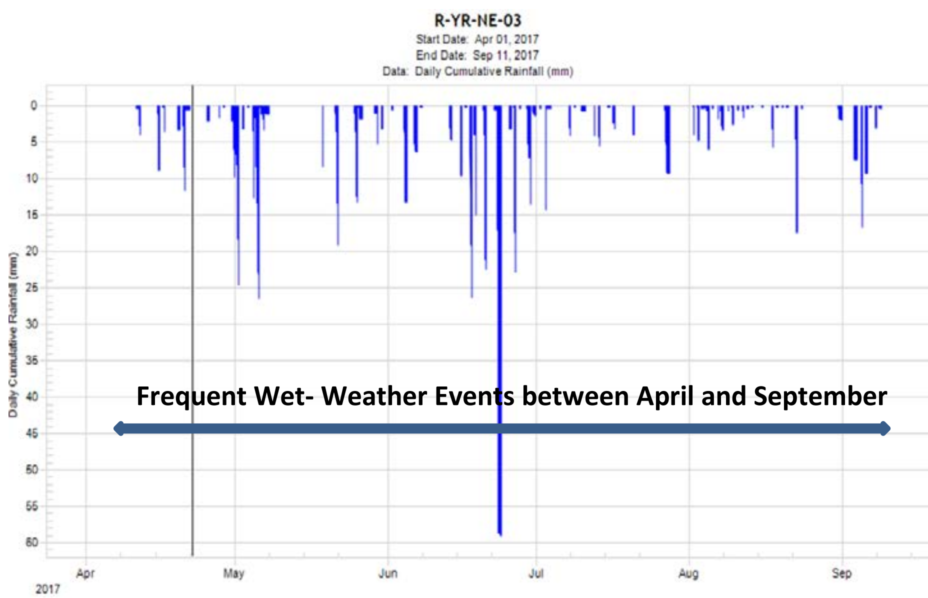


Figure 6: Newmarket Rain Gauge Showing Wet Weather Conditions between April and September of 2017

Figures 7 and 8 show different maps produced as part of the monitoring program following a major rainfall and based on the real-time data collected from rain gauges installed throughout the Region. These figures illustrate localized events that affected different parts of the Region in 2017.

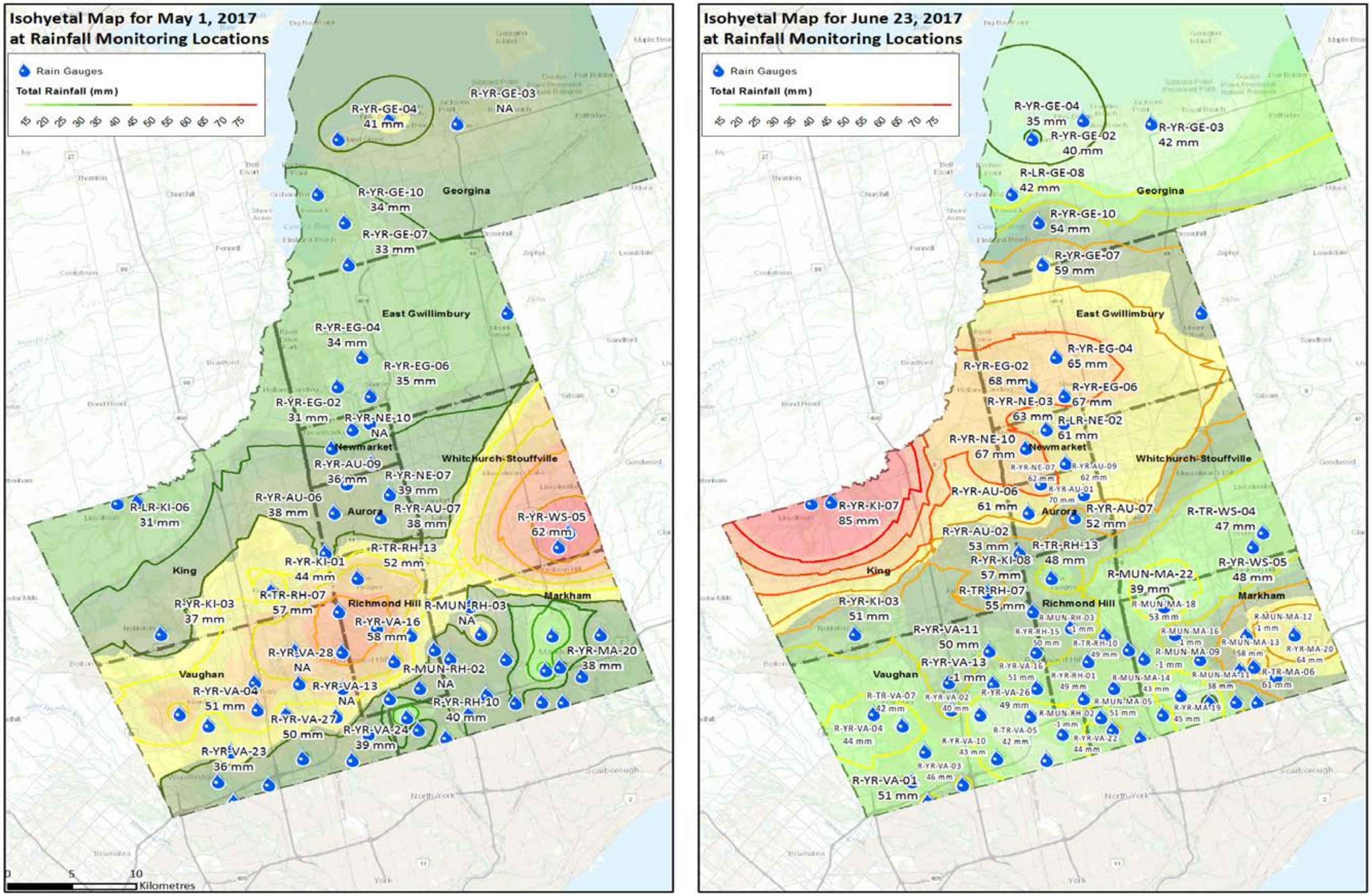


Figure 7: Isohyetal Maps for May 1st (left) and June 23rd (right), 2017 Rainfall Events showing different localized events

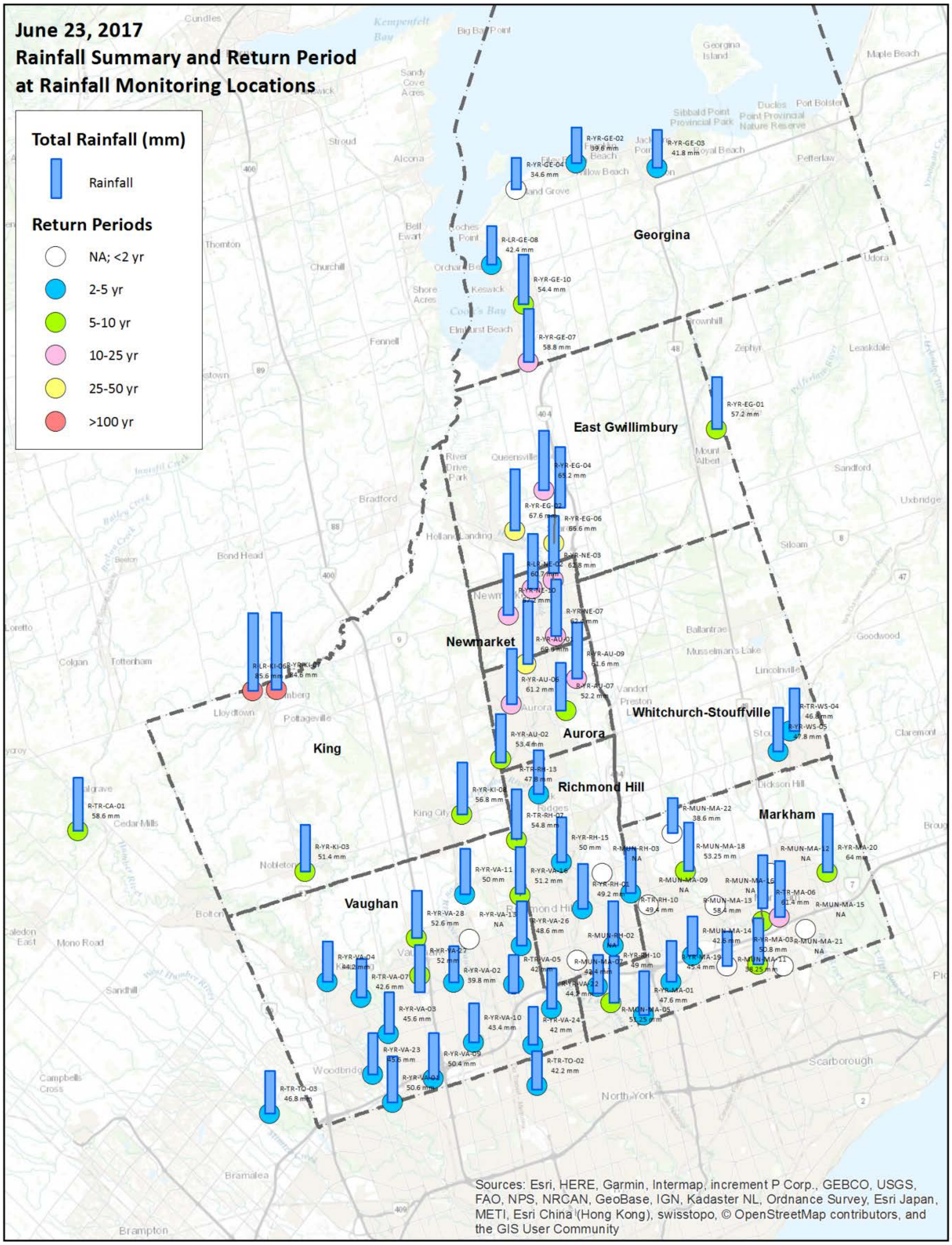


Figure 8: Rainfall Summary Return Periods on June 23rd, 2017 Event

All flow meters record real-time data in both the Regional and local municipal systems. Data is used by Regional and local staff and is available online through FlowWorks – a web-based "big data" management system. More than 88,000 records are transferred daily to the Region's Oracle data warehouse resulting in over 41 million readings (including various data channels for each device) collected each month. Flow and rainfall monitoring site assessments, installation, and maintenance reports are completed and updated for every site. Over 2026 site visits were completed from January 1st to December 31st, 2017 to ensure high quality data collection.

As of December 31, 2017 the Region owns and operates 43 rain gauges as shown in Table 6 and shares data from 28 rain gauges owned by stakeholders (Toronto Region Conservation Authority, Lake Simcoe Region Conservation Authority, Town of Richmond Hill and City of Markham). Rain gauge field maintenance is performed on a biannual basis in the spring and fall and within two business days if issues are suspected through monitoring.

Table 6 - Summary of Rain Gauges Installed Throughout the Region

Municipality	Total Number of Rain Gauges
York Region	43
TRCA	10
LSRCA	3
Town of Richmond Hill	2
City of Markham	13
TOTAL	**71**

Figures 9 and 10 present the sanitary sewer flow and rainfall monitoring locations installed and operating to-date.

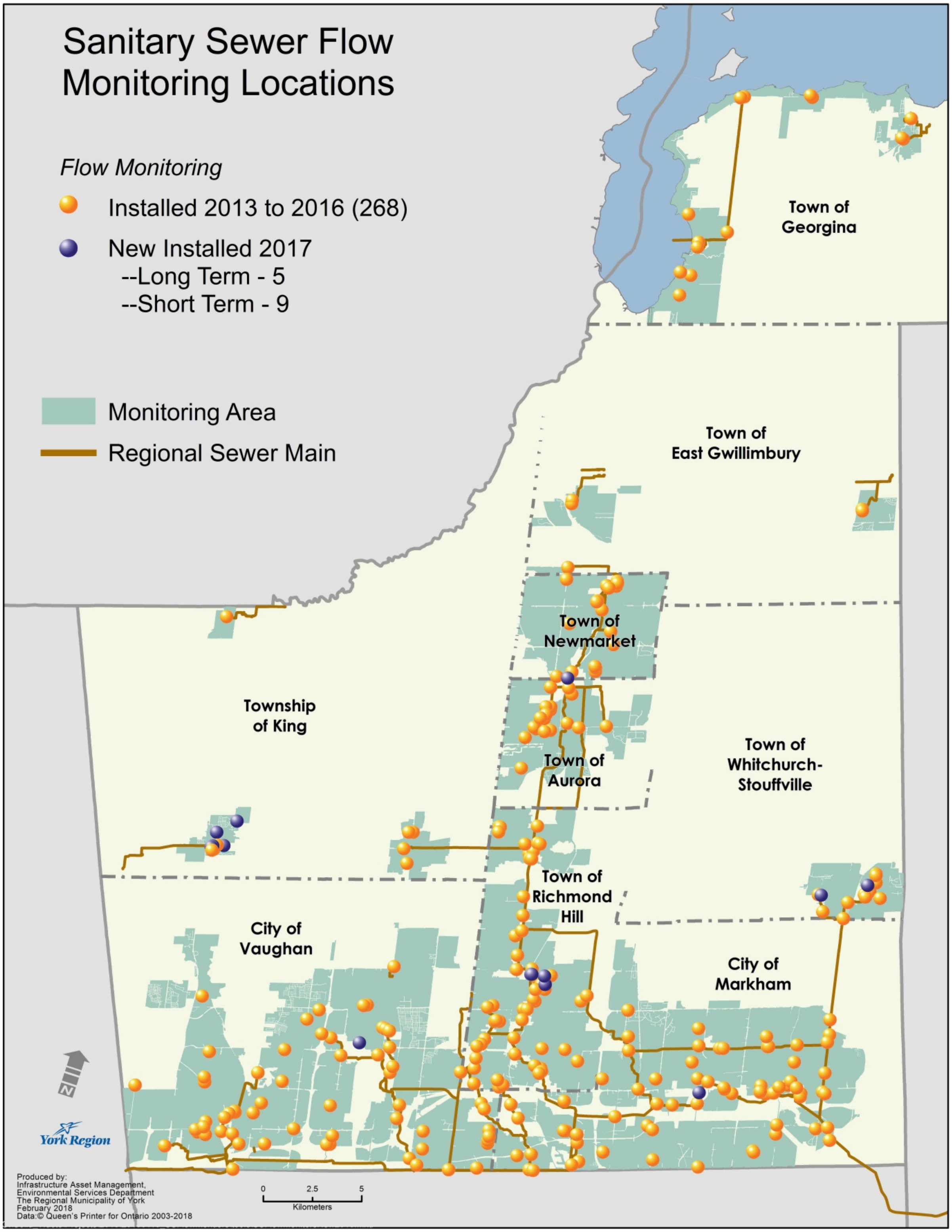


Figure 9: Sanitary Sewer Flow Monitoring Locations

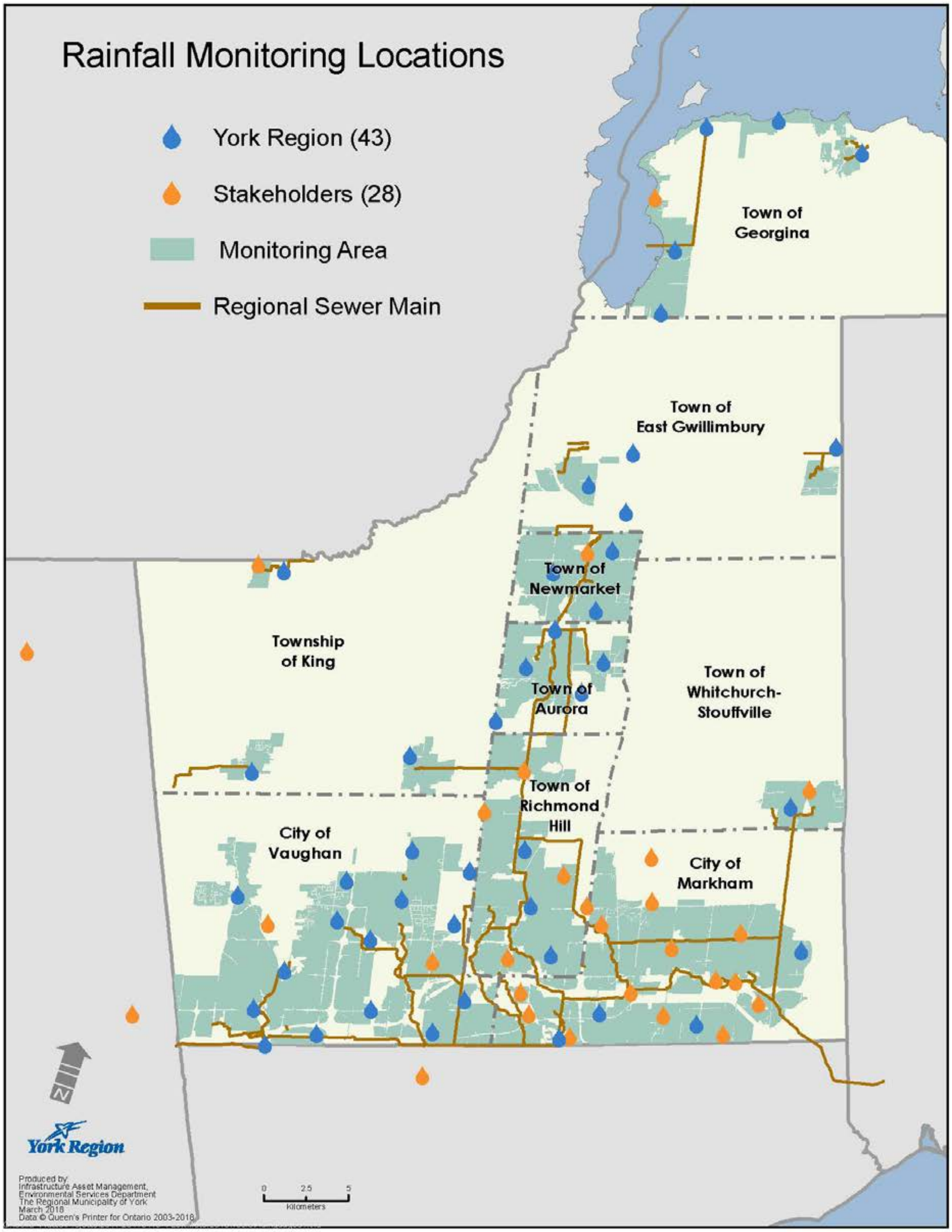


Figure 10: Rainfall Monitoring Locations

4.3 Short-Term Mini-Basin Monitoring

In 2017 a total of 14 mini basins were monitored to define areas requiring further action to reduce I/I; one in the Town of Aurora, three in the Town of Richmond Hill, three in the City of Markham and seven in the Town of Whitchurch Stouffville. Figure 11 provides an example of an audit basin in the Town of Whitchurch-Stouffville identified as high priority. This basin has been subdivided into seven smaller mini-basins to better identify the most responsive mini basins to rainfall.

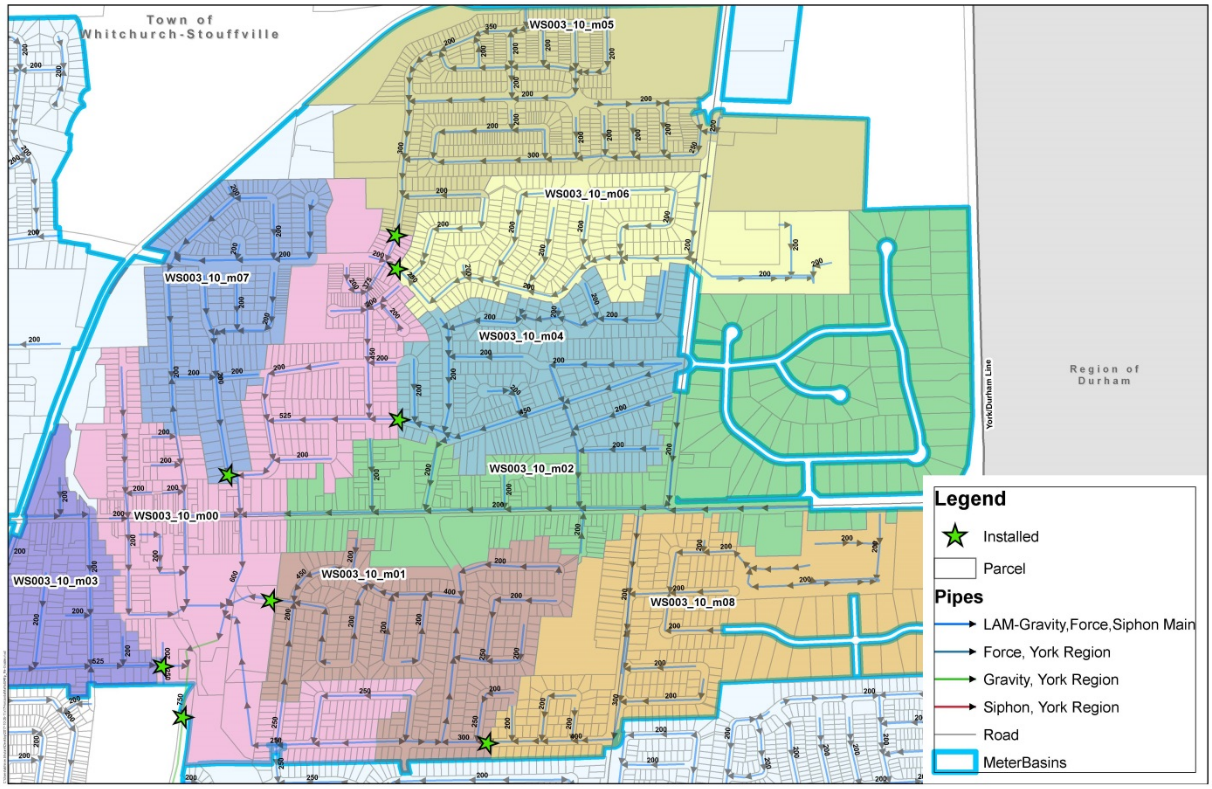


Figure 11: Map Showing Mini-Basins Generated in WS003 Audit Basin in the Town of Whitchurch-Stouffville

4.4 Short-Term Micro-Basin Monitoring

Shot-term micro-basin pilot monitoring program continued in 2017 to identify the feasibility of further subdividing the mini-basins into two or three micro-basins. The Long-Term Flow Monitoring Program’s annual wet-weather flow analysis identified two priority mini-basins for further monitoring at the micro-basin level. Leveraging new technology, measuring level-only from the top of the maintenance hole, was piloted in 2017 to minimize efforts to install and maintain the additional meters required for Micro-basin monitoring.

A total of 12 level-only micro-monitors were installed in two mini-basins: ten in the Richmond Hill mini-basin and two in Georgina. Spikes in the level during a rainfall event at the micro-basin level were compared to the spikes that occurred at the mini-basin level downstream in an attempt to identify the micro-basin that contributed the most to the increase in level downstream. Further analysis of the data is ongoing to determine the efficacy of this approach to further isolate the source contributing to increased wet weather flow responses. If successful, more selective use of Sanitary Sewer Evaluation Surveys (SSES) and rehabilitation work can be realized.

Depending on inflow and infiltration analysis results and criticality mapping, the sensors will be relocated in 2018 to complete a new study phase in another priority area.

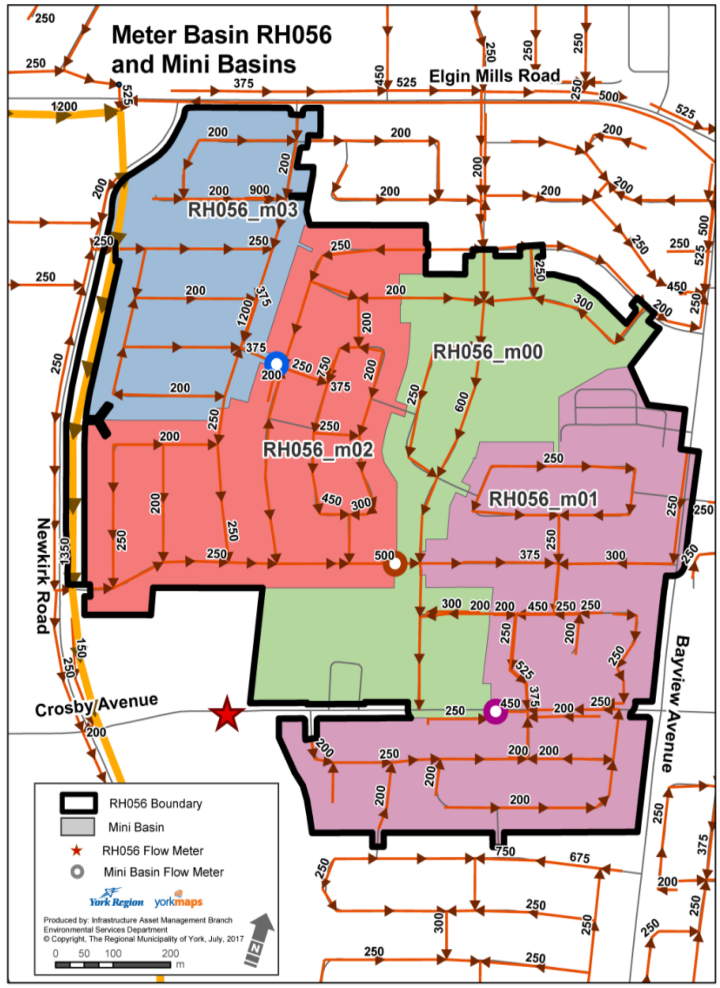


Figure 12: Map Showing Micro-Basin Monitoring Locations in the Town of Richmond Hill (RH056)

Figure 13: Level-only Flow Meter installed in the Town of Georgina

4.5 Temporary Flow Monitoring in the YDSS

Three programs were established in 2017 to monitor flows in the Regional Trunk System required for calibrating the Regional wastewater hydraulic model and monitoring flows before and after capital rehabilitation projects.

York-Durham Sewage System (YDSS) Model Calibration

The 2017 YDSS Model Calibration Project identified a requirement for flow monitoring at nine sites in the Regional trunk system. A separate project was established under the Long Term flow monitoring program to leverage the existing resources and equipment available from this program. Installations commenced in March 2017.

Strategic monitoring points were defined in the Cities of Vaughan and Markham and the Towns of Aurora and Newmarket. Table 7 details the installations completed for calibration purposes. An additional tenth site was installed to monitor infiltration into an abandoned but not decommissioned pipe in July 2017.

Table 7- Site Installation details for 2017 YDSS Model Calibration as of November 30, 2017

Municipality	Monitoring Sites Installed	Peak Combo Sensors Installed
Town of Aurora	2	2
City of Markham	1	1
Town of Newmarket	4	4
City of Vaughan	3	3
TOTAL	**10**	**10**

With the additional data collected during 2017, the hydraulic model will be calibrated and the data will be correlated and analyzed through the I/I prioritization process to support identifying new monitoring locations for areas that require further studies and to evaluate future inflow and infiltration reduction.

4.6 York Region Capital Projects

Aurora Sewage Pumping Station Outfall Gate

York Region Operations suspected a problem at the Aurora Sewage Pump Station overflow outfall flap gate in the summer of 2016. Extremely high flows at the pumping station during storm events led operations staff to believe that creek water may be entering the station through the overflow pipe, as the golf course was prone to flooding during large storms. See Figure 14 below, detailing a cross section of the overflow pipe and flap gate.

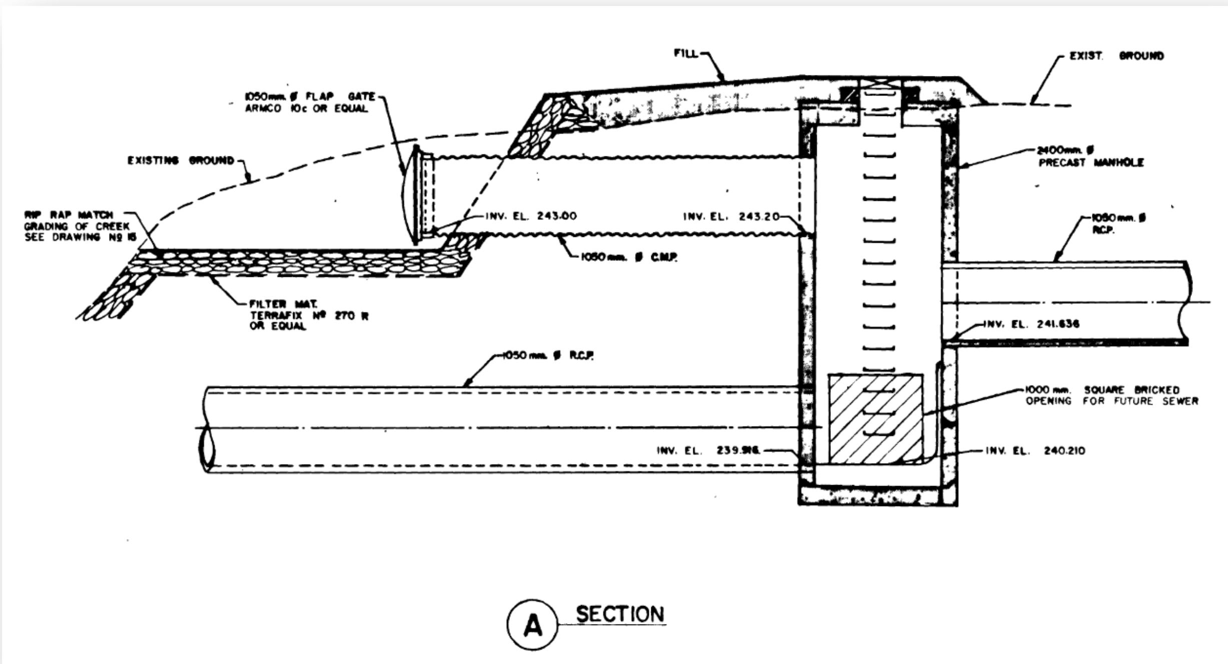


Figure 14 – Pipe Section and Elevations of the Outfall Pipe and Flap Gate at the Aurora Sewage Pumping Station Outfall (see drawing provided in Appendix B)

Further investigation revealed that the gate could not completely close due to accumulation of vegetation and debris. The opening ranged from approximately 45 mm at the bottom (Figure 15 – lower left picture) and 2 mm at the top (Figure 15- lower right picture).

Figure 15 – Aurora Sewage Pumping Station Flap Gate Opening and Field Measurements

The Lake Simcoe Region Conservation Authority (LSRCA) was consulted for their 25 year flood plain elevation of the creek at this location. Under a 25 year, 24 hr Type II Soil Conservation

Service (SCS) storm, the LSRCA model estimates the flood plain elevation at 246.31 m. The invert for the outfall flap gate was listed as 243.0 m in the Region's GIS records. With 3 m of hydrostatic pressure over an opening with a cross sectional area larger than a 200 mm pipe, it was clear that the flap gate could be an extremely large source of inflow and required immediate remediation.

An ultrasonic sensor was installed in May of 2017 to measure the rise and fall of the river in response to rainfall. The purpose was to verify operations staff sightings of golf course flooding, use the data to predict a 25-year storm response and confirm the results provided by the LSRCA flood model. The relative elevations of the outfall invert, river bank, monitoring point and surface of water in dry (top row), and flooded (bottom row) conditions are shown below in Figures 16-18.

Figure 16 –Aurora Sewage Pumping Station Overflow Outfall Flap Gate location in comparison to the creek levels during dry and submerged conditions
(During Jun 22-23, 2017 rainfall event)

Using level data for the creek (Figure 17), and the benchmarks shown in Figure 18, a reduction figure for the repair of this problem was generated from the June 23, 2017 storm event creek rise.

Figure 17 – Down-looking Ultrasonic Level Sensor Monitoring Creek Levels at Aurora Sewage Pumping Station in May (left) and June 23 (right) of 2017

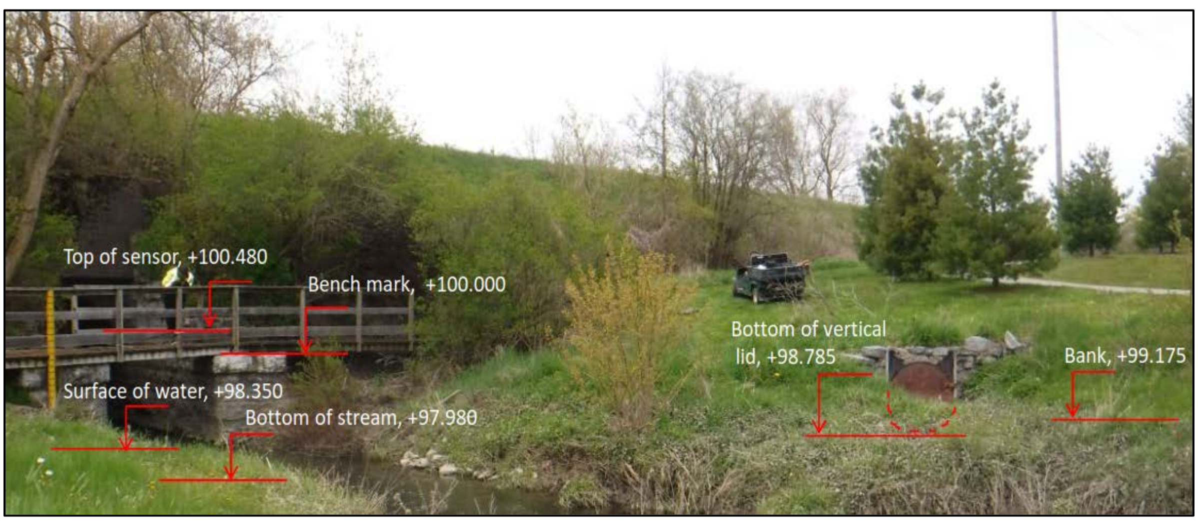


Figure 18 – Aurora Sewage Pump Station Stream Level (in meters)

The reduction of inflow is estimated to be 5.6 MLD, using weir and orifice equation calculations in InfoWorks modelling software and excel. See Appendix B for a detailed description of the problem and quantification method/calculations. A 36" Series 35-1 Tideflex Duckbill Check Valve and new concrete headwall was installed, along with the necessary regrading and restoration (Figure 19). This work will ensure creek water is isolated from the sewer system during high flow events.

Figure 19 – Construction Zone after Removing the Old Headwall (Left) and Formation of the New Headwall (Right)

A number of other Regional rehabilitation projects are ongoing and inflow and infiltration reduction quantifications will be reported in future annual reports.

4.7 Sanitary Sewer Evaluation Studies (SSES)

SSES programs are developed and executed by York Region in coordination with the associated local municipality for mini-basins identified as sources of significant inflow and infiltration.

In 2017, the Region expanded the micro-monitoring pilot to see if further refining the mini-basins into smaller micro-basins help isolate areas that show high peak response. The pilot will continue in 2018 to determine the effectiveness of this approach in comparison to investigating larger areas through other sanitary sewer evaluation studies (e.g. smoke and dye testing).

SSES activities were conducted in 2017 as part of the private initiatives in Newmarket as detailed in Section 6 and as part of the City of Markham's Downspout Disconnection Program (Section 5.6).

4.8 Inflow and Infiltration in New Development

Over the past seven years the Region and its local municipal partners have identified Inflow and Infiltration issues in new developments. Typical defects in new sanitary sewer systems include the following: offset joints, poor connections at the maintenance holes, leaking maintenance holes and poor connections at the lateral to mainline. These defects are not always identified in post construction CCTV and activities such as drain excavations through the newly constructed sanitary sewers. These defects have the potential to be a significant source of inflow and infiltration. This is especially concerning since it is expected that new sewers ought to be nearly watertight and any storm/groundwater entering the sewer will likely increase over time.

In August 2017, the Region, in collaboration with the local municipalities and the Steering Committee, initiated a project to survey the design, construction, inspection, testing and acceptance of new sanitary sewer infrastructure in the public and private right-of-way in York Region's nine local municipalities. The work involves a literature review and on-site inspection surveys. As part of this study, in September 2017, the Region held its second Inflow and Infiltration Reduction Design Standards working group meeting with municipal staff, building officials and plumbing inspectors. The goal of the meeting was to collaborate with the nine local municipalities to discuss I/I in new developments and means to address it through new design, inspection practices and technologies. Representatives from the local municipalities were surveyed regarding their design and inspection practices, with the intent to utilize the feedback received to update the Region's existing Sanitary Sewer System Inspection Testing and Acceptance Guideline (2011).

Also, in late 2017 individual meetings were held with local municipal staff from each of the nine local municipalities in York Region to investigate their practices for minimizing inflow and infiltration in new development. Another round of similar meetings and field survey visits will be held in early 2018.

4.9 Communication and Social Media

A communication strategy was developed in 2017 to increase information flow both internally and externally. The communication strategy acts as a framework and basis for the communication of the Inflow and Infiltration Reduction Program and is an important tool for implementing communication with the different stakeholder groups. The Strategy streamlines communication by defining resources, methodologies and tools needed and providing processes that will ensure that clear and consistent messaging is being shared by York Region and the nine local municipalities.

One facet of the Communication Strategy is the use of social media to interact with York Region residents. Twitter and Facebook are being explored as a means to increase resident awareness and participation in reducing problems associated with clean water entering the sanitary sewer system.

The purpose of introducing the Inflow and Infiltration Reduction Program through social media is to set the stage for future reduction education campaigns (such as downspout disconnection and lateral inspection) that can be delivered in collaboration with the local municipalities and require residents' participation. Primarily Twitter is being used to spread awareness and the information is supplemented by Facebook posts (See example in Figure 20).

Figure 20 – Example of a Twitter post that was released in November 2017

In 2017, technical language including the terms “inflow” and “infiltration” were introduced to resident programming to increase familiarity with the program and set the stage for future initiatives. A 3-D printed model of a house was created to help inform the public and build awareness of inflow and infiltration sources in public and private property. The model will be used at community events such as the Water Week and Earth Week events.

The Region updated its Inflow and Infiltration Reduction website in 2017 (www.york.ca/iandi) to ensure information is up-to-date and the public are well informed. Using a combination of brief text messages, photos, 3D models (see Figure 21) and links to resources, residents will be exposed to wastewater infrastructure and inflow and infiltration reduction methods.

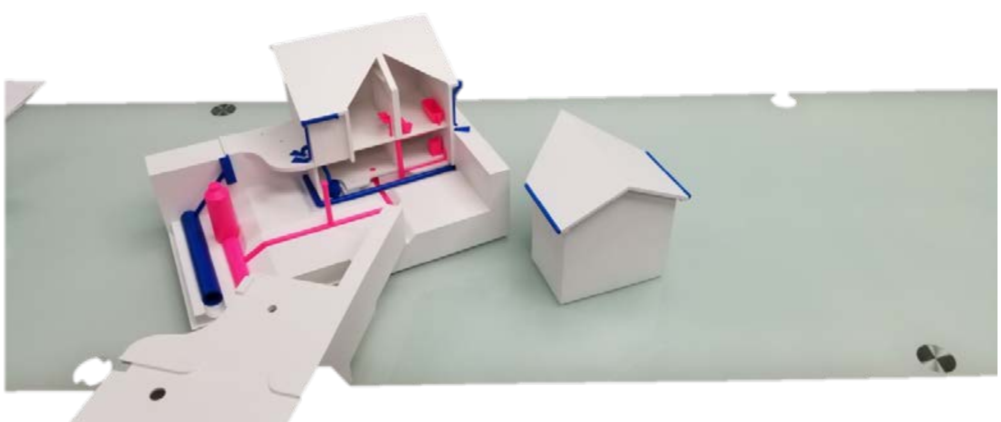


Figure 21 – 3D Printed Model used to Demonstrate Proper Pipe Connections

5.0 2017 Summary of Local Municipality Program Activities and Accomplishments

Over the course of 2017, the nine local municipalities continued with I/I investigations, operation and maintenance programs and other I/I reduction initiatives. Repairs were performed on priority assets deemed critical for rehabilitation and replacement and in areas identified as high priority per the Region's analyses from the flow monitoring data collected in the local system.

5.1 Inflow and Infiltration Reduction Programs

The City of Vaughan continued in 2017 with their city-wide Inflow and Infiltration Reduction Program. The primary purpose of the City's program is to target smaller areas identified by the Region as high I/I Priority areas in order to examine the flow monitoring data against the City's Design Criteria and understand possible causes of I/I. The City has also developed a webpage exclusively for I/I where information of current initiatives and programs are provided and updated regularly.

The Town of Newmarket's Council approved capital projects for 2017 which included rehabilitation of 20 sanitary sewer lateral pipes on Prospect Avenue, and a sanitary sewer on Queen Street and on Wilstead Drive (Phase 2 of the project will continue in 2018). The Town of Newmarket also continued with the investigative studies and rehabilitation as part of the Developer-funded Inflow and Infiltration Reduction Project Agreement as described in Section 6.1.

The City of Markham continued its efforts to reduce I/I from its local sanitary sewer system through various programs including high-standard routine operation and maintenance activities; targeted flow and rainfall monitoring and analysis and downspout disconnection program. To mitigate flood risk in the older areas caused by the 2017 summer intense storms, Markham's City Council approved on September 18, 2017 a series of flood remediation projects/programs which included budget and work approved to move forward with Phase 5 of their Sanitary System Downspout Disconnection Program. Additionally, they proposed an interim Private Property Plumbing Protection Program which includes backwater valve and sump pump subsidy program for high risk areas. Reductions achieved from Phase 2 of the City's Downspout Disconnection Program are reported in this year's report and as detailed in Section 5.6.

The Town of Whitchurch-Stouffville rehabilitated and replaced sanitary sewers mains during 2017, via three projects on Main Street, Burkholder Street and Stouffer Street. Post-monitoring in those areas is ongoing and reductions will be captured in next year's annual report. Additionally, the Town has embarked on a Sump Pump Disconnection Study and is developing an education program, a disconnection of rooftop downspouts, and sump pumps from their sanitary mainline sewer. Preliminary results will be available in early 2018 and will be reported in the 2018 Annual Report.

The Town of Georgina repaired infiltration issues in mainline and lateral sanitary sewer pipes through their Burke Garrett and West Watermain Project (BGW) and Dalton Rd Sanitary Lateral Rehabilitation Projects. The Town of Aurora decommissioned sanitary sewer laterals and an old clay sanitary line. Results are reported in this year report (See Table 1).

5.2 Sanitary Sewer Flow Monitoring

The local monitoring programs focus on mini-basins (smaller catchment areas within the larger Audit Basins monitored through the Region's program) identified with significant I/I; to better identify the sources, provide data to support the local municipal wastewater models and evaluate system capacity.

To supplement data from the Region's Long-Term Monitoring Program, the City of Markham continued collecting flow data from its 25 short-term flow monitors in its sanitary sewer system. Generally, the monitors are in place for approximately 13 months after which they are moved to other areas of interest. The purposes of Markham short-term flow monitoring program are:

1. To divide the Region's larger monitoring catchments into smaller ones to better target I/I sources

2. Prioritizing City's sanitary downspout disconnection program, lateral inspection and sewer rehabilitation program
3. Post-downspout disconnection benefit verification
4. Sanitary system capacity analysis and hydraulic model calibration; and,
5. To assist new development servicing options

Flow monitoring is also ongoing within new residential developments (Holland Landing, Queensville and Sharon) as part of the Town of East Gwillimbury's Sustainable Home Incentive Program (SHIP) and in coordination with the existing Sanitary System Inspection, Testing and Acceptance Guidelines. The Town has installed 20 flow meters throughout the mentioned developments.

The Town of Georgina took part in a mini basin flow monitoring study in Sutton in 2017 to investigate possible sources of I/I potentially proceeding from a newly developing area. As part of the project, the Town installed four short-terms flow monitors dividing the Regional audit basins (GE002_10 and GE002_20) into mini basins to further analyze the flows and identify I/I issues.

The City of Vaughan's 2017 mini basin flow monitoring consisted of six flow meters that covered an approximate gross area of 1,597 hectares. The two areas, one is commercial and institutional (ICI) in the east near Bowes Road and Oster Lane (Bowes Road) and one residential in the west near Highway 7 and Islington Avenue (Highway 7) were monitored for 13 months.

2017 flow monitoring location maps at the different municipalities are provided in Appendix C.

5.3 Investigation and Rehabilitation

The Cities of Markham and Vaughan and the Towns of Whitchurch-Stouffville, Georgina, East Gwillimbury, and Newmarket have annual CCTV inspection programs in-place for sanitary sewer mains. Below is a summary of the investigation and rehabilitation activities completed by the local municipal partners in 2017:

- The Town of Aurora inspected 15.6 km of mainline within its sanitary sewer mainline CCTV program and repaired four sanitary sewer laterals. A total reduction of 0.021 MLD was achieved.
- The Town of East Gwillimbury inspected over 33 km of mainlines in Holland Landing and Mount Albert to determine the structural I/I issues within the system. Results of the CCTV inspections will be provided in Q1 2018.
- A total of 47.5 km of sanitary sewer and 48.7 km of storm sewer were smoke tested under Phase 5 sanitary downspout disconnection program in the City of Markham.

- Based on annual CCTV mainline (5.2 km) and lateral inspection results in the City of Markham, mainline sewer full-length lining (three sections) and spot repair (24 spots), lateral full length lining, manhole repair (54), mainline grouting and lateral joint (1047 joints & 15 junctions) sealing work were identified and conducted.
- The Town of Georgina inspected approximately 63 km of mainline.
- CCTV videos for potential I/I sources were provided to the Region for further investigation and quantification. The Town of Georgina repaired infiltration issues in mainline and lateral sanitary sewer pipes through their Burke Garrett and West Watermain Project (BGW) and Dalton Rd Sanitary Lateral Rehabilitation Projects. A total reduction of 0.05 MLD was quantified.
- Over 12 km of mainlines were inspected and flushed by the Town of Whitchurch-Stouffville.
- Three reconstruction project including work to either rehabilitate or replace sanitary sewers (Main St, Burkholder St and Stouffer St) were undertaken by The Town of Whitchurch-Stouffville.
- The Town of Newmarket rehabilitated 20 sanitary sewer laterals pipes on Prospect Avenue and sanitary sewer mainlines at Queen St and Wilstead Dr.
- The City of Vaughan conducted CCTV in 0.5 km of sanitary mainline sewer to resolve multiple spots with I/I issues at Discovery Trail, Atkinson Ave, Keele St and Portage Pkwy.
- 3 cross connections were identified by the City of Vaughan at 10 Dundurn Crescent, 52 Maxwell Court and 11 Trafalgar Square via dye testing.
- The Township of King has finished investigation in the catchment areas in Nobleton and in Schomberg. Two Requests for Tenders will be issued in Q1 2018 to address rehabilitation of their system due to I/I issues. The Township will rehabilitate its sanitary sewer mains by using inversion and curing of a resin-impregnated tube, its maintenance holes by using chemical grouting and its sanitary sewer laterals by using chemical grout and the NASSCO suggested standard specification for pressure testing and grouting of sewer Joints, laterals and lateral connections.
- Approximately $2.8M were spent by local municipalities on sanitary sewer investigation and I/I reduction activities as specified in Table 8 below.

Table 8 - 2017 Expenditures by Local Municipalities

Activity	Approximate** Dollars Spent in 2017
Flow and Rainfall Monitoring	$ 181,117
Mainlines and Maintenance Holes Inspections, and Repair	$ 1,913,474
Laterals Inspections and Repair	$ 603,386
Downspout Disconnections & SSES	$ 127,900
TOTAL	**$ 2,825,877**

**Amounts provided are approximate and may not all be exclusively I/I related

5.4 New Developments

The implementation of new development initiatives is to reduce the amount of I/I occurring in new infrastructure. Notably, the Town of East Gwillimbury has imposed stringent allowances as part of their subdivision agreement approval process through their Sustainable Development Incentive Program (SDIP). The Town of Aurora also requires all new developments to fully implement a similar program following the Region's Servicing Incentive Program (SIP) program. All local municipalities are working collaboratively with the Region on the I/I in New Development Survey project.

5.5 Design Standards

In parallel with the Region's work with changing the Sanitary Sewer System Inspection, Testing and Acceptance Guidelines (2011), the Township of King updated their engineering design criteria in 2017, aiming to create a water-tight sanitary sewer system. The City of Markham and the Towns of East Gwillimbury and Whitchurch-Stouffville are currently in the process of implementing similar engineering design criteria updates to reduce inflow and infiltration. Ideas include, but are not limited to, water-tight maintenance hole covers and frames and membrane wraps around sewer joints and maintenance hole joints to make them more water-tight.

5.6 City of Markham's Downspout Disconnection Program

The City of Markham's Downspout Disconnection Program is multi-phased and started in 2013. It aims to reduce the risk of basement flooding and environmental concerns caused by the direct connection of downspouts to the sanitary sewer system. The program targets at risk areas and replaces the connections with splash pads that direct water away from property foundation walls.

The City's Downspout Disconnection Program is composed of four areas. Each area of focus within the City has been placed in a particular phase of the program based on available historical information including flow data and operational records of sewer backup/basement flooding.

- Phase 1 Program Area - began in May 2013 within the Thornhill area and the I/I reduction was reported in our 2016 report
- Phase 2 Program Area - began in May 2014 within the Thornhill area
- Phase 3 Program Area - began in May 2015 and covers the area within Thornhill, Milliken and Unionville
- Phase 4 Program Area - began in May 2016 within the Markham Area

Phase 1, was quantified and reported on in the 2016 York Region Inflow and Infiltration Reduction Annual Report. Phase 2, occurring between Yonge Street and Leslie Street has been quantified this year (Figure 22). The total benefit derived from the repair activities was estimated to be approximately 0.262 MLD for the disconnection of 85 downspouts on 58 properties as part of Phase 2.

The volume of flow from each downspout was derived using a simple modified Rational Method where the volume of rain was multiplied by the rooftop area and a runoff coefficient. The rainfall is simply 62.7 mm derived from a four-hour Chicago storm using Pearson International Airport (Intensity-Duration-Frequency) IDF values. The area is determined by roof shape and eavestrough slopes and field images are sketched out and transferred to GIS images to derive the total area. A 0.95 runoff coefficient for a roof in a 25-year storm is then applied to the area.

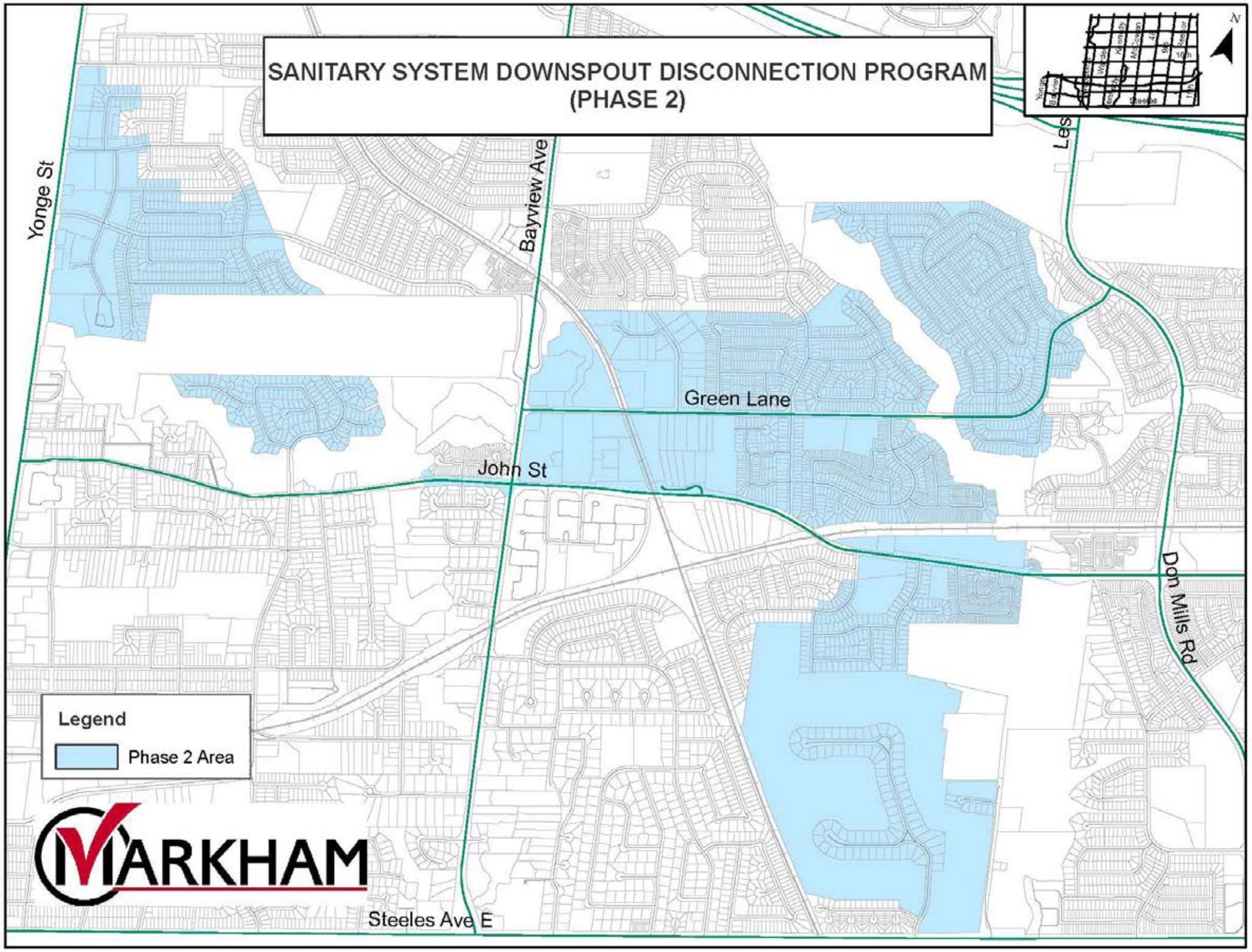


Figure 22 – City of Markham's Downspout Disconnection Program Phase 2

6.0 2017 Summary of Program Activities and Accomplishments for Private Initiatives

The Region has entered into five tri-party inflow and infiltration reduction pilot agreements (Developer-funded Inflow and Infiltration Reduction Project Agreements) with local municipalities and developer groups since 2011. The following local municipalities have participated in the past six years:

- City of Markham
- Town of Aurora
- City of Vaughan
- Town of Richmond Hill
- Town of Newmarket

Subsequent sections will cover new and on-going work in 2017 through the developer-funded agreement in the Town of Newmarket and the Servicing Incentive Program (SIP) implemented in the Town of Aurora.

6.1 Inflow and Infiltration Reduction Pilot Agreement - Town of Newmarket

Developer funded activities included repairs and further investigation activities in 2017. Repair work included:

- Disconnecting 14 downspouts at thirteen residential properties (see areas in Figure 23 below).
- Diverting flow away from one foundation drain.

Work was performed in Areas 1, 3, 8, 10, 11, and 14 (Figure 23) which are mini-basins within Regional Audit basins NE005a_10, NE005b_10, NE006a_10, NE006b, NE009_10.

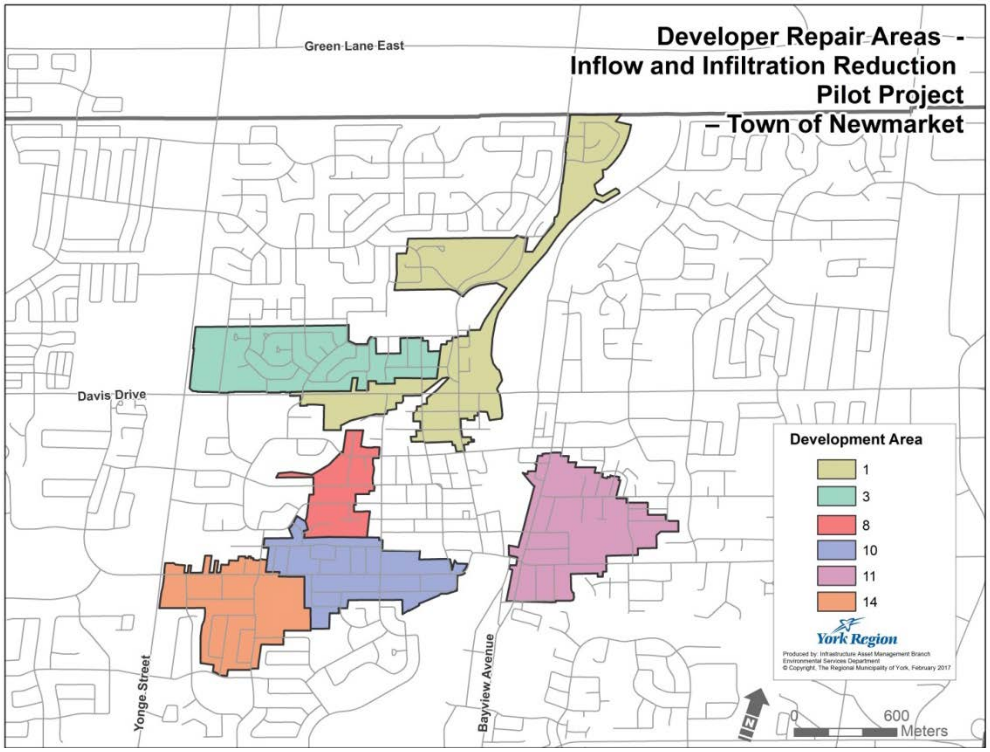


Figure 23 - Private Initiative Pilot Areas and Satellite Imagery

The total benefit derived from the repair activities was estimated to be approximately 0.034 MLD for 2017. Additional repair work will be done in 2018 as a result of the investigation done in 2016 and 2017. Figures 24 through 26 summarize the investigative work highlighting the areas where CCTV, smoke tests, dye tests, lot inspections and manhole inspections were performed. The smoke test numbers refer to the number of times one to two sewer segments were blocked to test the properties along the line and a dye test refers to an injection point on a property suspected of a positive connection. To date the following inspection activities have been performed:

- Over 50km of CCTV
- 865 hectares of area covered by smoke testing
- Over 4000 dye testing injections
- Over 8000 lot inspections
- 626 low lying manhole inspections

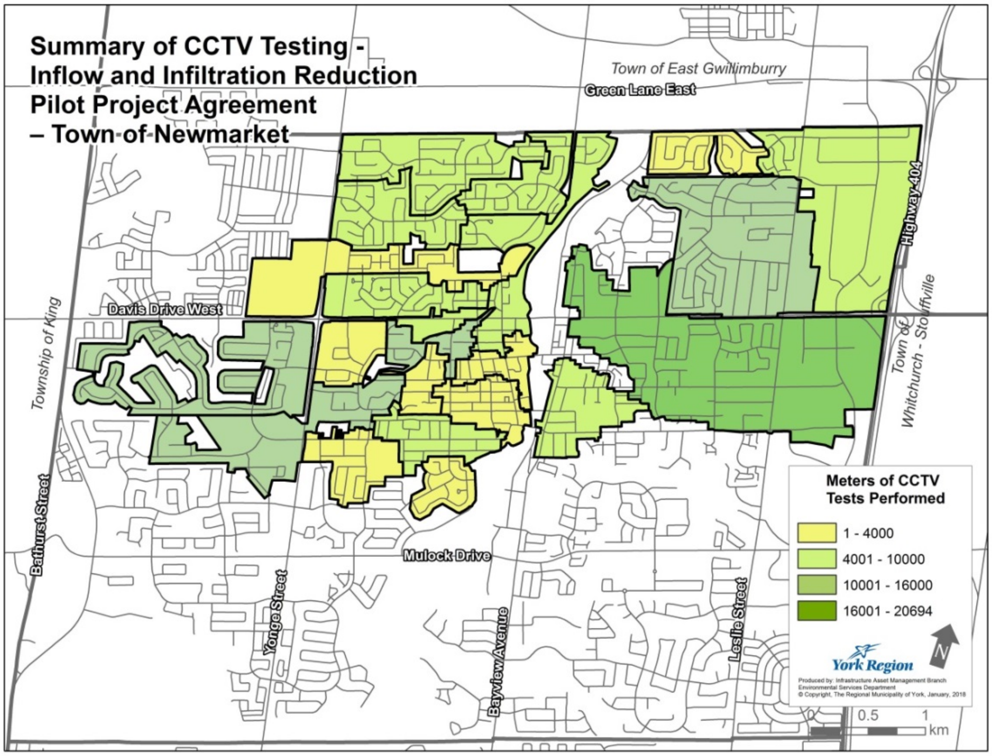


Figure 24 - Meters of CCTV investigated in the Town of Newmarket in 2015-2017

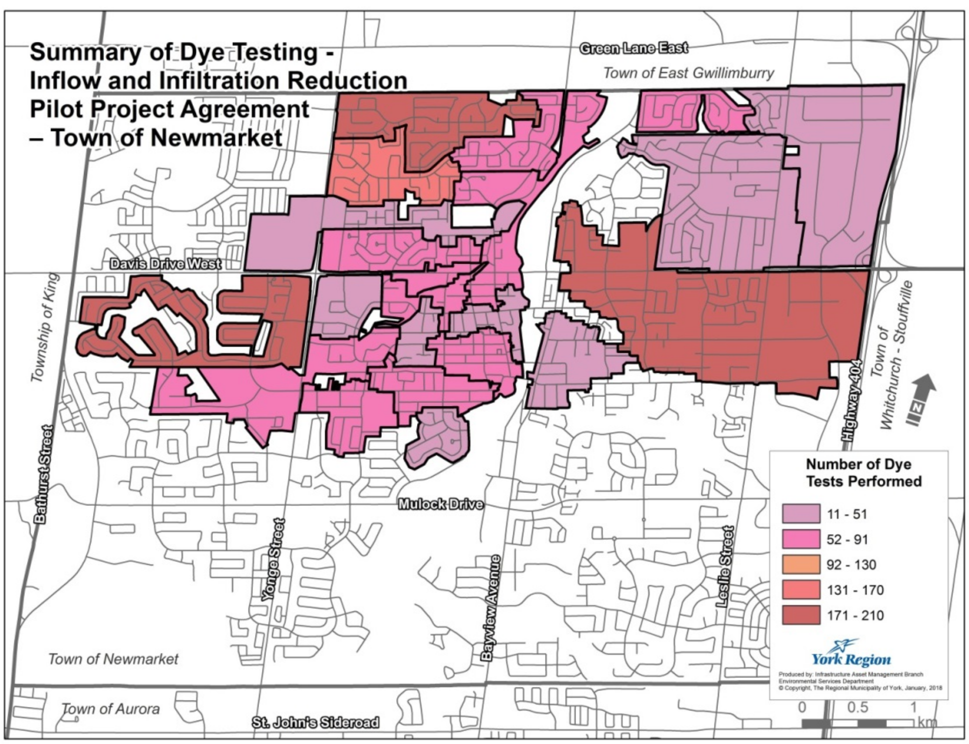


Figure 25 - Number of Dye Tests Performed in the Town of Newmarket in 2015-2017

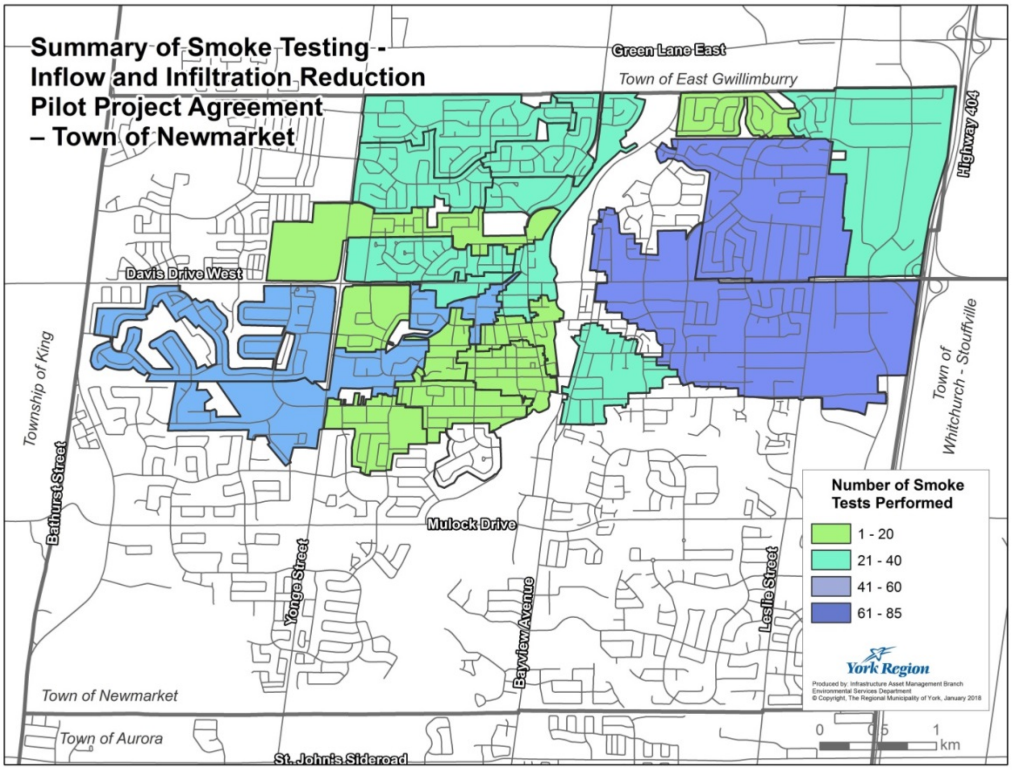


Figure 26 - Number of Smoke Tests Performed in the Town of Newmarket in 2015-2017

6.2 Implementation of Servicing Incentive Program (SIP) - Town of Aurora

In 2017, the Town of Aurora continued implementation of the Servicing Incentive Program (SIP) for new development in partnership with York Region. The program promotes sustainable residential grade-related developments through water efficiency, waste water flow reduction and inflow and infiltration reduction. These benefits are obtained through higher standards in construction and inspection of sewer works. Examples of construction standards for sanitary sewer in 2016 SIP include:

- Sanitary sewer pipes shall be constructed in a manner to ensure the absence of extraneous flows, using best available technology.
- Only pre-manufactured tees and standard fittings shall be permitted.
- Sanitary sewer pipes shall be comprised of PVC DR 35 (or better) based on the pipe depth, and shall be installed with bell and spigot gasketed joints, as per Local Area Municipal Standards.
- C900 (100 mm to 300 mm) or C905 (340 mm to 600 mm) PVC pipe (or concrete pressure pipe) will be specified in areas of high water table or where sewer is greater than 8.5 metres deep.
- Connections/joints shall be pre-manufactured gasketed connections.

Benefits are proven through flow monitoring in new developments for two periods of at least eight months and must satisfy the following benchmarks:

- Maximum instantaneous extraneous RDII flow allowance shall be 0.12 L/s/ha, under a 25-year event in the newly constructed sanitary sewer system.
- Maximum groundwater infiltration (GWI) allowance shall be 0.0375 L/mm diameter per 100 m of sewer pipe per hour, which is more stringent than the allowances outlined in the Ontario Provincial Standard Specification's (OPSS) for pipe sewer installation.

Increased participation in SIP activities was seen in the Town of Aurora. Within the Bayview Northeast Area 2C West Secondary Plan Area, six developments are currently enrolled in the SIP program. Five of these developments partook in the SIP flow monitoring program and seven flow monitors were installed within the area (See Figure 27). Details of the SIP flow monitoring program are as follows:

- Six Development Phases were monitored for wastewater flow
- Four Phases completed the first period of SIP flow monitoring; starting in April after the first building connection to the existing system immediately following the removal of the downstream bulkhead

Two Phases completed the second period of SIP flow monitoring; they were initiated after reaching 85 per cent occupancy within the development phase.

Figure 27 – Town of Aurora 2017 SIP Flow Monitoring Locations

7.0 Conclusion

Through a close partnership with its nine local municipalities, the Region continued to demonstrate leadership in inflow and infiltration reduction in 2017. This year, 5.99 MLD of I/I was reduced in the YDSS, bringing the overall total to 17.59 MLD. This represents 44 per cent of the 2031 target of 40 MLD which exceeds the 25 per cent reduction target set for 2017.

Long and short-term flow monitoring in mini and micro-basins continued in 2017. A new approach to investigate rather smaller areas started in 2016 and will provide results at the end of 2018. The effectiveness of this approach will be reported in the 2018 I/I Annual Reduction Report. New methods to quantify base infiltration were also explored. Additionally, a study detailing the effect of antecedent rainfall on RDII was started and will be published in consecutive years.

A number of rehabilitation projects were completed in 2017; from issues identified at the Aurora Sewage Pumping Station (AU SPS) Outfall to mainline and lateral sewer repairs throughout the system, new and innovative technologies along with proven methods were used to address the problems. A new Region-wide initiative to identify and standardize best-in-class sewer design inspection and testing guidelines to address I/I in new development was launched. Discussions over I/I issues in private property and the need for inspection and update of the sanitary sewer bylaws were reiterated and continue to be a priority in 2017.

Overall the Region and local municipalities spent a combined total of $5.9 M on I/I-related activities, including: flow and rainfall monitoring, inspection and repair of mainlines and laterals, sealing of maintenance holes, downspout disconnections, and SSES. Moving forward the Region will continue to leverage its knowledge and experience as it seeks to refine and expand its best-in-class I/I Reduction Strategy, and demonstrate world leadership in the field of I/I reduction.

Appendices A to C

Appendix A
Antecedent Rainfall/Moisture Conditions Study

The importance of antecedent moisture conditions has been prevalent across all basins in the Region, but especially in high response basins. The Region has found that good certainty in the line of best fit (r^2 values > 0.8) for Q vs I (RDII volume vs rainfall volume) plots over a season will not translate into good RDII predictions for results in another season (different moisture conditions). However, results during very wet, average wet, or dry conditions do seem to line up year over year. More data will be gathered over time to confirm this observation.

To illustrate the importance of antecedent rainfall over return period of a storm, three of the most significant events over three monitoring years are circled in green on Figure A1.

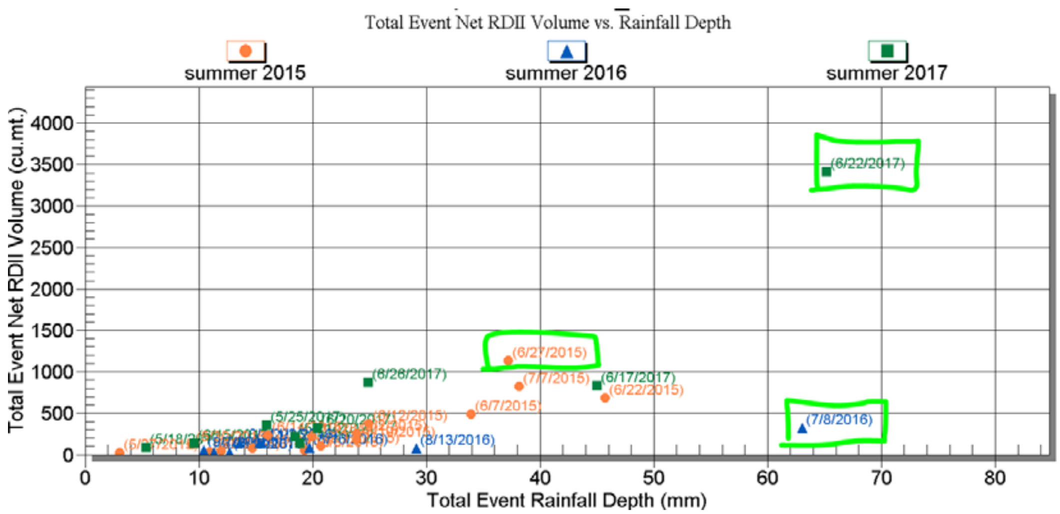


Figure A1 – Antecedant Rainfall vs Return Period on RDII

The 7/8/2016 storm in blue at the bottom of Figure A1 is an extreme intensity, 100 year return period storm – that occurred in dry conditions. The storm generated only one quarter of the RDII volume of the 6/27/2015 storm in orange, which was less than a 2-year event. The highest response on 6/22/2017 in green at the top, was relatively the same size in total volume as the 100 year event, but occurred in wet conditions similar to 6/27/2015. The result was that the 10-25 year storm generated more than 8 times the RDII volume of the 100 year storm.

The trend of antecedant rainfall importance over return period is not as extreme in every basin in the Region, but there are many with similar results – especially in basins that are high volume I/I responders. The observed trend leads to a caution in using results in one basin to compare to another in different years of monitoring with significant differences in rainfall/moisture conditions. However, when this basin is sorted into groups of < 12.5 mm rain (dry), 12.5-38.1 -mm rain (average wet) and > 38.1 mm of rain (very wet), the groupings have a very good correlation (r2 = 0.96, 0.89, 0.90). See Figure A2 for illustration. It can then be said with some certainty that the basin responds in certain ways in dry conditions, and in other ways in wet conditions. This will perhaps make for better comparisons across basins over varying seasons.

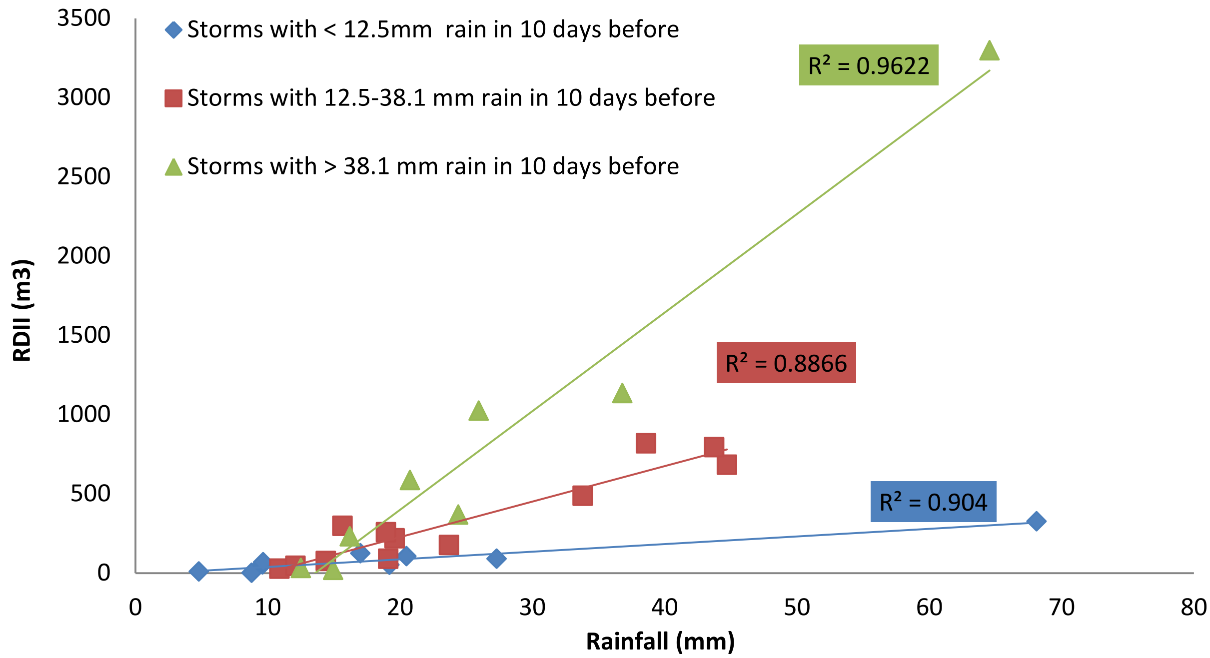


Figure A2 – Storm Trends by Antecedant Rainfall Volumes

Appendix B

Aurora Sewage Pumping Station Outfall Flap Gate- I-I Quantification

During the June 22-23, 2017 storm event, a near 25 year return period intensity storm response was observed in Aurora and recorded by camera and creek level monitoring. In some locations, the storm did not reach a 25-year intensity, however, the total rainfall lines up with the 25 year, 4 hour, Chicago Storm that we have used to quantify RDII in past MOECC reports (62.7 mm). The intensity of the storm is shown at different durations in Table B1 below.

Table B1: June 22-23, 2017 Storm Intensities for Aurora, Newmarket and East Gwillimbury

Maximum Rainfall Intensity (mm/hr) for 2017-06-22 10:05 to 2017-06-23 11:00

Site/Channel	5 min	10 min	15 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	Total Rain
R-YR-AU-01 / Final Rainfall	72	63.6	51.2	30	21.6	13	9.37	5.73	2.9	69.6
R-YR-AU-02 / Final Rainfall	45.6	33.6	29.6	27.6	20	11.7	6.13	4.38	2.23	53.4
R-YR-AU-06 / Final Rainfall	57.6	43.2	43.2	34.8	22.6	13.7	7.7	5.05	2.55	61.2
R-YR-AU-07 / Final Rainfall	50.4	36	31.2	25.6	17.2	11.1	6.27	4.28	2.18	52.2
R-YR-AU-09 / Final Rainfall	64.8	49.2	39.2	33.2	23	13.8	7.87	5.08	2.57	61.6
R-YR-EG-01 / Final Rainfall	33.6	28.8	24.8	24.4	20.6	15.7	8.23	4.7	2.38	57.2
R-YR-EG-02 / Final Rainfall	57.6	51.6	40	30	24.4	18.8	9.87	5.57	2.82	67.6
R-YR-EG-04 / Final Rainfall	43.2	36	37.6	29.6	22.6	18	9.37	5.37	2.72	65.2
R-YR-EG-06 / Final Rainfall	38.4	31.2	27.2	21.6	20.2	17.1	9.8	5.5	2.77	66.6
R-YR-NE-03 / Final Rainfall	33.6	28.8	22.4	20	19.6	15.1	9.03	5.18	2.62	62.8
R-YR-NE-07 / Final Rainfall	74.4	50.4	36.8	25.6	19.6	12.3	8.57	5.17	2.6	62.4
R-YR-NE-10 / Final Rainfall	40.8	39.6	31.2	25.6	18	14.1	9.53	5.57	2.8	67.2

Toronto Buttonville A, 1986 – 2007 21 years)

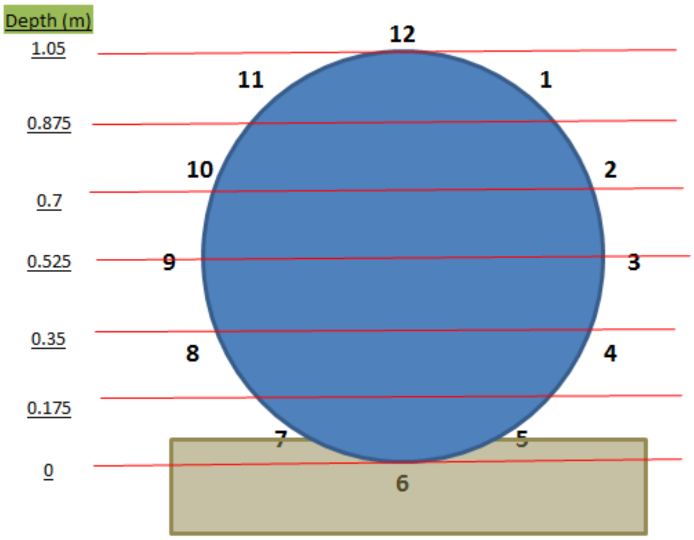
Storm	5 min	10 min	15 min	30 min	1 hr	2 hrs	6 hrs	12 hrs	24 hrs
2 Year Event (mm/h)	106.2	74.5	60.2	36.7	21.2	11.8	5.5	3.2	1.8
5 Year Event (mm/h)	136.4	95.6	77.8	51.2	31	16.6	7.2	4.1	2.3
10 Year Event (mm/h)	156.4	109.7	89.5	60.8	37.5	19.8	8.4	4.8	2.6
25 Year Event (mm/h)	181.7	127.4	104.3	72.9	45.6	23.7	9.8	5.6	3
50 Year Event (mm/h)	200.4	140.5	115.2	81.9	51.7	26.7	10.9	6.2	3.3
100 Year Event (mm/h)	219	153.6	126.1	90.8	57.7	29.6	12	6.7	3.6

At the time of the storm, the vegetation had been cleared and the debris removed while a more permanent fix of the problem was planned. When alarms sounded for creek levels rising over the river bank, the following images were taken. The oufall flap gate is circled in red in some of the images provided in Figure B1 (The fourth picture shows the top of the flap gate hinges, and confirms the submerged condition). While the storm result doesn't come close to the Lake Simcoe Region Conservation Authority predicted flood level, the flooding is significant. These pictures were taken at 9:50 am on June 23, 2017.

Figure B1 – Images of Submerged Condition of the Aurora Sewage Pumping Station Outfall Flap Gate – June 23, 2017

Two methods were used to quantify the potential reduction of having this gate closed during the June 22-23, 2017 event. The first method resolved flow through the opening by using an equivalent rectangular weir discharge until the gate was fully submerged, and then an equivalent submerged orifice. The equivalent area of the weir or orifice that the river water was flowing through was determined by a depth vs area curve. The average opening width was multiplied by the perimeter length at 6 depth increments to approximate the area opening at various depths.

It should be noted that the flow through the weir and orifice into the outfall outlet pipe were not restrained by any outflows during the event. There would be 20 cm of standing water at the bottom of the opening, for the rise to the nearest maintenance hole, but no flows due to surcharge were expected. Modelling of a 25-year SCS type II storm (used for the Lake Simcoe Region Conservation Authority floodline estimates), and the June 23, 2017 event, showed no surcharge of the system to the level of the outfall outlet pipe in the upstream maintenance hole. Addtionally, flows added from the creek through the flapgate opening, did not result in a change to the conditions that would increase surcharge to the level of the oufall pipe in the upstream manhole.

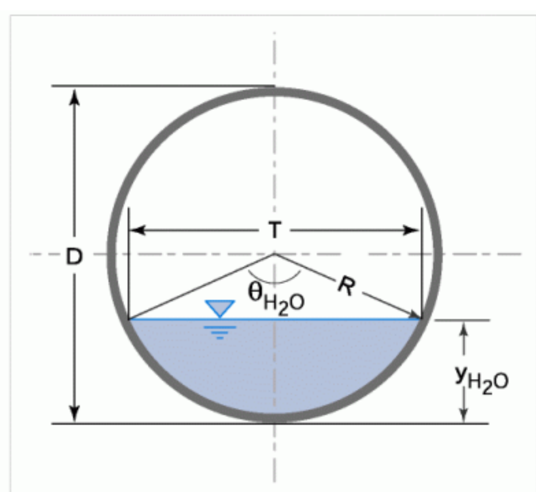


Clock Position	Opening (mm)
1	0
2	3.5
3	14
4	24
5	32
6	Blocked by veg/debris
7	45
8	35
9	30
10	15
11	5.5
12	2

Figure B2 – Measured Opening Widths at Various Clock Positions Around The Flap Gate

The calculations in the following tables can be found in many textbooks but the images below are taken from the Forest Science Labs website:
(http://www.fsl.orst.edu/geowater/FX3/help/7_Culvert_Basics/Geometry_of_Round_CMPs.htm)

Definition sketch for Geometry of a circular culvert:



Equations Used in the Calculation of Circular Culvert Geometry:

$$\theta = \cos^{-1}\left(1 - \frac{y}{r}\right)$$

$$y = r(1 - \cos\theta)$$

$$A = r^2(\theta - \cos\theta\sin\theta)$$

$$P = 2r(\theta)$$

$$T = 2r(\sin\theta)$$

$$R_h = \frac{A}{P}$$

Where:

d = Diameter of culvert

r = Radius of culvert
y = Depth of water in culvert
P = Wetted Perimeter of water on the bottom
T = Top width of water surface
A = Cross sectional area of flow
R_h = Hydraulic radius

Figure B3 – Pipe/Culvert Geometry Image and Calculations

The table below shows the estimated total area from openings at each depth line shown in Figure B2 above. At the first depth increment shown in Figure B2 (0.175 m), the wetted perimeter of the shape is highlighted, to signify that 2/12 of the total wetted perimeter was subtracted to represent the blockage of the ground, vegetation, and debris.

Table B2: Estimated Wetted Area at Different Depths

Depth (m)	Opening (mm)	Theta (See Fig.21)	Wetted Perimeter (m)	Area (m2)	Eq Dia (mm)	Centroid of Equivalent Orifice
0.000	0.000		0.000	0.000	0.000	0.416
0.175	38.500	0.841	0.333	0.013	127.862	
0.350	34.000	1.231	0.743	0.027	184.608	
0.525	25.750	1.571	1.100	0.036	213.974	
0.700	15.625	1.911	1.456	0.042	229.973	
0.875	6.000	2.301	1.866	0.044	236.678	
1.050	2.500	3.142	2.749	0.046	242.547	

From Table B2, the depth vs equivalent area curve was resolved in Figure B4.

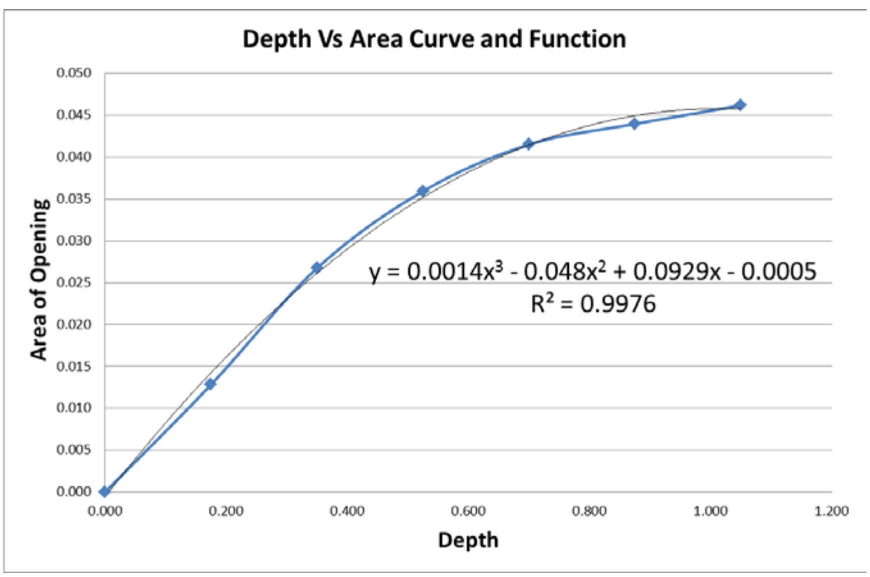


Figure B4 – Depth vs Area Curve for Equivalent Weir and Orifice Calculations

Until the depth of the river was greater than the diameter of the outfall pipe, a rectangular weir equation was used to determine flow through the opening. The equivalent area was resolved by the function above at each 5 min level monitored interval. The width of the equivalent weir determined by dividing the equivalent area by the depth of flow over the invert.

When the depth exceeded the diameter of the outfall pipe, a submerged orifice equation was used for an equivalent area of circular orifice, centred at the calculated centroid location of the open space (0.416 m – shown above in Table B2).

For 24 hours, from the start of the storm at 11:00 pm on June 22, 2017, the total inflow estimated by this method is 6.557 MLD. A calculation worksheet can be provided upon request for review. Figure B5 on the following page charts the depth of the creek over the overflow outfall invertand the total cumulative inflow volume.

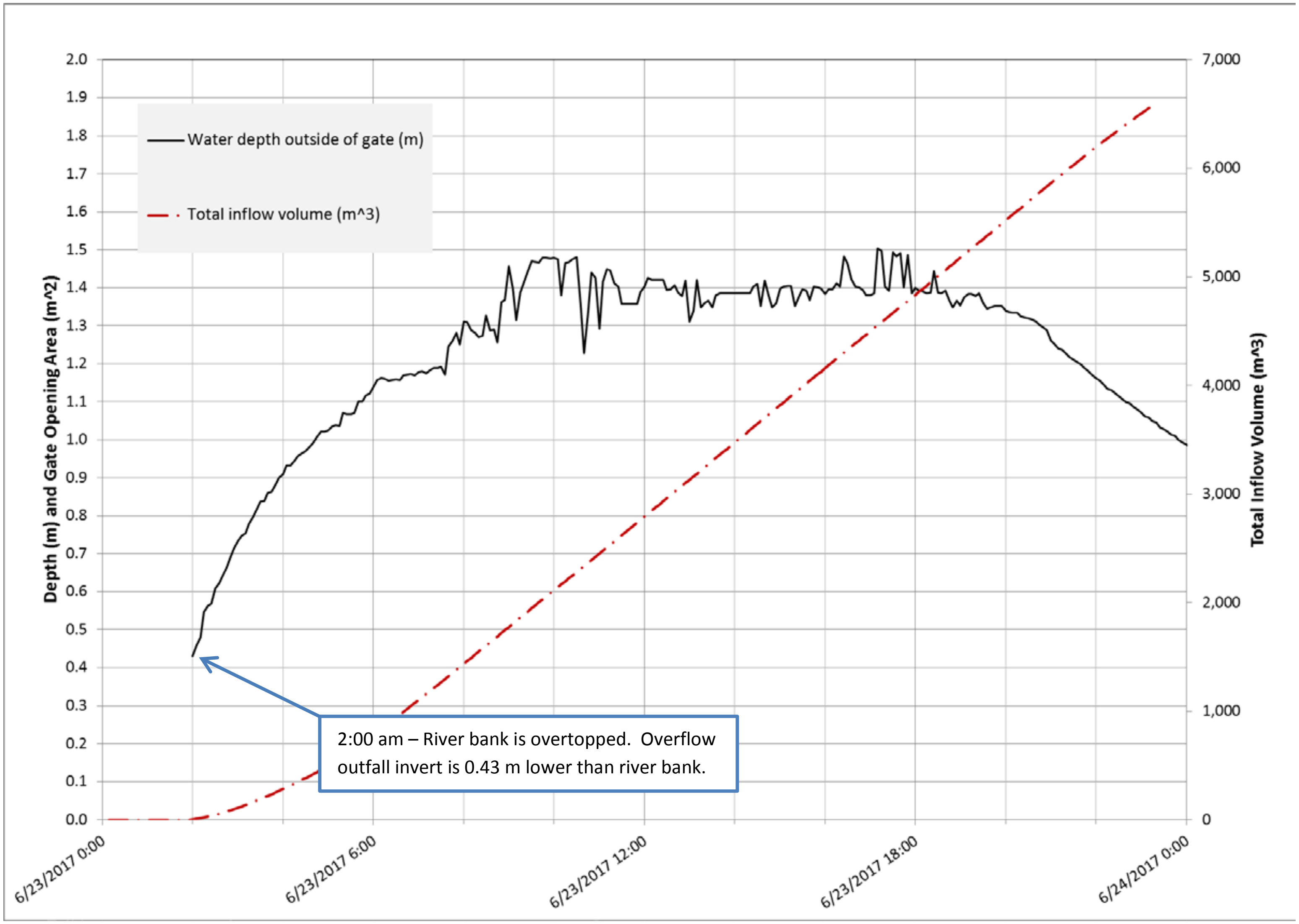


Figure B5 – River depth above outfall and cumulative inflow at Aurora Sewage Pumping Station Overflow Outfall

The second method used to quantify the flow through the overflow outfall flapgate, employed a similar approach, in the InfoWorks integrated modeling platform.   Twelve weir shapes were aranged at depth positions similar to the measurements taken at clock positions around the circular flap gate (See Figure B6). Each weir operated with 1/12 of the circumference used either as the roof height or width of the weir, depending on the position. Since the opening was 0 mm at the 1 o'clock position, and 2 mm at the 12 o'clock position – which was rounded to 0 mm by the software - there were essentially only ten weirs used in the calculation.

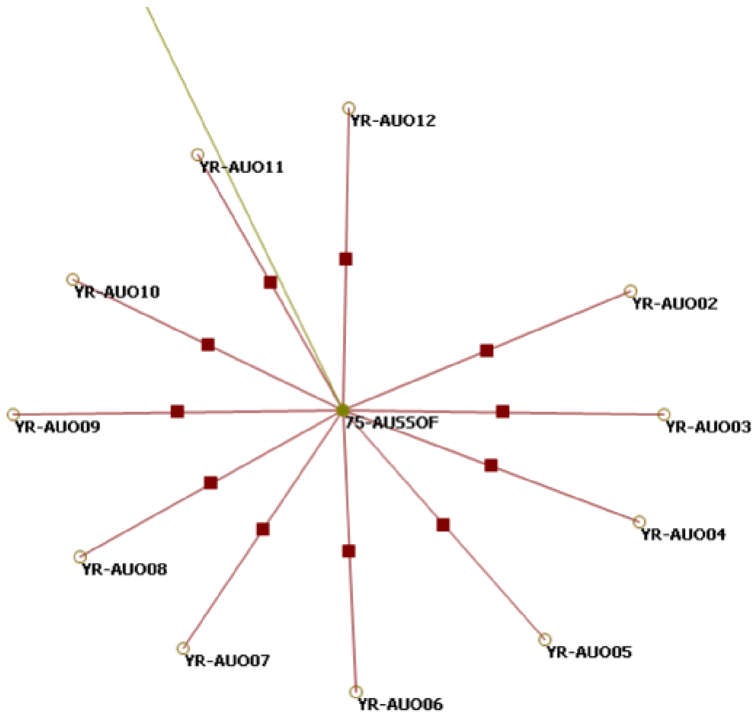


Figure B6 – InfoWorks Weir Arrangement to Approximate Flap Gate Openings

Crest elevation for each weir varies depending on the position in the circumference. Most weirs are vertical (tall and narrow) with the width set as the flap gate opening measured at that location. Weirs 7, 5 and 11 o'clock are horizontal (short and wide) with the roof height set at the opening for that location. Weir 6 o'clock has zero width because it is blocked, and weirs 5 and 7 o'clock have only half of 1/12th of circumference because partially blocked by the ground, vegetation, and debris.

Using this methodology, the total inflow volume for the 24 hour period following the storm was approximately 5.512 MLD. If the 12 o'clock location 2mm opening was added (instead of rounded down to zero), the total would be approx. 5.6 MLD. An export of the discharge from the model is shown in Table 3.

Table B3: InfoWorks Inflow Volume Estimate Outcome at Aurora Sewage Pumping Station

Weir	Crest (m AD)	Width (m)	Roof Height (m)	Area (m2)	Discharge Coefficient	Inflow Volume (m3)
YR-AU002		0.004	0.275	0.0011	0.62	88
YR-AU003	243.53	0.014	0.275	0.0039	0.62	423
YR-AU004	243.35	0.024	0.275	0.0066	0.62	880
YR-AU005	243.18	0.138	0.032	0.0044	0.62	590
YR-AU006	243	0	0.045	0	0.62	0
YR-AU007	243.18	0.138	0.045	0.0062	0.62	829
YR-AU008	243.35	0.035	0.275	0.0096	0.62	1288
YR-AU009	243.53	0.03	0.275	0.0083	0.62	906
YR-AU010	243.7	0.015	0.275	0.0041	0.62	378
YR-AU011	243.875	0.275	0.005	0.0014	0.62	130
YR-AU012	244.05	0.275	0	0	0.62	0
Total				**0.0456**		**5,512**

As the modelling method calculated a more conservative estimate, the modelling method figure was used as the reported number. Both methods provide some margin of safety in the total reduction calculation, since the start of the storm was used for the 24 hour analysis period (11:00 pm June 22nd to 11:00 pm June 23rd). Using the start of storm means that there is a 3 hour lag time where no flow is calculated through the overflow outfall gate.

If the peak 24 hour period, with the highest level of inflow is used (3:05 am June 23rd to 3:05 am June 24$^{th)}$, the total inflow volume would be approximately 7.18 MLD. Additionally, if the Lake Simcoe Region Conservation Authority flood plain elevation, for a 25 year, 24 hour, Type II SCS storm was used for the calculation, the total inflow would be greater. The river depth over the outfall invert is a maximum of 3.3 m using the conservation authority storm flood elevation. Since the June 23, 2017 max elevation was only 1.5 m over the outfall invert, the flows would likely be more than double if the conservation authority flood plain elevation was used.

Model output and calculation spreadsheet can be provided for review upon request.

Aurora Sewage Pumping Station Outfall Repair

A 36" Series 35-1 Tideflex Duckbill Check Valve was installed to replace the existing steel backflow gate. The one piece, fabric reinforced elastomer material of the duckbill design eliminates moving components and mechanical parts that create problems with conventional check valve designs. The valve functions when upstream pressure in the valve forces the lips or "duckbill" apart to permit flow. As pressure or flow increases, the lips open further, allowing more flow. This feature allows upstream material to pass unhindered with low pressure loss.

The 35-1 series of valve will typically open when there is 25-50mm of water column over the invert of the upstream pipe. When there is backpressure or reverse flow from elevated river levels, the lips squeeze tightly together, preventing backflow from entering the sewer system. Under the Regional flow event, the water surface is approximately 7.0m higher than the pipe invert.

A new concrete headwall was required to replace the existing masonry headwall. The headwall design accommodates the new Duckbill backflow valve and will ensure creek water is isolated from entering the sewer system during elevated flow events.

In addition a formalized channel lined with 200-300 mm riprap will convey flow from the new headwall and check valve to the Holland River. The new channel will ensure positive drainage and avoid ponding.

Images of the repair are shown in Figures B7 and B8

Figure B7 – Construction Zone after Removing the Old Headwall

Figure B8 – Formation of the New Headwall

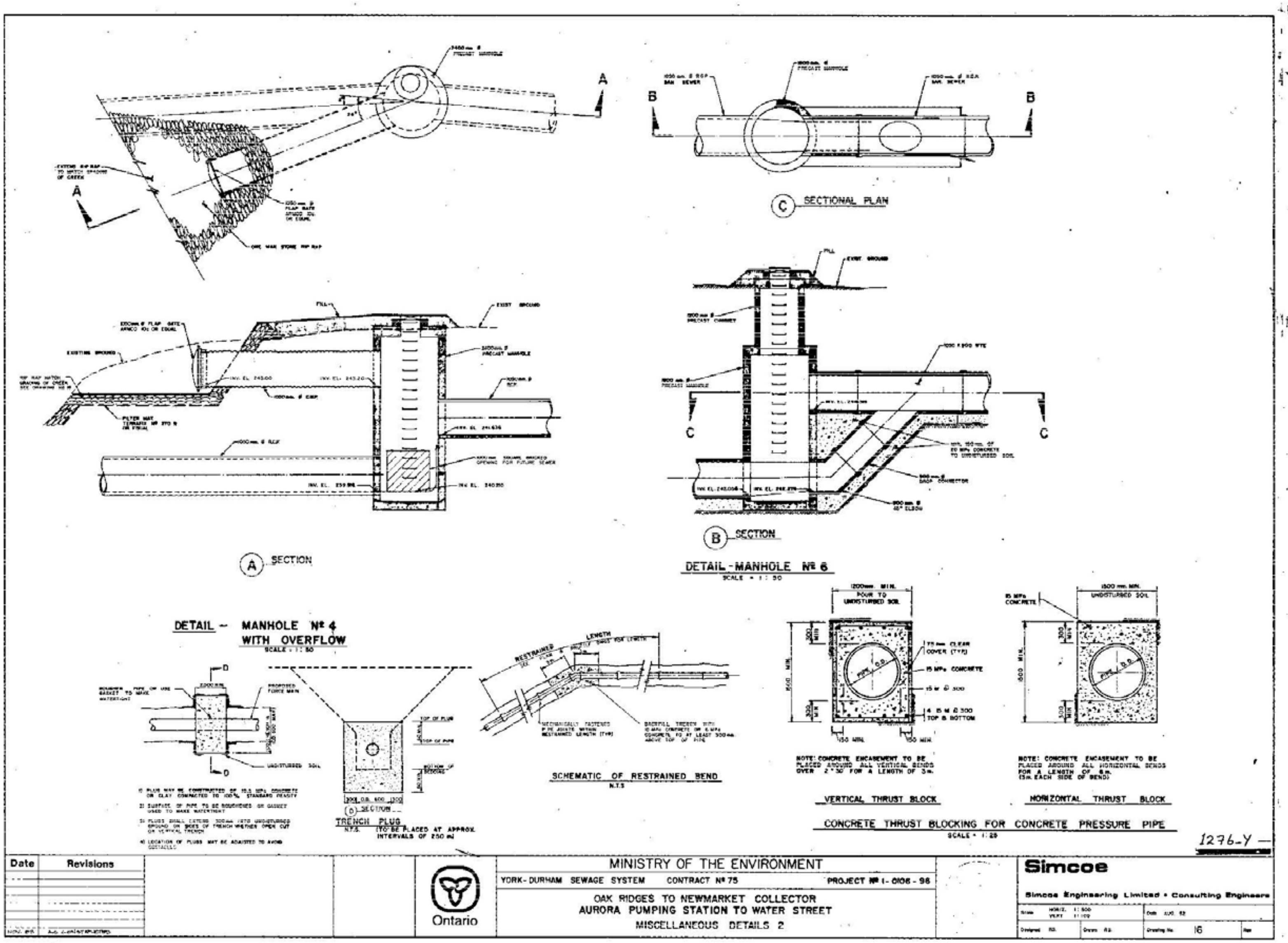


Figure B9 – Contract 75 (Aurora Pumping Station to Water Street) – Cross Sections Drawing

Appendix C
Local Municipalities' Flow Monitoring Location Maps

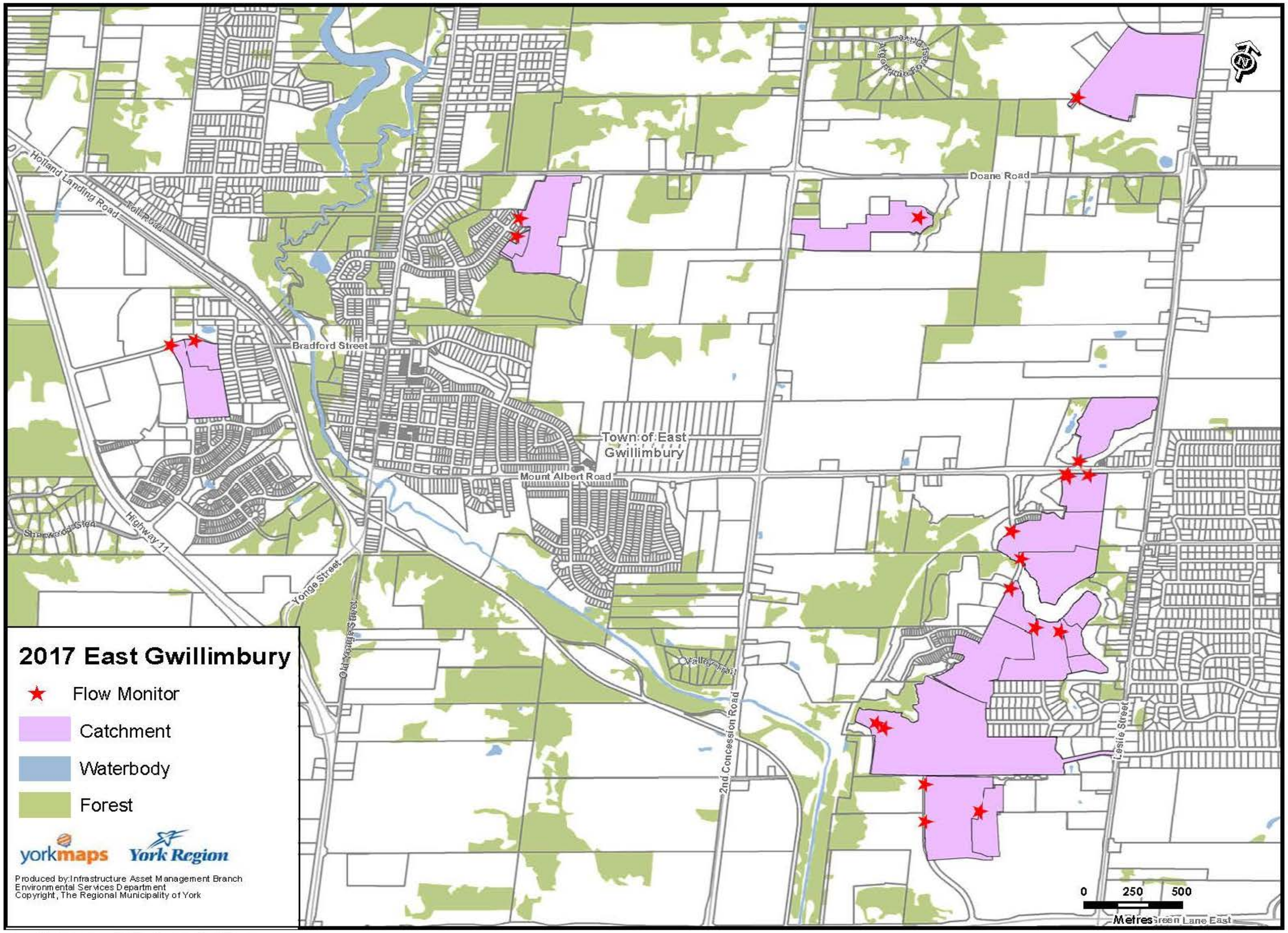


Figure C1 – 2017 Town of East Gwillimbury Flow Monitoring Location Map

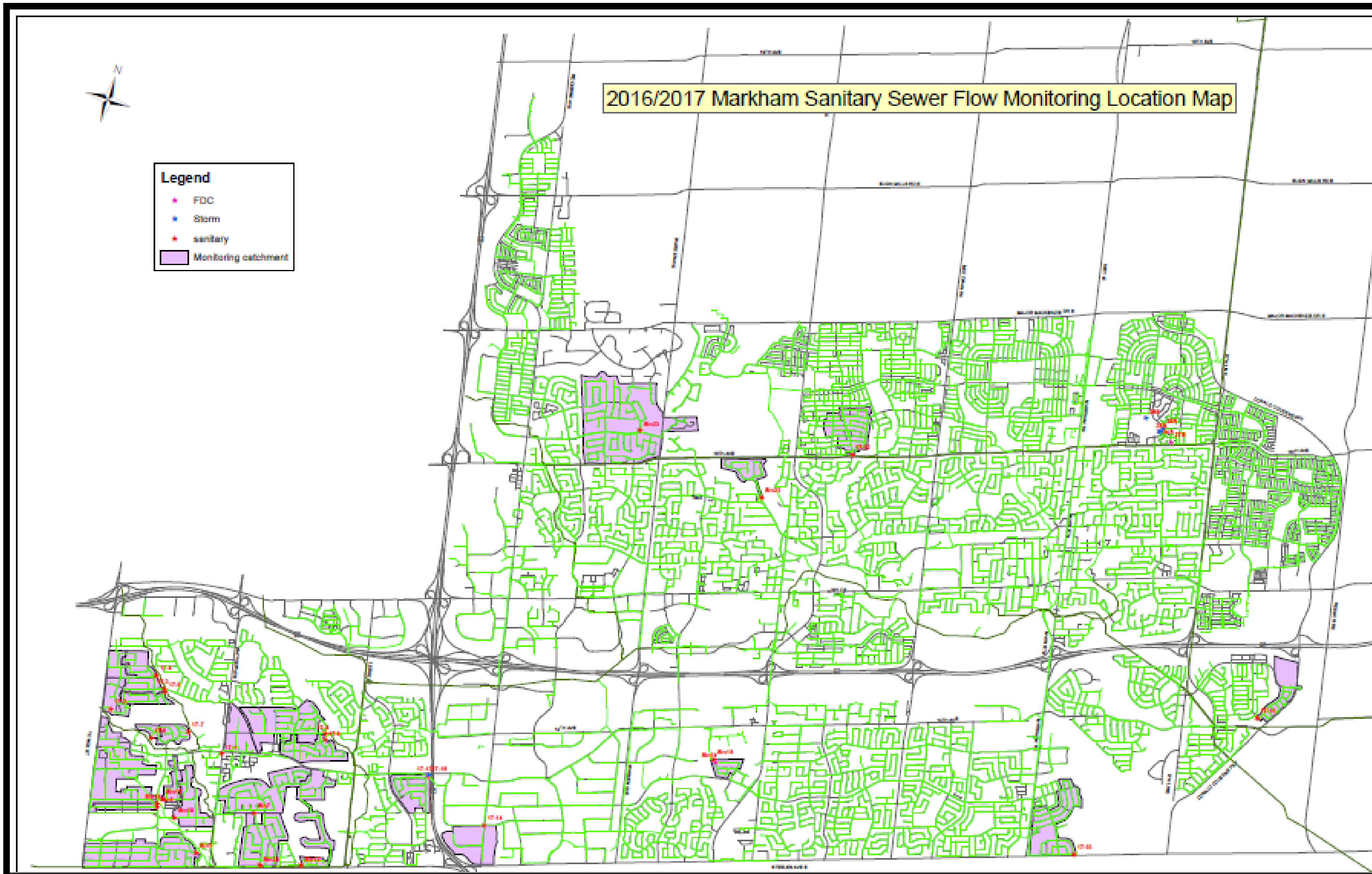


Figure C2 – 2017 City of Markham Flow Monitoring Location Map

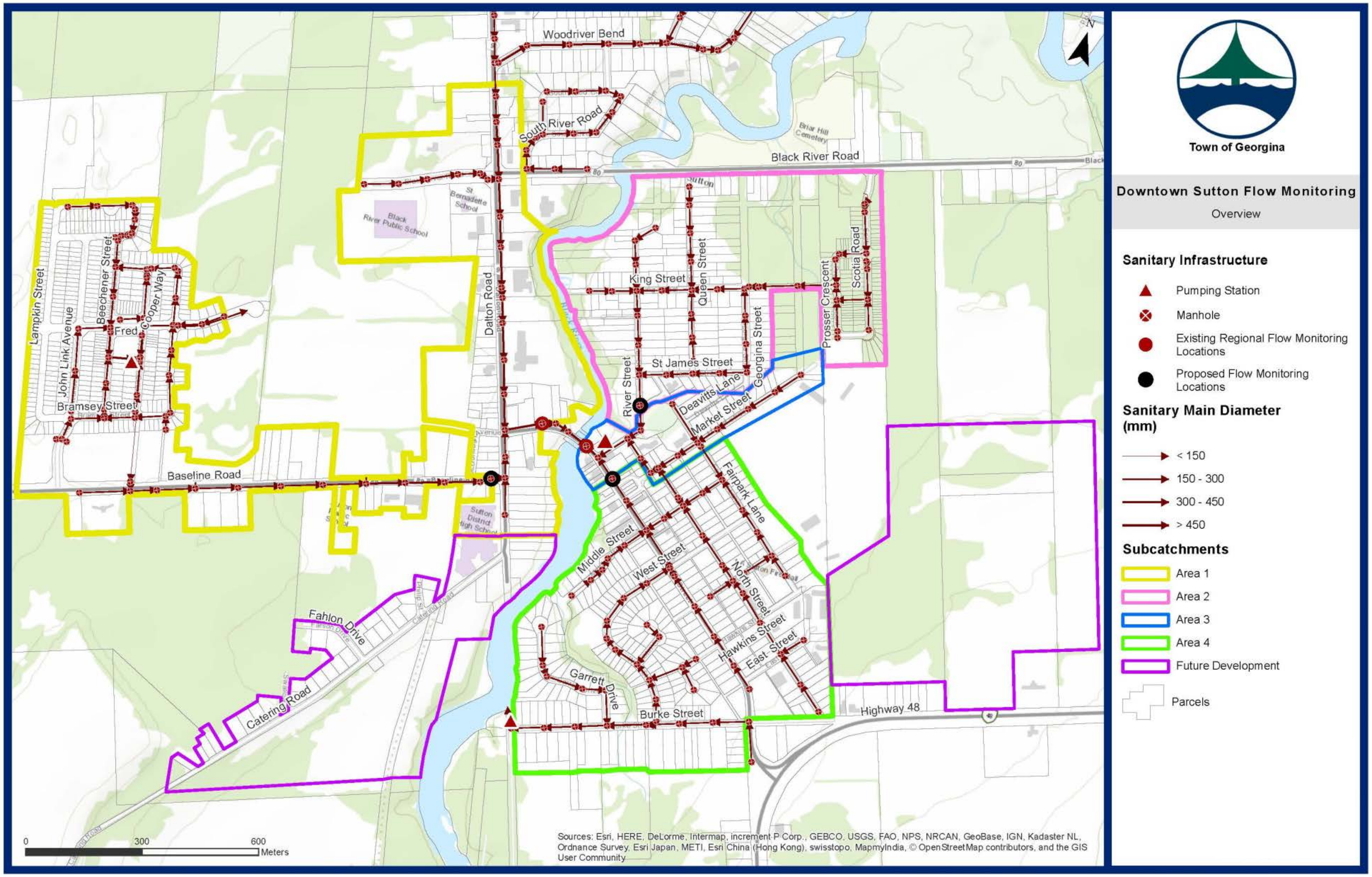


Figure C3 – 2017 Town of Georgina Flow Monitoring Location Map

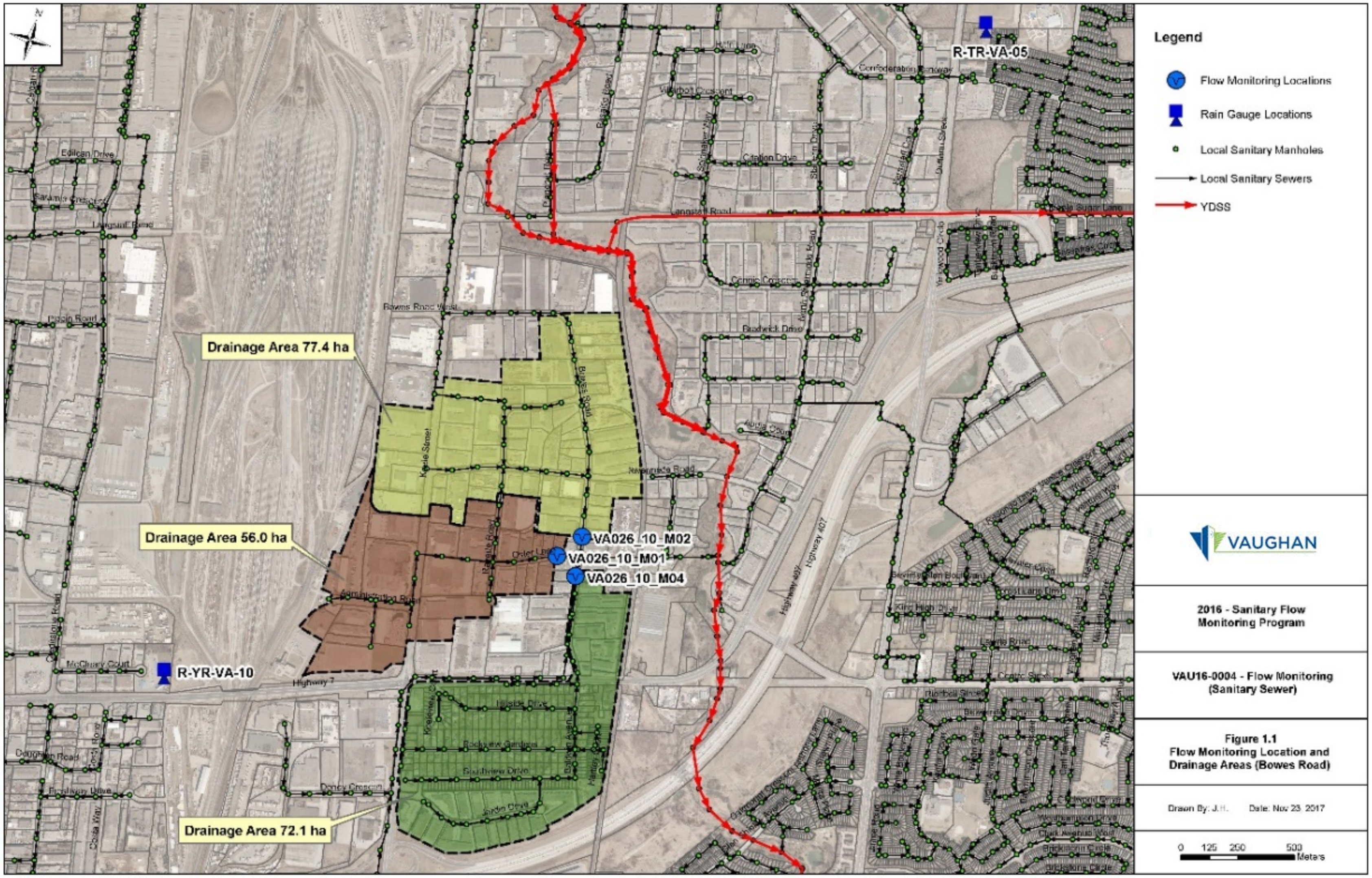


Figure C4 – 2017 City of Vaughan Bowes Road Flow Monitoring Map

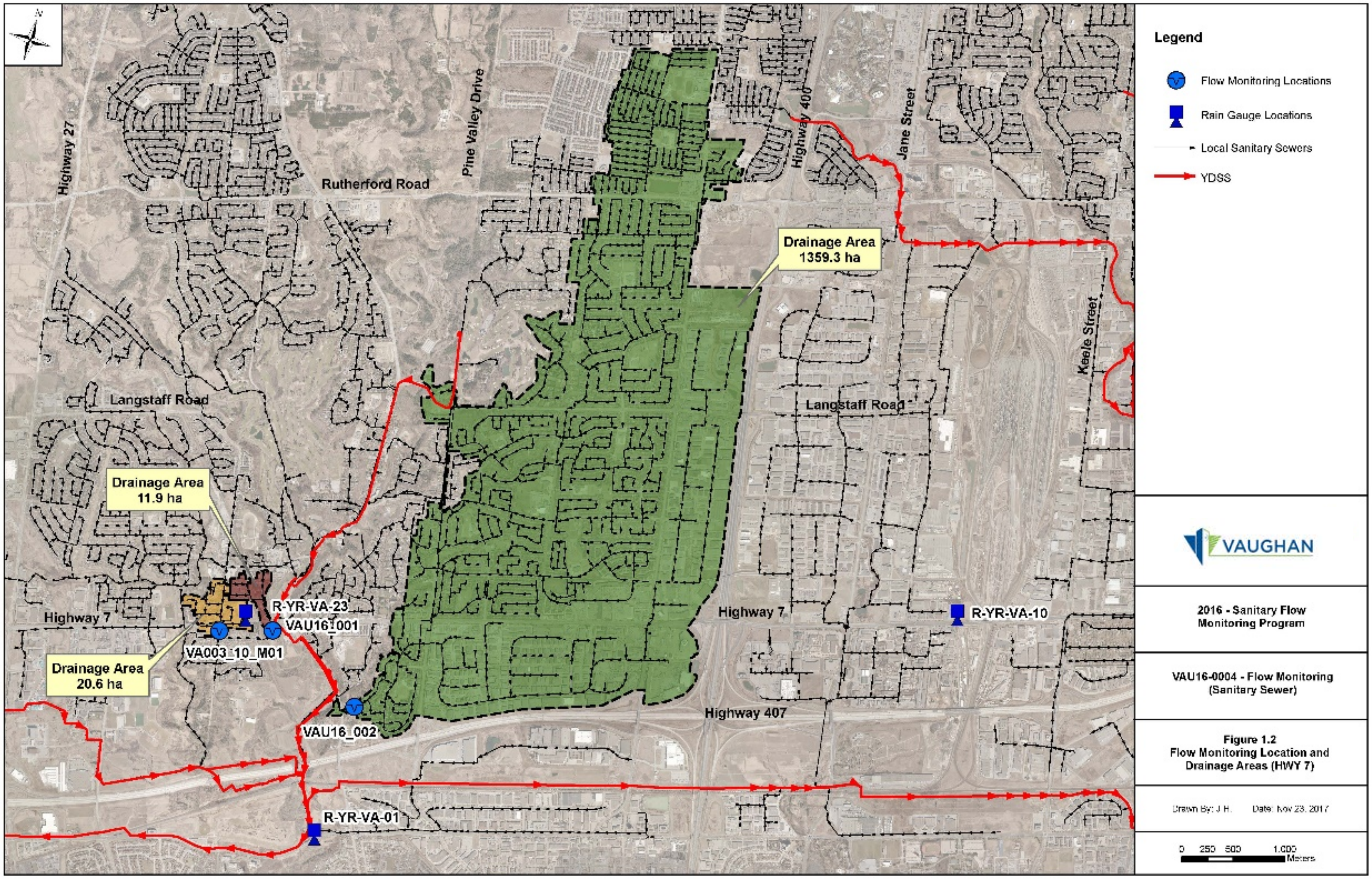


Figure C5 – 2017 City of Vaughan Highway 7 Flow Monitoring Map

York Region