White Paper

Inflow and Infiltration in New Development:

A York Region Perspective

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Inflow and Infiltration Reduction Program

York Region

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1.0 INTRODUCTION

The Regional Municipality of York (York Region) has been working to reduce extraneous sanitary sewer flows through an Inflow and Infiltration Reduction Strategy (Strategy) since 2011, under a condition of approval from the Province of Ontario (Province) for the Southeast Collector (SEC) Individual Environmental Assessment (IEA). The Strategy has been multi-pronged since its inception and has realized success over the years through York Region's strong partnerships with its local municipalities, the public, third party engineering and construction vendors and the development industry.

As part of the Strategy, York Region commissioned a project in 2017 in collaboration with its local municipalities and the development industry to develop a consistent, effective and practical region-wide framework for the prevention of inflow and infiltration in new developments. At a recent project engagement meeting with the development community, consisting of representatives from the Building Industry and Land Development Association (BILD), Greater Toronto Sewer and Watermain Contractor's Association (GTSWCA), Ontario Concrete and Drain Contractors Association (OCDCA) and Ontario Concrete Pipe Association (OCPA), stakeholders were interested in better understanding inflow and infiltration in York Region and how changes in new construction practices, pipe materials and inspections can effectively reduce inflow and infiltration in new developments. This discussion paper expands on the Regional perspective offered at the recent industry engagement meeting by presenting the history of York Region's Inflow and Infiltration Reduction Strategy (Section 2.0), a review of inflow and infiltration issues and programming in the industry (Section 3.0), analysis of York Region's wastewater flow monitoring data (Section 4.0), examples of inflow and infiltration in new and recent Regional construction (Section 5.0) and concluding remarks and York Region's next steps (Section 6.0).

2.0 BACKGROUND ON INFLOW AND INFILTRATION REDUCTION IN YORK REGION

2.1 Southeast Collector Individual Environmental Assessment (SEC IEA) Approval

On March 31, 2010, the Province approved the SEC IEA with 13 conditions. One of the conditions required York Region to develop, implement, update and report annually to the Province on a strategy to conserve water and reduce inflow and infiltration entering the SEC. The objective of this strategy would be to reduce peak wastewater flows to the SEC by 10%.

2.2 Inflow and Infiltration Reduction Strategy Development

Following the Province's approval condition for the SEC IEA in 2010, York Region began collaborating with its nine local municipalities to develop an Inflow and Infiltration Reduction Strategy (Strategy) to target sources of inflow and infiltration from the Regional, local municipal and private sanitary sewer systems. A Water and Wastewater Steering Committee (Steering Committee) was formed with representatives from each local municipality and York Region to guide development and implementation of the Strategy. Today, the Steering Committee continues to guide implementation of the Inflow and Infiltration Reduction Strategy and associated updates.

In 2011, York Region Council, as well as all nine local municipal Councils, endorsed the first Strategy. A commitment to update the Strategy every five years was also made. The first Strategy update was endorsed by Regional Council in 2016 and the next update is scheduled for 2021.

2.2.1 Inflow and Infiltration Reduction Targets

Based on the contemplated 10% reduction in peak flows to the SEC, hydraulic modelling was completed to develop an equivalent volume per day target reduction of 71 megalitres per day (MLD) by 2031, under a 25-year storm condition. It was agreed by the Province that 40 MLD of this inflow and infiltration reduction would be achieved through reduction of rainfall derived inflow and infiltration (RDII).The balance would be from dry weather flow reduction, realized through water conservation and reduction of groundwater infiltration (known as base infiltration, or BI).

2.3 Inflow and Infiltration Reduction Achievements

Since implementation of the Strategy in 2011, York Region, its local municipalities and private partners have reduced inflow and infiltration to the SEC by over 19 MLD. This achievement is equivalent to eliminating the daily wastewater flow from approximately 20,000 homes.

These flow reductions were achieved through Regional and local municipal operation and maintenance programs and capital works, as well as private initiatives, and were quantified through on-going flow monitoring, hydraulic modeling, field observations and investigative studies. Reductions achieved to date through the various initiatives are provided in Table 1. Of the total RDII reductions to date, almost one quarter has been achieved through Public-Private Partnership (P3) initiatives with the development industry.

Table 1 - RDII Reductions Achieved in York Region between 2011 and 2018

Initiatives	RDII Reduction (MLD)	Proportion of Total RDII Reduction (%)
Regional Initiatives	11.0	56.5
Local Municipal Initiatives	3.99	20.5
Public-Private Partnership (P3) Initiatives	4.48	23
Total	**19.47**	**100**

2.4 Inflow and Infiltration Reduction Strategy Implementation

York Region's inflow and infiltration program framework is founded on several program areas aimed at managing inflow and infiltration in both existing sewer systems and new construction. The key program areas to ensure successful implementation of the Strategy are the monitoring and analyzing of wastewater flows, the investigation and rehabilitation of existing inflow and infiltration sources, and the prevention of inflow and infiltration in new construction. Collaboration with local municipalities and the development industry are also critical to achieving the Strategy objectives (Figure 1).

Figure 1: Schematic of York Region collaborations with its local municipalities and the private sector on inflow and infiltration reduction initiatives

2.4.1 Monitoring and Analyzing Sanitary Sewer Flow and Rainfall

The continuous collection of accurate sanitary sewer flow data is key to success of the Strategy. York Region currently manages over 300 sanitary sewer flow monitoring locations and 43 rain gauges, and also collects data from 28 rain gauges owned by stakeholders. Monitoring locations (installed in 2013 and beyond) are distributed across the region throughout the local and Regional sanitary sewer systems as shown in Figure 2 and Figure 3.Through this effort, York Region is able to analyze peak sanitary sewer flows and delineate priority areas for inflow and infiltration investigation and remediation. The sewer flow data is also relied upon for the quantification of inflow and infiltration reductions following remedial works.

The majority of York Region's flow monitoring devices are installed in the local sanitary sewer systems. The devices provide sanitary sewer flow data to local municipal staff on an ongoing and annual basis to support efficient implementation of local inflow and infiltration reduction initiatives.

Over the past five years, staff analyzed flow monitoring data to measure efficacy of initiatives, including those led by developers as part of the P3 initiatives. Information obtained through the analysis provides staff with tools to evaluate future development proposals, ensuring mutually beneficial outcomes, while minimizing capacity risks to the conveyance system.

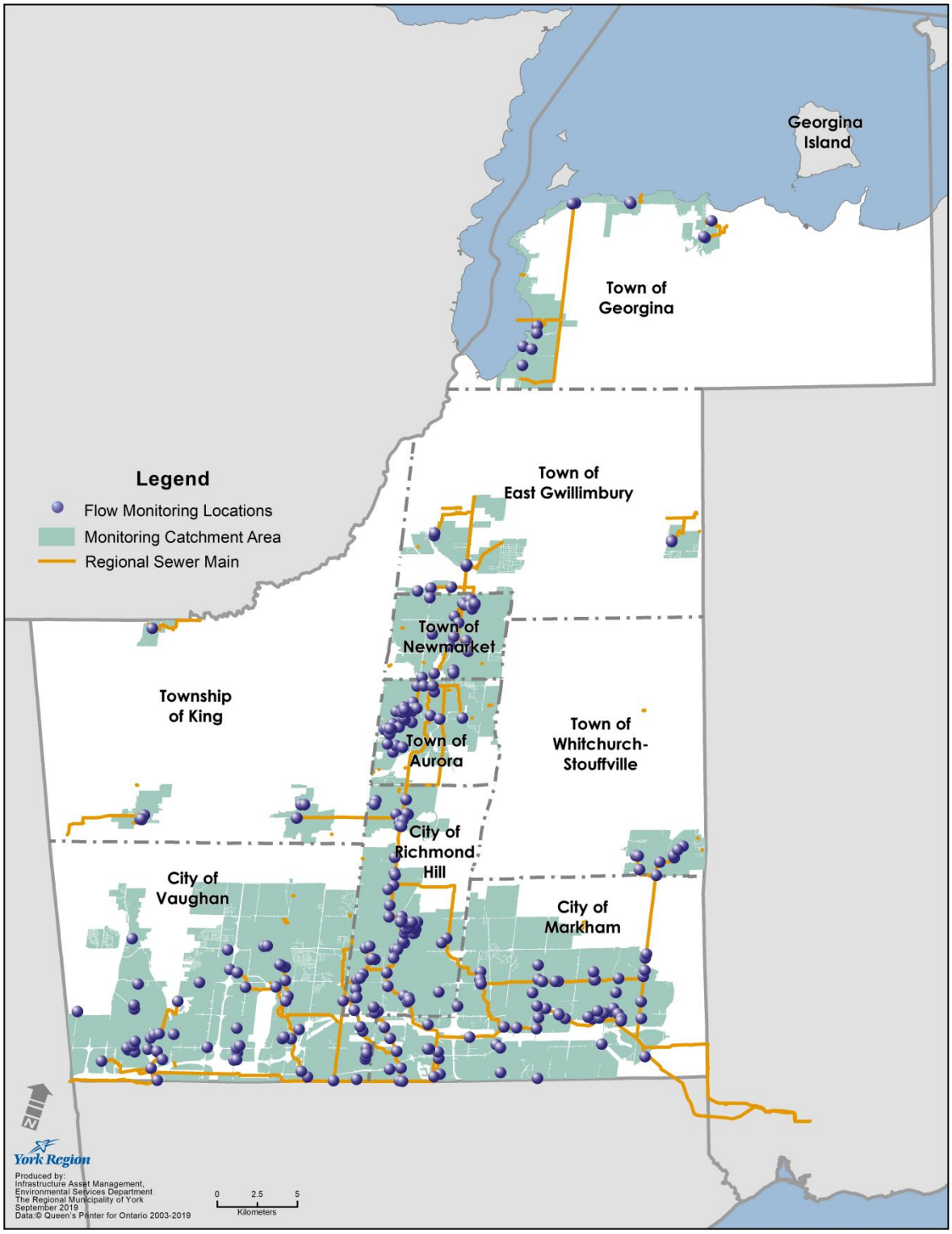

Figure 2: Sanitary sewer flow monitoring locations in York Region

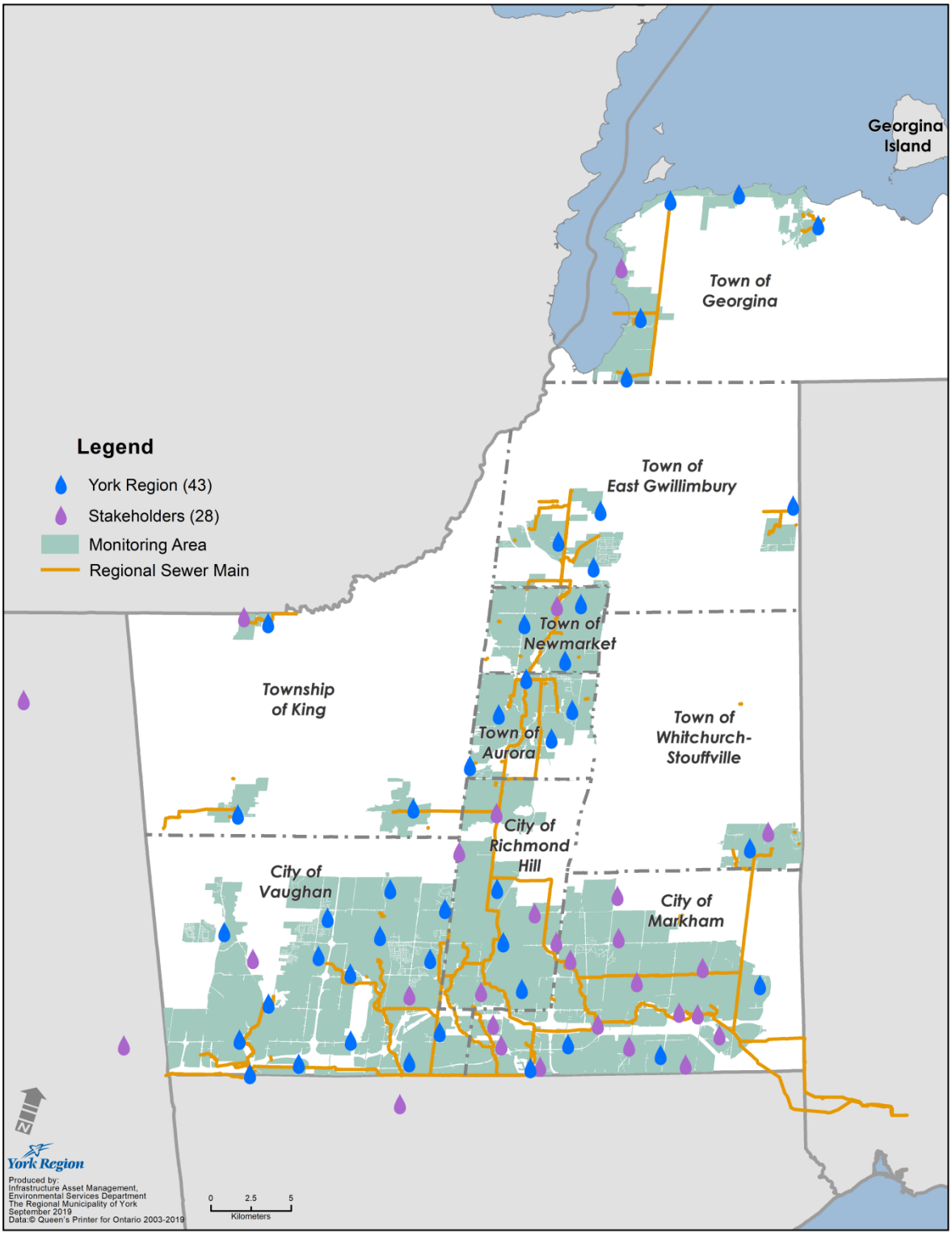

Figure 3: Rainfall monitoring locations in York Region

2.4.2 Investigation and Rehabilitation of Existing Inflow and Infiltration Sources

York Region and its local municipalities have been completing sanitary sewer evaluation studies and associated remedial works on assets deemed critical for rehabilitation and replacement in areas identified as high priority per York Region's hydraulic modeling and analyses. The sewer evaluation work includes annual CCTV inspections of the municipal system, as well as field surveys and tracer studies on private properties. The majority of remedial works completed to date include relining and spot-repairing of sanitary sewer mainlines and laterals, maintenance hole repairs on public infrastructure, and downspout and/or sump pump disconnections on private properties.

Complementing the noted private property investigations, York Region retained a consultant who developed an innovative hydraulic and hydrologic model to predict which private sources of inflow and infiltration are contributing most to peak flows and to estimate inflow and infiltration reductions from remediation activities.

York Region has also engaged in P3 initiatives with several local municipalities and the development industry for the mutual benefit of reducing existing inflow and infiltration. Since 2010, York Region has been a party to several developer-funded agreements that permit completion of inflow and infiltration reduction work in exchange for capacity allocation at a two-to-one ratio of achieved reductions to allocation credits. The program allows a level of planned growth to continue without additional infrastructure investment. The portion of recovered capacity retained by York Region helps mitigate future capacity risks in the conveyance system by buffering against the effects of aging infrastructure and climate change. Five pilot project agreements have been executed since the start of this P3 initiative and are at different stages of completion. Based on success of the pilots, two additional projects are being planned for 2019.

Inflow and infiltration remedial works completed under the noted P3 agreements have predominantly included disconnection of residential and commercial downspouts from the sanitary sewer system. Other types of work have included in-line spot repairs and maintenance hole repairs on local sanitary sewers, modifications to drains on reverse-sloped residential driveways, disconnection of sewer cross-connections, and residential sump pump disconnections.

2.4.3 Prevention of Inflow and Infiltration in New Construction

York Region's strategy for new construction is to ensure sanitary sewers are watertight at the time of construction using sound engineering requirements in design, and vigilant enforcement during construction and commissioning. The Strategy recommends new construction to be examined through three main categories: (1) design and construction

standards; (2) site plans and service permits; and (3) inspection, testing, commissioning and assumption procedures.

York Region published its first sanitary sewer inspection, testing and acceptance guideline for Regional infrastructure in 2011 (York Region 2011), with input from representatives of the development community. Several local municipalities subsequently adopted this guideline for their own sanitary sewer infrastructure.

Following this, York Region developed a Servicing Incentive Program (SIP) in 2014 to encourage the prevention of inflow and infiltration in new development by offering sanitary sewer allocation credits to developers in exchange for proven low inflow and infiltration rates (less than 0.12 litres per second per hectare, L/s/ha, under a 25-year storm condition) achieved through best design and construction practices. If a new development participates in the SIP, York Region agrees to provide up to 20% extra allocation to the local municipality (Figure 4). In 2015, one of York Region's local municipalities, the Town of East Gwillimbury, incorporated the SIP program requirements into their Sustainable Development Incentive Program Implementation Guidelines (SDIP).

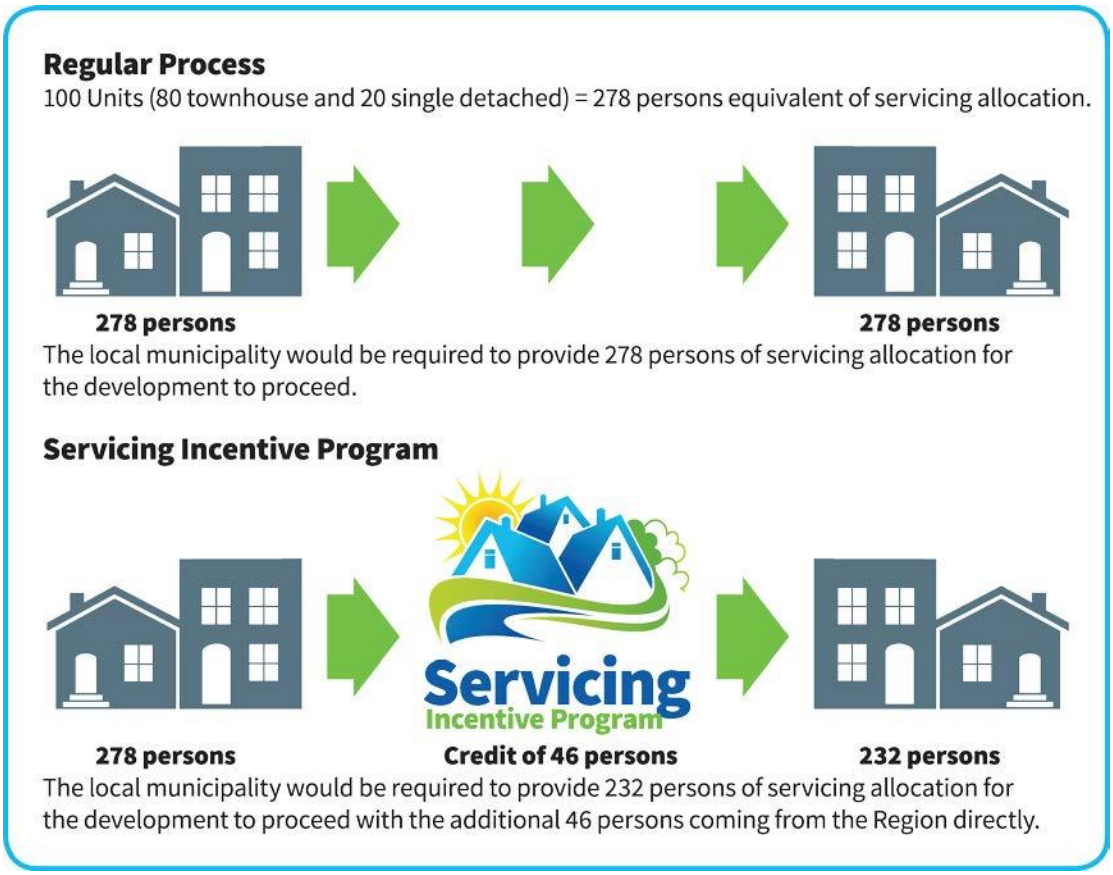

Figure 4: Comparison of the regular versus SIP servicing allocation process (York Region 2015)

To date, 26 subdivisions have participated in the SIP/SDIP programs, resulting in a commitment of approximately 1,181 single detached equivalent units of extra sanitary sewer capacity. So far two conformity reports under the SDIP program have been submitted by developers. Preliminary data from these reports shows success of the program and its prescribed stringent inflow and infiltration allowance of 0.12 L/s/ha. Success of the SIP/SDIP programs will be further evaluated as more conformity reports are submitted in the coming months and years.

Building on the commitment to reduce inflow and infiltration in new developments, York Region initiated a project in 2017 to review and update the 2011 sanitary sewer inspection, testing and acceptance guideline. The project scope of work was to expand the existing guideline document to cover inflow and infiltration prevention practices for both public and private infrastructure, and all stages of new development, from planning to assumption. The objective was to update the guideline document, leveraging proven and cost-effective industry best practices, and apply it Region-wide. To ensure success of the project, York Region has worked closely with its local municipalities and the development industry to better understand challenges and how to overcome them with practical and flexible solutions.

The 2017 study scope had four main phases:

- Phase 1, Literature Review of standards, programs and procedures for each local municipality within York Region and select Greater Toronto Area (GTA) municipalities;
- Phase 2, Municipal Surveys with each local municipality on sanitary sewer inflow and infiltration reduction practices during design, construction, inspection, testing and acceptance phases of new development;
- Phase 3, Construction Site Surveys and consultation with the construction industry; and
- Phase 4, Final Report of Region-wide recommended inflow and infiltration reduction standards and specifications for new development (from planning to assumption).

As part of Phase 3, in the fall of 2018 six construction site visits were conducted to gather information in the field on possible ways to reduce inflow and infiltration in new development. At the construction sites, ideas were sought from municipal staff, consultants and contractors. Three sanitary sewer system component manufacturing plants were also visited: one polyvinyl chloride (PVC) sanitary sewer pipe and fitting manufacturer, and two concrete sanitary sewer and maintenance hole manufacturers. Discussions with these manufacturers aimed to explore options to reduce inflow and infiltration in new development by introducing new materials and construction practices. One idea was to use an improved gasket for sewer lateral connections to reduce inflow and infiltration at pipe connections.

At the end of 2019 a final project report will be issued with recommended design guidelines, acceptance criteria/checklists, inspection and testing protocols and checklists, and flow monitoring requirements. Following acceptance of the recommendations, York Region will commence implementation plans in partnership with its local municipal partners, and in consultation with the development industry.

3.0 INDUSTRY REVIEW

As a leader in inflow and infiltration programming, York Region regularly reviews industry initiatives, programs and partnerships, and adapts its Strategy to meet best-in-class approaches. For development of York Region's 2011 Strategy and 2016 update, two best in-class reviews were carried out of municipalities in North America and internationally to better inform the strategy (York Region 2011a; York Region 2016).

To specifically address inflow and infiltration in new development a literature of York Region's local municipality standards for new construction was completed in 2018 (as part of Phase 1 of the project mentioned above). Individual meetings and an online survey were also conducted with each of the nine local municipalities in York Region to further investigate their practices for minimizing inflow and infiltration in new development phase 2 of the project mentioned above. These meetings brought together public works staff, building officials and plumbing inspectors to collaboratively identify the best means to address inflow and infiltration in new developments through new design, inspection, testing and acceptance practices and technologies. The development industry was also consulted on best practices. The feedback received from the stakeholder engagement will be used to update the 2011 sanitary sewer inspection, testing and acceptance guideline (York Region 2011b) and to expand the document to include guidelines and requirements from design stage to commissioning and handover.

3.1 Municipal Programs Targeting Inflow and Infiltration in New Development

Through its best-in-class reviews York Region found a universal acknowledgement by municipalities of the problem of inflow and infiltration in municipal sewer systems and a prevalent agreement that new developments are contributing to it. Examples include the following:

- The Regional Municipality of Peel, Ontario developed a multi-year strategy endorsed by their Council in May 2019 that involves structured investigation and repair prioritization programs as well as new construction standards for the sanitary sewer system (Region of Peel 2019). The Region of Peel's new development standards for sewer construction outline requirements such as concrete pressure pipe for sanitary gravity mains in certain circumstances and

specialized waterproofing products to minimize inflow and infiltration (Region of Peel 2019).

- In 2010 King County, Washington and its local agencies worked on releasing a set of standards, guidelines, and procedures for future King County sewer system construction, with the intent of correcting past shortcomings in design, construction, inspection and testing. One of the issues they discussed is that the likelihood of pipeline failures were often a result of inappropriate material use and constructing maintenance holes in wet ground where they would be susceptible to infiltration due to inadequate sealing of the external walls (XCG 2010).

- Milwaukee Metropolitan Sewage District (MMSD), Wisconsin noticed similar problems to King County, Washington and developed an inflow and infiltration reduction program which put an emphasis on inspection during construction (XCG 2010). One unique approach under the program was the designation of a field representative to satellite municipalities to observe work occurring at construction sites. To further encourage good construction practices, MMSD hosts an annual Inspection Conference for construction inspectors and engineering staff to highlight important construction and inspection practices (XCG 2010).

- Metro Vancouver, British Columbia has also successfully reduced inflow and infiltration from new construction by implementing and enforcing design requirements. Through the Community Charter and the Local Government Act, municipalities in Metro Vancouver have enacted bylaws to set design and construction requirements for new developments (XCG 2010).

3.2 Allowable Limits for Inflow and Infiltration

Municipalities across Canada have RDII design allowances for the construction of new sanitary sewer infrastructure. These can range from 0.10 L/s/ha such as in the Cities of London and Barrie to 0.286 L/s/ha such as in Halton Region (City of London 2019; City of Barrie 2017; Halton Region 2019). These published RDII values from municipalities are generally design allowance recommendations but, aside from the York Region's SIP/SDIP, are not typically enforced through monitoring of flows from new subdivisions.

3.3 Industry Data on Inflow and Infiltration Rates

In recent years, stakeholders including municipalities, insurance agencies and land developers have completed studies to investigate the magnitude of inflow and infiltration in new developments to help inform new practices. One particular study completed by Kerr Wood Leidal Associates Ltd. for the Capital Regional District (CRD), British Columbia showed that infrastructure systems as young as six years old reached 80% of

its design capacity eleven years ahead of the planned upgrades (Johnston *et al.* 2005). Data from Port Moody study, in particular, shows some of the peak inflow and infiltration rates observed in relatively young infrastructure when plotted against sewer age (see Figure 5). As shown in the figure, inflow and infiltration rates have exceeded the typical 11,200 l/ha/day (0.129 L/s/ha) allowance, demonstrating that some catchments are "not acting their age" (Johnston *et al.* 2005).

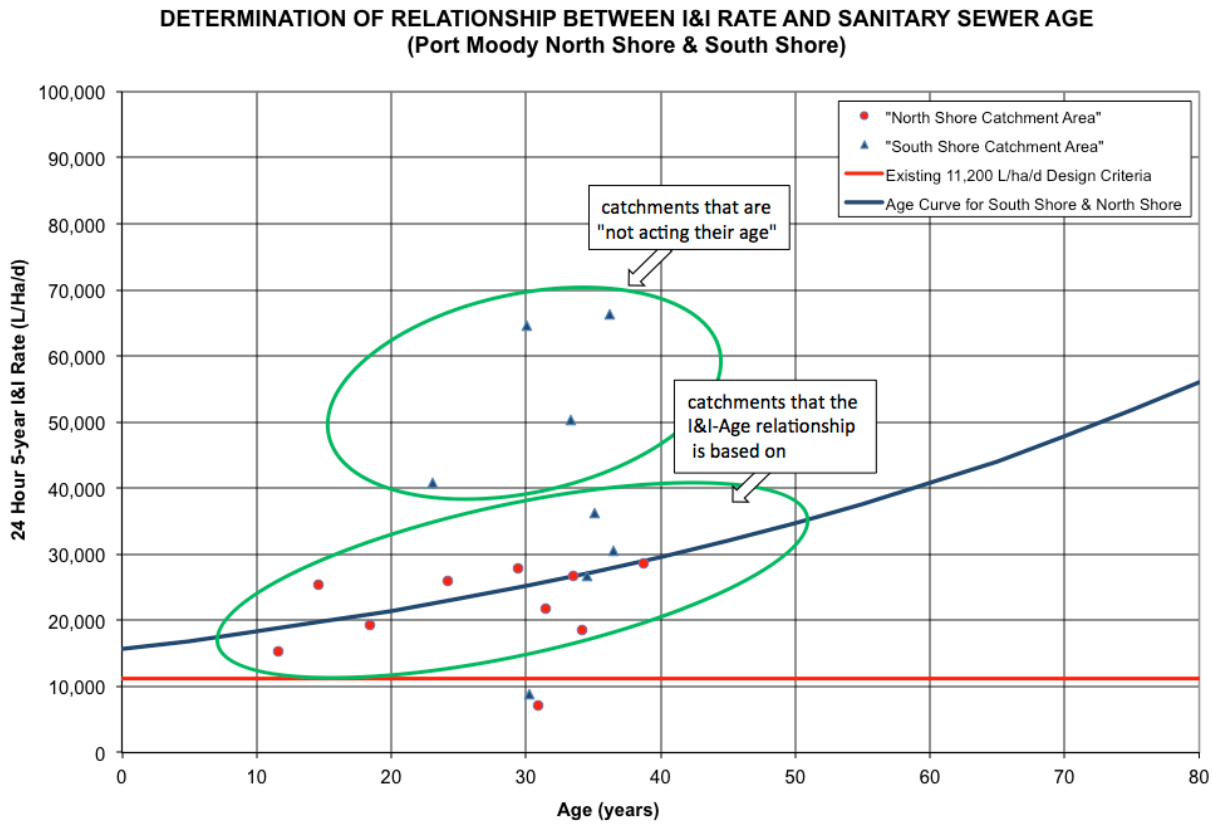

Figure 5: Relationship between RDII rate and sanitary sewer age in Port Moody, British Columbia (Johnston *et al.* 2005)

3.4 Industry Standards Development

Independent institutes from the insurance industry along with experts in the field such as the Institute for Catastrophic Loss Reduction (ICLR) and Norton Engineering Inc. also began working on a Guideline on basement flood protection and risk reduction in published by Canadian Standards Association in 2018 (CSA 2018 – Z800-18). The Guideline examines required implementation of protective plumbing measures and other house level measures for both new and existing infrastructure. In addition to preventing basement flooding the recommended measures are also aimed at reducing inflow and infiltration into the sanitary sewer system.

Norton Engineering, ICLR and Engineers Canada have recently embarked on developing a foundational document for the development of a Canadian National Standard aimed at reducing the risk of clean water (inflow and infiltration) in new sewer construction in consultation with expert stakeholders (Robinson *et al*. 2019), the most recent draft, dated June 26, 2019 has been distributed to the industry. It aims to establish a foundation of knowledge and stakeholder insights for the development of a national standard through the Standards Council of Canada (SCC).

4.0 ANALYSIS OF YORK REGION'S INFLOW AND INFILTRATION DATA

Through the comprehensive set of wastewater flow data collected across its system, York Region has confirmed a need to better manage inflow and infiltration in new development, as many other jurisdictions have.

4.1 York Region's Inflow and Infiltration Rates in Young Sewers

Since the expected lifespan of a sanitary sewer is approximately 80 years, the sanitary sewers in York Region are considered to be generally young, with approximately 40% of pipes being less than 20 years old and 85% of pipes being less than 40 years old, as illustrated in Figure 6. A breakdown of the percentage of York Region's sanitary sewer system categorized by age is provided in Table 2.

Table 2: Percentage of York Region's Sewer Pipe by Age

Age Category	% of York Region Sewer Pipes
Young (0-20 years old)	40
Middle (20-40 years old)	45
Old (>40 years old)	15

With a younger sanitary sewer system, it would be expected that inflow and infiltration rates would be relatively low; however, through analysis of 2015 to 2018 wastewater flow and rainfall data at over 300 monitoring locations, York Region has found high levels of inflow and infiltration in several of its younger sewer basins. This examination included analysis of peak hour RDII rates for a 25-year regression storm event and BI estimates calculated using the Stevens-Schutzbach method. These findings are particularly concerning and warrant closer management of inflow and infiltration in new

developments as York Region continues to expand its sewer infrastructure over the next few decades to meet a residential population increase of approximately 600,000 people by 2041.

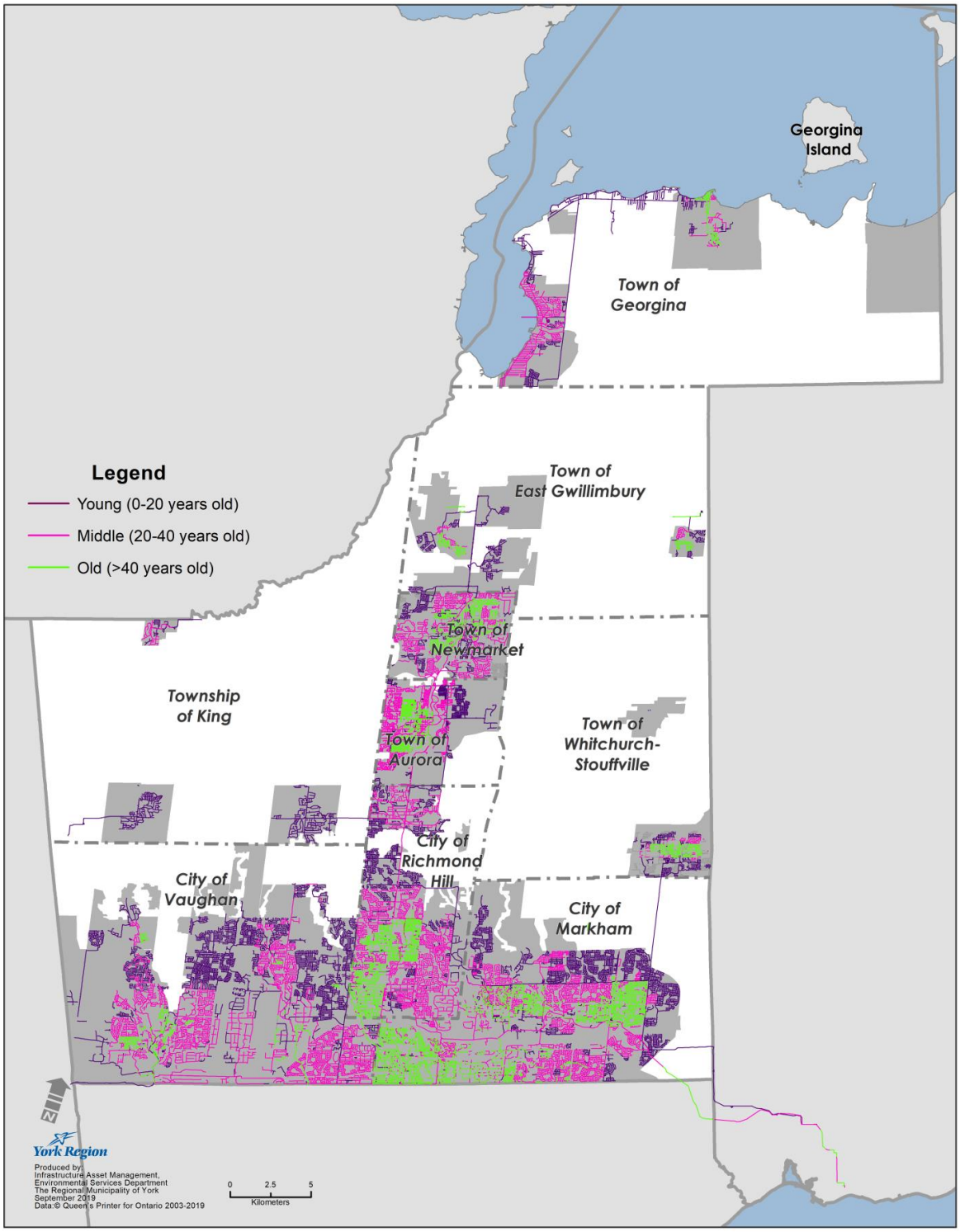

Figure 6: Map of York Region's sanitary sewer pipe age

Diving deeper into why York Region has seen high inflow and infiltration numbers in new developments the RDII and BI levels were calculated for each sanitary sewer basin as shown in Figure 7 and Figure 8. Since the average sewer pipe age in some of the meter basins could be skewed by smaller areas of very high or very low pipe age, a weighted average was used.

Figure 7, which plots the peak hour RDII against average sewer pipe age, shows several monitoring basins in the young to middle pipe age categories exceeding typical peak RDII allowances in Ontario (0.1 to 0.26 L/s/ha). More specifically, approximately 24% of basins with an average pipe age of less than 20 years old are exceeding the design inflow and infiltration allowance of 0.26 L/s/ha and almost 94% are exceeding the tighter inflow and infiltration allowance of 0.1 L/s/ha. One could argue that basins with an average age between 20 and 40 years should not be in exceedance of the upper limit allowance of 0.26 L/s/ha either, however more than 41% of these basins are above it.

Figure 7: Peak RDII rates versus average sewer basin age*

**It should be noted that the typical limits of 0.1 to 0.26 L/s/ha are instantaneous peak RDII design rates, whereas the data in Figure 7 is based on 25 year storm event peak RDII projections, averaged over one hour, so the numbers are not directly comparable. However, if the data in Figure 7 was based on instantaneous peak flows the results would be even higher than currently shown.*

Figure 8, which plots the BI against average sewer basin pipe age, shows high quantities of groundwater (over 40% of the dry weather flows) are infiltrating young pipes. More specifically, over 33% of the sewer basins with an average age below 20 years are exceeding the acceptable threshold. Some of these exceedances are as high as 68% BI for areas as young as 15 years.

Figure 8: Base infiltration percentage versus average sewer basin age

5.0 EXAMPLES OF INFLOW AND INFILTRATION IN NEW AND RECENT REGIONAL CONSTRUCTION

Over the past several years York Region and its local municipal partners have identified inflow and infiltration issues in new construction. Sources of inflow and infiltration typically include offset joints, poor connections at the maintenance holes, leaking maintenance holes and poor lateral connections. These types of defects are not always identified during construction, or in post construction CCTV.

This section outlines examples of identified sources of inflow and infiltration in York Region's relatively young sanitary sewer systems and new developments. The actual

locations of the new development or sewer system are not shown to protect the privacy of the subdivision owners and the municipality.

5.1 Sources of Inflow and Infiltration Identified During Construction

In 2017, excessive wet weather flows were identified downstream of subdivisions under construction in York Region. To further investigate, York Region conducted a site visit during a rain event which revealed ponding water at numerous sanitary maintenance holes. It was found that a number of the “bolt-down” maintenance hole covers were not properly secured, allowing a constant flow of water to enter the system. It was also found that in one of the subdivisions several sanitary sewer lateral end caps were installed incorrectly, resulting in a peak instantaneous sewer flow of approximately 20 L/s. Once these defects were addressed, follow-up flow monitoring under a similar storm event revealed a peak instantaneous sewer flow of 0.3 L/s. As a direct result of enforced and inspected construction practices a 98% reduction in flow was realized.

In 2017, a similar investigation for another subdivision revealed a sanitary maintenance hole as a major source of inflow. This particular maintenance hole was under construction and did not have its frame and cover properly installed yet; instead, it was covered with only a steel plate. This maintenance hole was located near a stormwater management pond and when the area flooded during storm, the steel plate shifted, allowing inflow into the top of the maintenance hole. To eliminate the sources of inflow, the developer completed remedial works including raising the maintenance hole to avoid flooding and installing of a watertight frame and cover.

These incidents highlight the potential issues associated with having sanitary maintenance holes in areas at risk of ponding or flooding, and demonstrate the significance of having sound site drainage plans and watertight frames and covers. Increased and more effective inspection practices and flow monitoring could also help mitigate these issues form occurring in the future.

While some of the above noted issues may have been fixed by the time the development was ready for handover, inflow and infiltration occurrences during construction can impact municipalities by causing excessive pumping station flows, basement flooding and/or bypasses to the environment.

An example looking at inflow and infiltration issues during construction happened during the emergency replacement of a segment of York Region’s trunk sewer. Watertight requirements were not scoped as part of the initial design, and the first of three new maintenance holes was constructed without waterproofing. Unanticipated high groundwater conditions were encountered at the remaining two maintenance holes, and a waterproof membrane sheeting was applied to maintenance hole joints and cone structure to ensure watertightness (Figure 9). Had this issue not been addressed during

construction, the newly constructed pipe could have been susceptible to large amounts of infiltration sooner than expected. To proactively manage the risk associated with infrastructure under the influence of high groundwater pressures, design guidelines should be updated to include specific requirements for construction methods and materials to ensure watertightness in specific hydrogeologic conditions.

Figure 9: Use of a waterproof membrane to make maintenance hole joints watertight

5.2 Sources of Inflow and Infiltration Identified through Post Construction CCTV and Field Inspections

York Region continues to identify sources of inflow and infiltration in younger areas of the sanitary sewer system through post construction CCTV, field inspections and flow monitoring. In 2017, York Region identified excessive inflow and infiltration in one of its trunk sewers constructed in 2006. Based on CCTV footage as shown in Figure 10, a number of infiltration runners and gushers were identified at the pipe segment joints, totalling an estimated flow rate of 3.72 L/s. Since there were no recorded observations of excessive inflow and infiltration during the last 2014 inspection, it is possible that the leaking joints were missed due to seasonably lower groundwater conditions.

While the trunk sewer is only 13 years old and still considered to be in good structural condition apart from the identified inflow and infiltration, rehabilitation is necessary and planned for 2020 to 2021. This work will prevent washout of the pipe bedding, recover premature loss of conveyance capacity and reduce extraneous wastewater treatment costs. Preliminary cost estimates for the rehabilitation work range between $1.5 million and $3.5 million depending on the selected methodology. While rehabilitation will extend the pipe's lifespan by up to 50 years, the lack of proper design and watertightness for the site-specific hydrogeologic conditions are resulting in excessive and premature capital expenditures.

Figure 10: Photos from 2017 CCTV showing infiltration runners and gushers (left) and close-up view of an infiltration runner (right) in the Regional sanitary trunk Sewer constructed in 2006

Another example identified inflow and infiltration entering a maintenance hole constructed in 2002 (see Figure 11). Groundwater in this case seems to have entered through displaced or poorly constructed joints. These types of deficiencies are not easily identified during construction or in post-construction CCTV inspections, possibly due to dry weather conditions at the time of the inspections or ground shifting after construction. In this scenario, a deficiency may only become evident months or years after construction through real-time flow monitoring, potentially after warranty periods have expired.

The above examples demonstrate the need for stringent specifications for watertight products and construction techniques to reduce the risk of inflow and infiltration in high groundwater conditions even months or years after construction.

Figure 11: Excessive inflow and infiltration in a local sanitary maintenance hole - constructed in 2002

5.3 Sources of Inflow and Infiltration Identified Through Flow Monitoring

An example of inflow and infiltration detected in a younger sewer basin through flow monitoring is shown in Figure 12. The peak hour RDII result is estimated to be 0.48 L/s/ha which is almost twice the upper limit allowance of 0.26 L/s/ha, and almost five times the lower limit allowance of 0.1 L/s/ha. Peak responses could be an indication of direct connections from private properties (such as, downspouts, sump pump discharge pipes, reverse driveways) or sources on the public side such as cross connections or low lying maintenance holes that are not watertight and susceptible to overland flooding or ponding.

The above example shows the benefits associated with long-term flow monitoring in sanitary sewer systems and the need for stringent specifications, design requirements and construction practices/procedures to ensure improved watertightness in new developments.

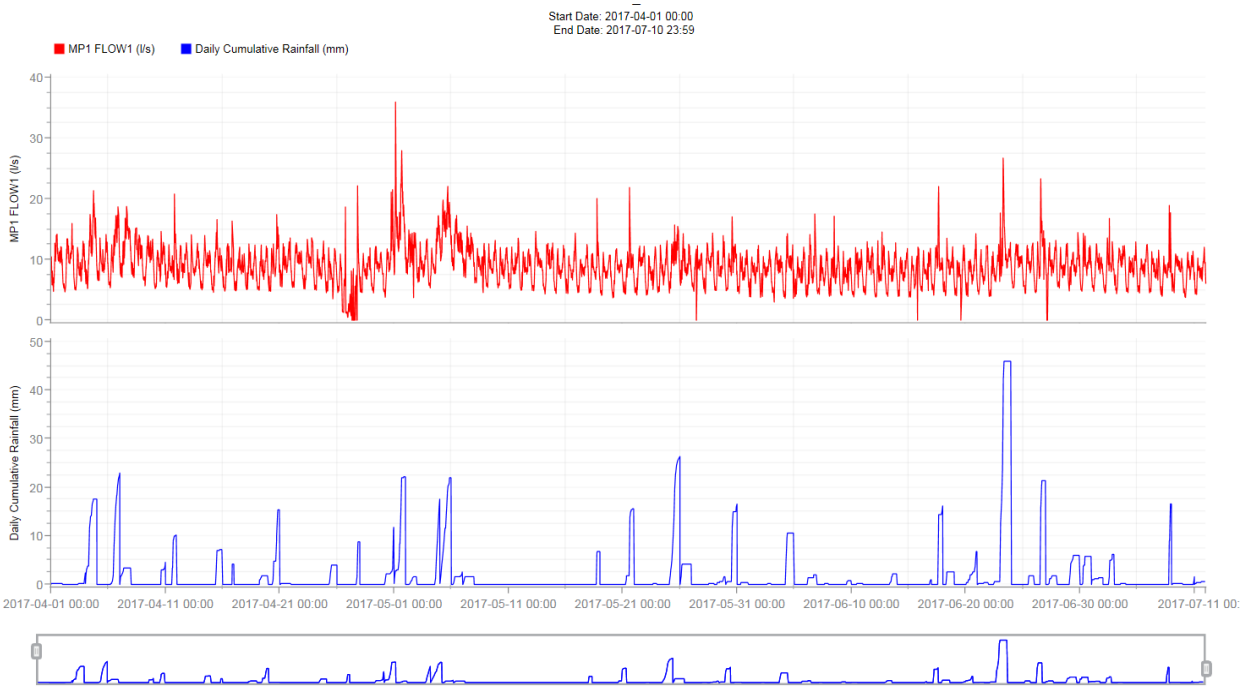

Figure 12: Graph of rainfall and sewer flow from April 1 to July 10, 2017 for a monitoring basin with an average pipe age of 13 Years

6.0 IMPACTS OF INFLOW AND INFILTRATION

Despite York Region's proactive and conservative management of its wastewater system, extreme storm events such as the one occurred in June of 2017 could result in overflows at pumping facilities and areas of basement flooding due to increased inflow and infiltration. Impacts associated with extraneous sewer flows, such as spills to adjacent surface waters, environmental fines, residential sewer backups and extra pumping and treatment costs are carefully considered by York Region. This particular paper discusses the need to revisit and update design, construction and inspection practices to ensure best-management and consistent practices are applied to new construction to help minimize these impacts.

The risk of such wastewater overflows in York Region is expected to increase over time, due to forecasted growth rates and more extreme rainfall events due to climate change. As a result, York Region continues to invest in the reduction and prevention of inflow and infiltration. To evaluate the cost-effectiveness of proposed remedial projects and programs, York Region is researching and piloting new models to quantify the secondary impacts of inflow and infiltration such as effects on wildlife, the natural environment, homeowner well-being and community recreation.

To provide further insight into the breadth of impacts associated with excessive inflow and infiltration from both existing and new sewer systems, a summary of economic, social or environmental impacts is presented in Table 3 below.

Table 3: Summary of Economic, Social and Environmental Impacts Due to Inflow and Infiltration

Type of Impact	Description	Potential Costs & Examples from York Region
Economic		
Source Rehabilitation	New projects and associated funds are required to rehabilitate inflow and infiltration sources in the public and private sewer systems.	Costs for York Region rehabilitation projects have ranged from tens of thousands to several millions of dollars.
Additional pumping, treatment and system maintenance needs	Additional costs are associated with pumping and treatment of extraneous sewer flows, as well as increased system maintenance.	Each unit of extraneous sewer flow results in additional incremental wastewater pumping and treatment costs at York Region facilities. The eventual premature facility upgrades and expansions are sometimes unplanned and even more costly.
Wastewater discharges to the environment	Fines may need to be paid to the Province as a result of a sewage overflow, bypass or system backup to the environment.	In 2017, a bypass event at a York Region pumping facility was reported to the Province following the extreme rainfall event. Depending on the circumstances of such incidents, environmental fines associated with overflows can be applicable and typically range from thousands to millions of dollars per day.
Premature expansion of infrastructure	High peak flows due to inflow and infiltration may require the expansion of conveyance infrastructure, pumping stations and wastewater resource recovery facilities	Several facilities across York Region, including those in the Township of King, Towns of Georgina, Newmarket and Aurora are currently being evaluated for interim

	earlier than would otherwise be necessary.	measures and eventual upgrades associated with extraneous peak flows, valued in the millions of dollars, to overcome premature capacity bottlenecks.
Loss of development revenue	Due to a premature loss of conveyance capacity from inflow and infiltration, there will be loss in Development Charges and tax revenue (for example, lost opportunity costs).	A reduction of 1 L/s of inflow and infiltration from constrained infrastructure allows an advancement of a few million dollars in development charges.
Additional municipal engineering and operations staff time	Increased engineering and operations staff costs are associated with management of inflow and infiltration related issues (particularly addressing basement flooding and overflow incidents).	York Region is spending approximately $1 million annually on its internal engineering staff time to support the inflow and infiltration reduction program. This does not include staff time associated with York Region operational resources nor local municipalities' resources.
Compassionate grants	Municipal expenditures may be needed in the form of grants or settlement agreements to property owners for mitigation of basement flooding impacts. Associated increases to municipalities insurance premiums may also result.	Considering the average value of a York Region home, and a 10% devaluation rate after a case of basement flooding, a compassionate grant can amount to $170,000 per house (Felmate 2018).
Disaster relief programs	Understanding the lens of climate change management, increased provincial and federal expenditures may be needed to support programs aimed at disaster mitigation, including the mitigation of wastewater resource recovery facility overflows, bypasses and basement flooding (such as the recent federal Disaster	Funds such as the 2018 federal DMAF will allocate close to $2 billion dollars to large-scale infrastructure projects aimed at mitigating climate-related hazards, such as flooding. Projects must have a minimum cost of $20 million

	Mitigation and Adaptation Fund, DMAF).	(Infrastructure Canada 2018).
Social		
Health risks and trauma	There are potential health risks for homeowners that have had: • Sanitary sewer system back-ups in their homes • Exposure to flooding of wastewater in basements • Ingestion of potable groundwater/well supplies that have been contaminated by the flood water	New cost models that help evaluate this type of impact or the avoidance of it are being introduced in the industry (Ramboll, 2017). Avoided costs from these indirect impacts can be in the order of hundreds of thousands, to millions of dollars.
Disruption to residents	Community disruptions can arise during repair of leaking conveyance systems, including traffic delays due to partial/full lane closures for road excavations and work space, reduced accessibility of driveways, the closure or relocation of bus stops, temporary water shut offs, and construction noise and dust.	
Insurance validity problems for homeowners	Basement flooding-related claims can be denied by some insurance providers or result in increased premiums/capped payouts.	
Decreased ability for York Region to meet Provincial growth plans	If capacity is lost in the sanitary sewer system it will decrease York Region's ability to meet the Province's growth plan.	
Environmental		
Increased greenhouse gas emissions	Increased treatment and pumping due to extraneous wastewater flows results in increased energy consumption	By 2031, York Region's inflow and infiltration reduction program will have saved an estimated $1 million in energy

	and greenhouse gas emissions.	consumption costs and hundreds of tons of greenhouse gas emissions.
Environmental impacts from bypasses/ overflows	Wastewater overflows from the conveyance system and bypasses at treatment plants may result in quality impacts to receiving waters, impacting aquatic habitat.	New cost models that help evaluate this type of impact or the avoidance of it are being introduced in the industry (Ramboll, 2017). Avoided costs from these indirect impacts can be in the order of hundreds of thousands to millions of dollars.

7.0 CONCLUDING REMARKS AND NEXT STEPS

The adoption of best practices for the management of inflow and infiltration in new developments is a proactive and cost effective means of avoiding future expenditures and promoting sustainable growth and development. Leveraging partnerships with both local municipalities and the industry is one approach York Region is proceeding with to establish specific, cost-effective, consistent and implementable solutions/guidelines or standards to address inflow and infiltration in new development.

Ongoing and future initiatives proposed by York Region as part of the “Inflow and Infiltration in New Development Survey” and best-management practices will focus on design specifications and guideline updates, planning or development application approval criteria, updated inspection requirements, procedures and guidelines and establishing procedures for flow monitoring. These focus areas will be detailed in a final report later this year and will include the following:

- Updated Design Specifications and Guidelines

  York Region’s review found a high variability and inconsistency amongst the design guidelines currently being used by the nine local municipalities within York Region. This focus area will generate design guidelines and suggestions for key inflow and infiltration contributors to be implement during the design stage. It will leverage industry expertise and successes to cover material selection, structure placement and alignment, riser details, key specifications and testing procedures and requirements.

- Development Application Approval Criteria

Streamlining the requirements and process for planning application approvals can contribute to inflow and infiltration reduction as well as benefit developers seeking approvals from a particular local municipality. A guideline and checklist for the approval process will be developed in coordination with the nine local municipalities to ensure flexibility in implementation. This will ensure it fits local needs and establish consistency in the review process. The checklist will correlate with the design specifications guidelines and will focus on ensuring design strategies required to reduce inflow and infiltration are being implemented.

- Site Inspection Requirements, Procedures and Guidelines

  Consistent inspection and testing in new development to ensure conformity with design and approval requirements is another important area York Region will be focusing on. An inspection checklist will be created to be followed by the developer's inspector and submitted to the local municipality. It will cover all levels of inspection to ensure key installation procedures and standards are adhered to during construction and that all inspections are recorded.

- Flow Monitoring Procedures and Performance Conformity

  Develop a Region-wide flow monitoring procedures and performance standards by setting minimum requirements. This may include revisiting infiltration allowance rates to determine if a reduction to the "allowable" infiltration is warranted. Refining the infiltration allowance over time as new processes are implemented is one option York Region is looking at exploring for setting new allowable inflow and infiltration limits across York Region. Flow monitoring and conformity outcome from existing SIP/SDIP participating developments will be used as they become more available to inform the development of this focus area.

York Region continues to demonstrate leadership in inflow and infiltration programming by regularly reviewing industry initiatives, programs and partnerships and adapting its Strategy to meet best-in-class approaches. Through these initiatives and collaboration with municipal partners, industry leaders, the development industry and more, York Region hopes to develop a consistent, effective and practical framework for the prevention of inflow and infiltration in new development.

Moving forward York Region will continue to leverage its knowledge and experience as it seeks to refine and expand its best-in-class Inflow and Infiltration Reduction Strategy, and demonstrate world leadership in the field of inflow and infiltration reduction.

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