Stantec

100% STUDY REPORT TO ADDRESS ITEMS 5.1 TO 5.4 OF MECP ORDER NO. 1-142403796

FINAL

May 9, 2023

Prepared for:
City of Hamilton

Prepared by:
Stantec

Project Number:
163401837

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
1	Draft 50%	Pierre Wilder, Joon Choi, Adrien Comeau	24/03/23	Michael Kocher	24/03/23	Gerald Bauer	24/03/23
2	Draft 90%	Pierre Wilder, Joon Choi, Francine Lei	18/04/23	Michael Kocher	18/04/23	Gerald Bauer	18/04/23
3	Final	Pierre Wilder Joon Choi, Francine Lei	26/04/23	Michael Kocher	27/04/23	Gerald Bauer	27/04/23
4	Final Rev 1	Pierre Wilder Joon Choi, Francine Lei	08/05/23	Naomi Latimer	08/05/23	Michael Kocher	08/05/23

The conclusions in the Report titled 100% Study Report to Address Items 5.1 to 5.4 of MECP Order No. 1-142403796 are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

Stantec has assumed all information received from City of Hamilton (the "Client") and third parties in the preparation of the Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

This Report is intended solely for use by the Client in accordance with Stantec's contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

Prepared by: ____________________
Signature
Pierre Wilder, P.Eng.

Prepared by: ____________________
Signature
Adrien Comeau, P.Eng.

Prepared by: ____________________
Signature
Joon Choi, E.I.T.

____
Signature
Francine Lei, E.I.T.

Reviewed by: ____________________
Signature
Michael Kocher, P.Eng.

Reviewed by: ____________________
Signature
Gerald Bauer, P.Eng.

Reviewed by: ____________________
Signature
Naomi Latimer, P.Eng. C.E.T.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Executive Summary

Introduction, Purpose and System Description

This report was prepared in response to Ministry of the Environment, Conservation and Parks (MECP) Order No. 1-142403769 issued to the City of Hamilton (City). Stantec completed a review of the City's collection system and its current inspection-related programs and initiatives to address MECP Order Items 5.1 to 5.4 (refer to **Sections 3 to 6**, respectively). The purpose of this report is to summarize this review, address the MECP Order Items and provide recommendations to improve the City's ability to identify spills and unauthorized discharges from its collection system.

The City of Hamilton operates a large network of sewers to service its population and manage both sanitary sewage and rainfall runoff (i.e. stormwater). While the newer, peripheral parts of the City have generally been developed with separated systems (i.e. with sanitary sewage flowing towards treatment plants and collected stormwater being discharged into surface water bodies), the urban core is mostly serviced by combined sewers, as is common in larger and older cities. The City's combined sewer is designed to manage excess flow during rainfall events and balance sewage treatment with limiting sewer surcharge and flooding. In total, the City has over 3,080,237m of sewers, of which 40% is sanitary, 41% is storm and 19% is combined. There are also areas that were formerly combined and are now separated, including a number of storm relief sewers that reconnect into the combined network. Refer to **Section 2** for more descriptions and maps of the City's collection system.

With such a large, complex sewer network that was mostly constructed several decades ago and which continues to be expanded and upgraded over time, there exists the possibility of cross connections within the network that could lead to spills and unauthorized discharges, which is not uncommon for collection systems of a similar size and age to Hamilton. Based on review of the City's collection system, the most likely unknown sources of spills and unauthorized discharges that may exist includes the following (detailed descriptions of each are provided in the report):

Table 1-1: Potential Sources of Spills and Authorized Discharges

Condition	Type of Discharge	Frequency
Mainline Cross-Connection	Continuous, Dry Weather	Occurs most or all of the time (dry weather)
Sewer Lateral Cross-Connection	Continuous, Dry Weather	Occurs most or all of the time (dry weather)
Unknown / Unauthorized Critical Regulator	Intermittent, Wet Weather	Occurs over shorter / more limited time periods
Failed Critical Regulator	Transitory, Dry Weather	Occurs rarely and without predictable frequency

Item 5.1 - Feasibility Analysis to Complete a Detailed In-Pipe Inspection Program

As requested in Item 5.1 of the MECP Order, Stantec evaluated the City's collection system and performed a high-level feasibility analysis for conducting a potential City-wide detailed in-pipe inspection program (refer to **Section 3** for details and assumptions of the analysis). The following table shows estimated CCTV Contractor costs for various ranges of sewer sizes:

Table 1-2: Estimated CCTV Costs for Various Sewer Sizes

Sewer Size (mm)	Total length (m)	CCTV cost per m ($)	Total cost ($)
<=750	2,532,560	$ 10.50	$ 26,591,885
750 to 1200	320,851	$ 13.75	$ 4,411,695
>1200	226,826	$ 25.00	$ 5,670,639
		TOTAL COST	**$ 36,670,000**

The cost above is considered a low-end cost as it assumes ideal conditions (favorable weather, no traffic restrictions, no accessibility or visibility issues, etc.). We expect the actual cost to complete this inspection program to be at least 35% higher, **approaching $50M.**

City-wide CCTV inspections not practical: 7-10 years, 4-5 new staff, $50M+

The program would be expected to take over 10 years using 2 CCTV crews in tandem and would require the hiring of 4 additional City staff members (at an estimated City resourcing cost upwards of $3.7M).

Additionally, completing in-pipe camera inspections is not likely to provide the most benefit in identifying spills or unauthorized discharges, as the vast majority of these conditions (as listed in **Table 1-1** above) are expected to occur at a maintenance hole (MH) or structure - aside from sewer lateral cross-connections, which would occur most commonly along smaller local sewers in separated areas. Unknown critical regulators would be discovered by first opening MH covers, while mainline sewer cross-connections are most likely to occur due to a sanitary or combined sewer being connected to the wrong MH (i.e., into a storm MH).

For these reasons, conducting a City-wide in-pipe sewer inspection program for the purposes of identifying unauthorized discharges is not recommended. It should be noted that the City's current condition assessment inspection program, is expected to remain ongoing outside of the inspections discussed in this report.

Item 5.2 - Feasibility Analysis to Complete a Risk-Based Inspection Program

This section of the report (**Section 4**) outlines the components of a programmatic approach and risk-based assessment methodology that is based on Industry Good Practices and deemed to be a feasible approach to address the risk of unauthorized discharges impacting water quality at CSO and storm drainage outfalls within the City of Hamilton. It is important to note that the City has, in fact, been following many of these practices over the past 10 years since they have initiated a program to address cross-connections within their separated sewer system, and have recently begun to focus their efforts within the combined sewer system with pilot area studies. While various City programs use Industry Good Practices to inspect, identify and correct potential spills and unauthorized discharges, there is a need for a centralized task-force or overall program (referred to herein as the System-wide Unauthorized Discharge Removal and Inspection Program, aka SUDRIP) that will oversee these inspection efforts and connect current programs with an integrated prioritization process.

It is also recommended that the City continue and expand its current programs that are designed to identify potential sources of spills and unauthorized discharges within the combined sewer area and the separated sewer area of the City. The combined sewage area is covered via the Regulator Inspection Program and the Risk-Based Proactive Pilot Program (aka the Pilot Program), which inspects high-risk, or "critical" MHs for potential cross-connection or unknown regulators / mainline relief connections. Refer to **Section 5.1.1.1** for prioritization and definition of "critical" MHs and outfalls. It is recommended that the Pilot Program be expanded to inspect all storm sewer MHs and adjacent combined sewer MHs within the combined sewer area of the City. This would likely take an additional 5 years to complete.

The separated sewer area is very effectively covered by the Sewer Lateral Cross-Connection (SLXC) Program, which has been ongoing since 2009 to trace, identify and correct sewer lateral cross-connections. We recommend that a verification step (i.e. re-sampling and re-testing outfalls that previously showed evidence of sanitary sewage contamination) be adopted by the program moving forward. This will also require some additional staffing resources.

Expected Resources Needed for New Program and Expansion SLXC and Pilot Program:

> 4 new or reassigned full-time employees and 2 additional junior staff or coop-students.
> Additional funding for increased frequency of CCTV video inspections (contracted work)
> Additional funding for increased sampling and additional physical / analytical tools.

Estimated expanded program costs: $600K / Year

In summary, we expect the City would need to **<u>hire or reassign an additional 4 full-time employees and 2 junior engineers or co-op students</u>** to carry out the new and expanded inspection programs described in this section, at an estimated annual program cost of **$600,000 / year** for the initial 5 years of the Program, which would be in addition to the City's existing programs such as their SLXC program (refer to **Table 1-3** for other details). The Program costs and staffing needs can then be re-assessed based on both the number of issues identified and resolved, and the anticipated success of the program moving forward after the four critical areas have been thoroughly investigated.

Table 1-3: Summary of New and Expanded Program Resource Requirements and Interim Completion Dates

	Overall Program Management	Combined System Program	Separated System Program
Description of Needs	Establish and oversee new program, including reporting and ongoing improvements	Complete remaining storm / adjacent combined MH inspections within combined sewer area	Begin follow-up screening of previously inspected outfalls / subcatchments
Additional Staff Requirements (FTEs)	1 Program Manager FTE	3 WW Collection Staff FTEs shared among programs	
Additional Support Staff	0.5 Co-op / Junior Staff	1.5 Co-op / Junior Staff	
Estimated Additional City Staffing Costs	$110,000 / yr	$310,000 / yr	
CCTV Contractor Costs (in addition to current budget)	N/A	$100,000 / yr	$40,000 / yr
Additional Sampling and Analytical Costs (in addition to current budget)	N/A	$20,000 / yr	$20,000 / yr
Expected Interim Completion Date	On-Going	2028-2029	On-going

<u>**Item 5.3 – Gap Analysis of the City's Current Sewer Inspection-Related Programs**</u>

Current approaches very effective and in line with Industry Good Practices

Within **Section 5**, we provide a review of the City's other programmatic initiatives and compare them with each of the components of the recommended risk assessment-based framework with the purpose of evaluating their consistency with Industry Good Practices, and identifying any gaps and/or opportunities for enhancements. The scope of this review serves as the Terms of Reference for a Gap Analysis as specified under MECP Order Item 5.3. The current City programs and initiatives were found to be very effective and in line with Industry Good Practices. This assessment informed the recommended program enhancements and new overall program (SUDRIP) described within **Section 4**.

Programs in place target a variety of potential spill / unauthorized discharge sources. No clear blind spots remain after expansion of Pilot Program.

In addition to comparing against Industry Good Practices, the Gap Analysis includes a review of the City's current programs and their potential for identifying each of the potential sources of spills or unauthorized discharges listed above. We found that the implementation of the Risk-Based Proactive Pilot Program filled a major gap within the combined sewer area by providing an inspection initiative that targets potential mainline cross-connections and unknown regulators / mainline relief connections. Further expansion of this program is recommended and described under **Section 4.**

Item 5.4 – Additional Physical and Analytical Inspection Programs

This section identifies a number of potential physical and analytical inspection programs that the City may consider for enhancements or additions to their existing programs, procedures and measures to inspect, monitor and identify spills and unauthorized discharges. The following technologies and analytical inspection programs were reviewed for the City's consideration. **Table 6-1** provides a summary of each program, including a high-level summary of its local availability, effectiveness/timeline and cost impact.

- Chemical indicators
- Dye testing
- Canine scent tracking
- CCTV on storm relief sewers
- Flow monitoring on storm relief sewers
- Dry weather sand-bagging
- Sequence-based genetic testing
- Lab-based microbial analysis
- Rapid coliform tests
- qPCR

As noted in **Section 6**, it is recommended that the City proceed with implementing field-based physical investigations including dry weather sand bagging within storm sewer MHs, dye flooding (trial as part of existing SLXC program), CCTV storm relief sewers in critical storm outfall areas, chemical indicators (trial as part of existing SLXC program or the combined sewer area investigation), and flow monitoring on storm relief sewers. In addition, it is recommended the City continue with microbiological lab-based testing and consider sequence based genetic testing where other sampling results are inconclusive.

1 Introduction and Purpose

This report has been prepared in response to Ministry of the Environment, Conservation and Parks (MECP) Order No. 1-142403769 issued to the City of Hamilton (the City). The City retained Stantec Consulting Ltd (Stantec) to support in the completion of Compliance Item No. 5 (specifically sub-items I to IV – referred to herein as MECP Order Items 5.1 to 5.4), as follows:

> ***Item No. 5 Compliance Due Date: 05/12/2023***
>
> *Identify recommendations for enhancements to the City's sewer inspection programs to better identify identifying Spill(s) and unauthorized discharges of untreated sewage within the City of Hamilton sewer system. These recommendations shall include at a minimum but not limited to:*
>
> *I. An analysis of the feasibility of conducting a detailed in-pipe inspection of the City of Hamilton's sewer system.*
>
> *II. An analysis of the feasibility of conducting risk-based inspections of the City of Hamilton's sewer system.*
>
> *III. The Terms of Reference for an assignment to complete a gap-analysis review of current programs, procedures, and measures to inspect, monitor and identify Spill(s) and unauthorized discharges from the City of Hamilton's sewer system.*
>
> *IV. A review of additional physical and analytical inspection programs to identify Spill(s) and Spills(s) and unauthorized discharges from the City of Hamilton sewage system.*

Item 5.5 (V) was completed by the City of Hamilton staff:

> *V. Procedures for updating City of Hamilton's current digital mapping system when discrepancies are determined.*

Stantec completed a review of the City's on-going and planned sewer inspection programs to address MECP Order Items 5.1 to 5.4. This report summarizes Stantec's findings and recommendations and generally follows the sequence of the MECP Order Items above. The following summarizes how the MECP Order Items are addressed in this report:

5.1: Stantec evaluated the City's collection system and performed a high-level feasibility analysis for conducting a potential City-wide detailed in-pipe inspection (refer to **Section 3**). This includes estimated costs based on past CCTV contract data and estimated program duration and staffing requirements, as well as potential limitations due to available resources within the CCTV Contractor industry.

5.2: The MECP Order specifies a feasibility analysis for conducting "risk-based inspections". The City currently has a number of inspection-type programs or programmatic initiatives in effect that can be considered "risk-based" and aim at identifying potential cross-connections and other sources of spills and unauthorized discharges. As such, in

Section 4 we identified a larger need for an new overall management program (referred to herein as the System-wide Unauthorized Discharge Removal and Inspection Program, aka SUDRIP) that will connect these initiatives under a common goal and can be used for the Gap Analysis in **Section 5**. Industry good practices for such a program are discussed in the first part of this section, however a feasibility analysis (i.e., total program costs, duration and resources) for this would be difficult to conduct until the program begins to take form and immediate and ongoing needs are identified.

The second part of this **Section 4** provides an overview of the City's Risk-Based Proactive Sewer Inspection Pilot Program (referred to herein as the "Pilot Program") that was initiated in Fall 2022. To satisfy Item 5.2, we have conducted a feasibility analysis on an expansion of this program, with recommendations for improvement.

5.3: Stantec has completed a Gap Analysis of the City's current programmatic initiatives as discussed in **Section 5**. The scope of this Gap Analysis, which serves as the Terms of Reference specified under MECP Order Item 5.3, is to compare the City's collection of programmatic initiatives against the Industry Good Practices for an overall risk-based framework (discussed in **Section 4**).

5.4: Finally, under **Section 6**, we investigate a number of potential physical and analytical technologies, techniques and methods that the City could consider implementing within the SUDRIP program.

2 Overview of The City's Collection Systems

2.1 Summary of City Collection System Infrastructure

The City of Hamilton operates a sewer network that services the City and parts of the previous municipalities (now amalgamated) of Flamborough, Dundas, Ancaster, Glanbrook and Stoney Creek. The network consists of storm, sanitary and combined sewers. Sewage (sanitary and combined) is treated at two municipal wastewater treatment facilities (Woodward and Dundas). The peripheral areas of the City are generally separated systems (sanitary and storm sewers only), while the urban core (referred to as the "combined area") is serviced by combined sewers as well as localized storm and sanitary sewers. The combined area features 195 known critical CSO regulators, which under certain wet weather conditions, divert excess combined sewage from the wastewater collection system towards one of the City's 22 combined sewage outfall locations. In total, the City has over 3,080,237m of sewers, of which 40% is sanitary, 41% is storm and 19% is combined. There are also areas that were formerly combined and are now separated, including a number of storm relief sewers that reconnect into the combined network.

Table 2-1 and **Table 2-2** below provide a further breakdown of the City's collection system features based on areas of the City. The trunk sewer network is also illustrated on **Figure 2-1**, while **Figure 2-2** presents an overview of the regulators and outfall locations within the combined sewer area.

Table 2-1: Summary of City of Hamilton Collection System

Area	Sanitary Sewers (m)	Storm Sewers (m)	Combined Sewers (m)	CSO Points	Critical Regulators
Flamborough	92,052	108,705	0	0	1
Dundas	97,590	74,701	71	1	6
Ancaster	163,712	122,451	0	0	1
Glanbrook	90,375	75,391	0	0	0
Stoney Creek	272,812	241,767	0	0	6
Hamilton	506,186	660,774	573,649	29	181
Total	1,222,728	1,283,789	573,720	30 (CSO Points) 22 (CSO Locations)	195

Table 2-2: City of Hamilton Sewer Length Breakdown

Area	Diameter (mm)	Sanitary (m)	Storm (m)	Combined (m)	All (m)
Flamborough	<=750	87,640	85,992	0	173,631
	>750-<=1200	4,103	15,698	0	19,801
	>1200	309	7,015	0	7,324
Dundas	<=750	89,082	66,334	71	155,487
	>750-<=1200	6,379	6,465	0	12,844
	>1200	2,129	1,902	0	4,031
Ancaster	<=750	152,921	93,322	0	246,242
	>750-<=1200	8,261	21,330	0	29,590
	>1200	2,530	7,799	0	10,330
Glanbrook	<=750	82,339	51,872	0	134,211
	>750-<=1200	5,776	14,964	0	20,740
	>1200	2,260	8,556	0	10,816
Stoney Creek	<=750	257,914	176,608	0	434,522
	>750-<=1200	3,270	40,917	0	44,187
	>1200	11,628	24,242	0	35,870
Hamilton	<=750	447,822	458,666	481,978	1,388,467
	>750-<=1200	30,668	106,556	56,464	193,688
	>1200	27,696	95,551	35,207	158,454
All	<=750	1,117,718	932,794	482,049	2,532,560
	>750-<=1200	58,457	205,930	56,464	320,851
	>1200	46,553	145,065	35,207	226,826

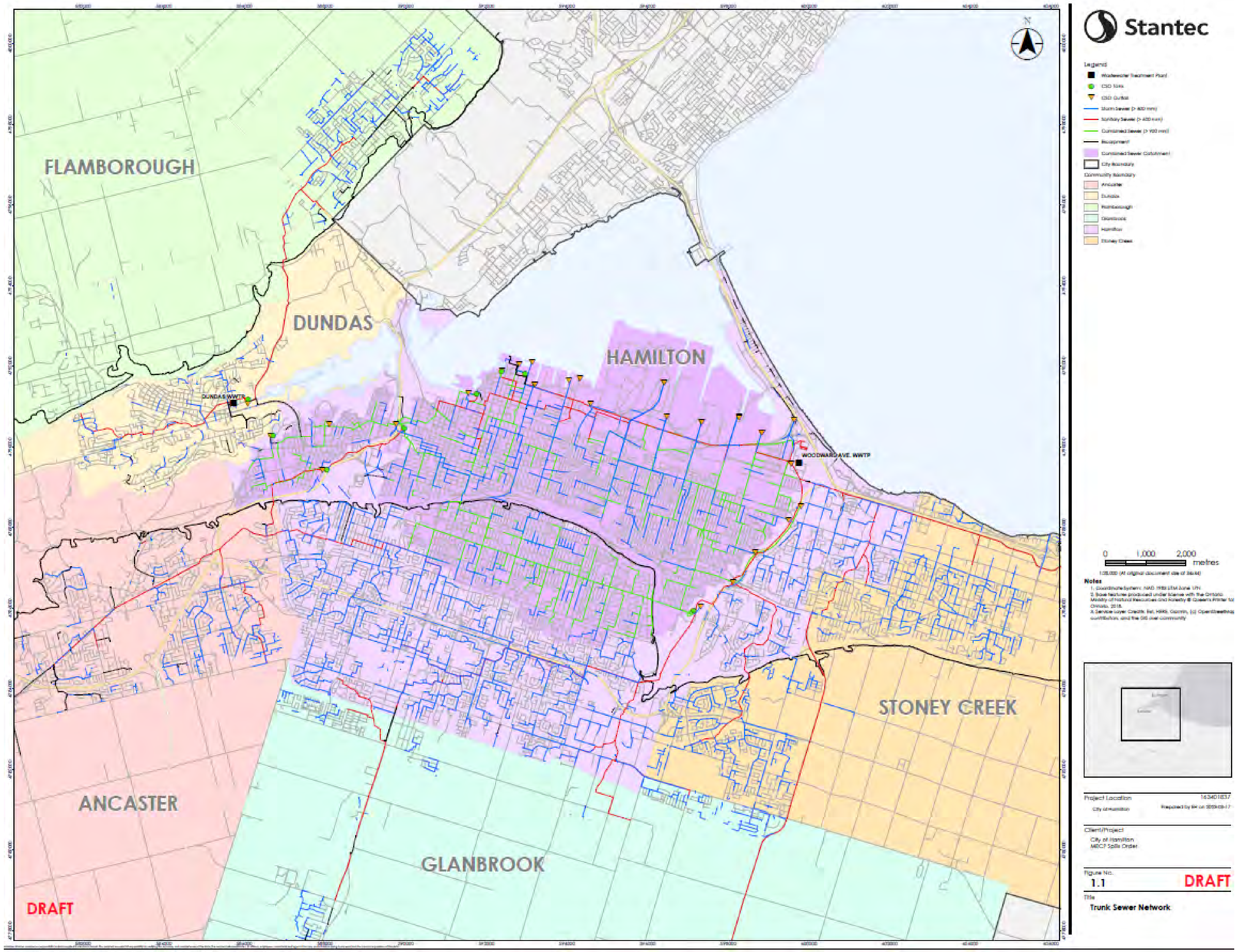


Figure 2-1: City of Hamilton Trunk Sewer Network (Refer to Appendix A for full-sized Figure)

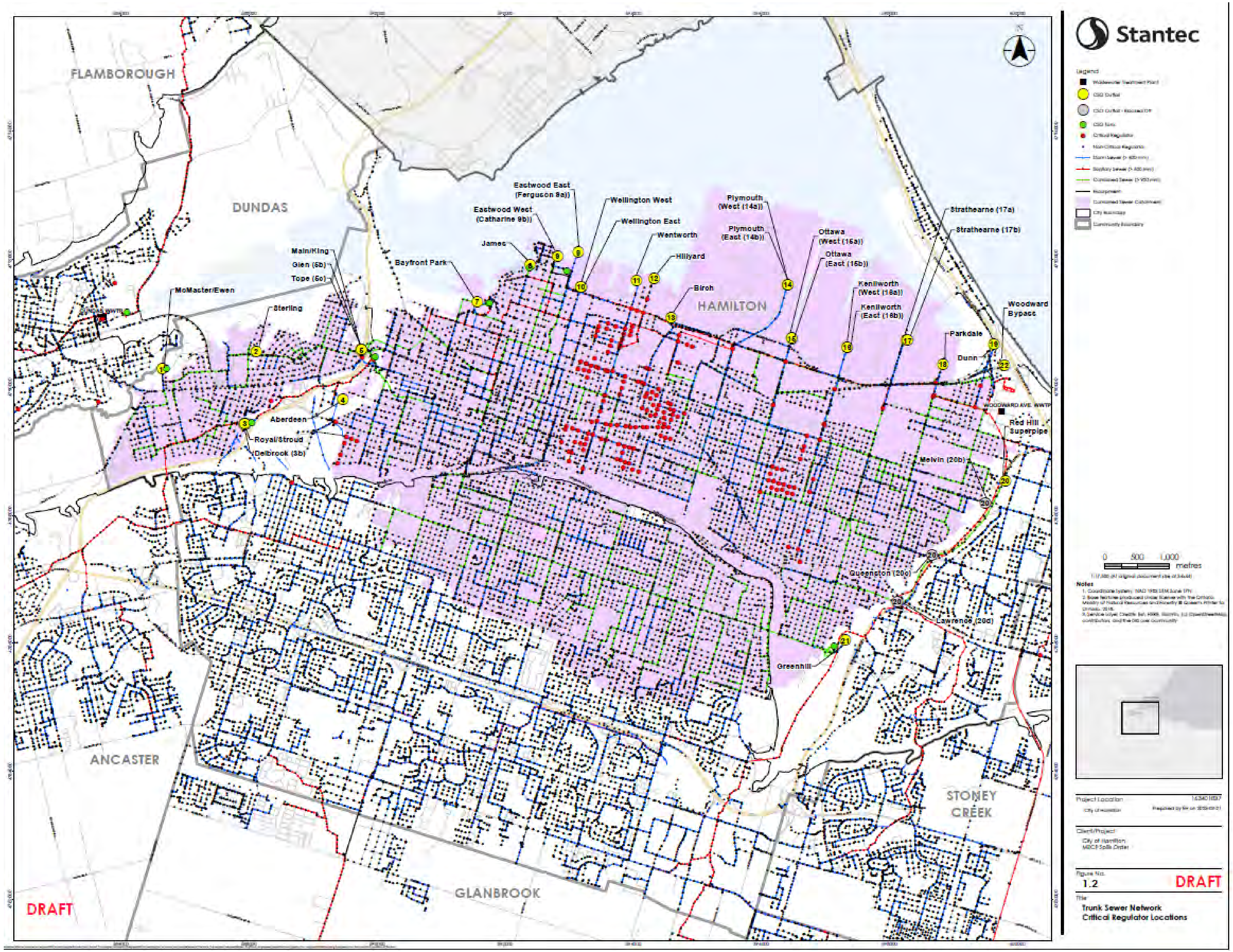


Figure 2-2: City of Hamilton Combined Sewage Area – Outfalls and Regulators (Refer to Appendix A for full-sized Figure)

2.2 Potential Sources of Spills and Unauthorized Discharges

Based on a review of the City's sewer systems, Stantec has identified the following four (4) potential unknown and undesired conditions that may exist and lead to spills and unauthorized discharges:

1. Mainline Cross Connection (Sanitary/Combined to Storm)
    a. This condition involves a sanitary or combined sewer main discharging into a storm sewer main. These are unintentional connections due to field errors during original construction or retrofit of existing systems. For example, a contractor may unknowingly connect a sanitary or combined sewer to a storm MH due to incorrect or insufficient as-built records. These most often occur at a MH structure.
2. Sewer Lateral Cross Connection (Sanitary/Combined to Storm)
    a. This condition involves one or more sanitary sewer laterals from a house or building that is directly connected to a storm sewer. These are normally isolated cross-connections (only impacting one house on a street) but are occasionally found in clusters, in which multiple units in a row of houses may have been accidentally connected to the wrong pipe during construction or during a sewer replacement. These are most often found along the span of a sewer segment.
3. Unknown / Unauthorized Critical Regulator (i.e. Mainline Sewer Relief Connection)
    a. Discovering an unknown critical regulator (or mainline sewer relief connection) does not necessarily mean that a dry weather spill has occurred, however, any overflow from this structure that discharges into the environment is considered unauthorized because the regulator is not approved by the MECP and not covered under a current ECA. These are normally discovered during a MH inspection. Person-entry inspection is required to confirm the regulator features, flow configuration and dimensions.
4. Failed Critical Regulator
    a. This condition involves the failure of a critical regulator feature, causing sanitary sewage discharge during dry weather conditions, or potentially leading to a reduced rate of combined sewage capture during wet weather compared to the regulator's design. Dry weather spills from failed regulator may be caused by a number of defects such as a collapsed weir, a pipe blockage or a damaged / leaking relief gate. A regulator may also be deemed to have failed if a gate is inadvertently set to the wrong position or if monitoring equipment that controls it is faulty.

These conditions can also be described based on the type of discharge (continuous, intermittent or transitory) as per **Table 2-3** below.

Table 2-3: Types of Potential Spills and Unauthorized Discharges

Condition	Type	Frequency of Spills / Unauthorized Discharge
Mainline Cross-Connection	Continuous, Dry Weather	Occurs most or all of the time (dry weather)
Sewer Lateral Cross-Connection	Continuous, Dry Weather	Occurs most or all of the time (dry weather)
Mainline Sewer Relief Connections (Unknown / Unauthorized Critical Regulator)	Intermittent, Wet Weather	Occurs over shorter / more limited time periods
Failed Critical Regulator	Transitory, Dry Weather	Occurs rarely and without predictable frequency

This report and the program recommendations herein are limited to these types of spills and unauthorized discharges. Other conditions that such as broken pipes, which may lead to contamination of soil and groundwater, are not discussed in this report but are expected to be identified on an ongoing basis through the City's current condition assessment inspection program.

3 Feasibility of Completing a City-Wide Detailed In-Pipe Inspection Program (MECP Order 5.1)

3.1 Approach

Stantec's interpretation of this task is to complete a feasibility analysis on the option to conduct a detailed in-pipe inspection program of the entire sewer network to find potential spills and unauthorized discharges, including CCTV camera inspection of every meter of sewer, as well as MH s and other structures. Under this scenario, any past inspections are assumed to be unusable as they were generally completed for other purposes (e.g. condition assessment or construction records), and not conducted with the intent of identifying all of the potential spill sources listed above under **Section 2**.

The feasibility analysis includes a high-level cost estimate and program duration. Program duration depends on the number of CCTV crews deployed simultaneously, which is highly variable and dependent on industry availability. As such, we evaluated the number of CCTV crews (and City staffing resources) required to complete the program within various time-frames (5-years, 10-years and 20-years). An assumption of how many additional CCTV crews the industry can support (further to other on-going inspection needs for construction, condition assessment and other) was made and used to evaluate the feasibility of each time-frame.

3.2 Inputs and Assumptions

This feasibility analysis is based on the following assumptions:

- Assumes every linear meter of City-owned sewer (min 150mm) will be inspected via CCTV camera.
- Assumes past inspections cannot be reviewed for this assessment and do not count towards the total length to inspect.
- Includes only the cost and time required to inspect the sewers. Cost and time to repair or correct any issues discovered will be extra.
- Cost per meter of sewer inspected is based on previous CCTV contract data from the Sewer Lateral Cross Connection (SLXC) Program and from capital projects, generally for condition assessment. The unit costs for condition assessment projects is much higher than for the SLXC program because they generally have larger, more complex sewers with higher flows, and require a greater level of cleaning and flushing. A weighted average was used to establish a cost that accounted for these differences.
- Assumes MHs inspected by City field staff while waiting for CCTV camera truck to set up. No additional time or cost assumed for this.

- Inspection speed was assumed based on past experience:
  - <750mm pipe: 800m/day
  - >750 to <=1200mm pipe: 600m/day
  - >1200mm pipe: 400m/day
- Program duration assumes that inspection can be completed on all available working days (weekdays less holidays), however a 20% increase to the program duration was added for delays due to inclement weather.
- Maximum number of additional CCTV crews available: 3
  - Assumed each of the 3 primary CCTV contractors in the area could recruit and assemble 1 additional crew if needed
- Assumes the following full-time employees (FTE’s) will be required for the program:
  - 1 manager to coordinate the program;
  - 1 field staff per CCTV crew to direct / review video on site (dedicated to a CCTV contractor crew)
  - 1 office staff per every 3 CCTV crews to review and log CCTV data and coordinate the crew’s progress
  - Staffing cost (including overhead, vehicles and equipment) is assumed to be $100,000 / year on average

3.3 Cost Analysis

Table 3-1: Detailed In-Pipe Inspection Cost Estimate

Sewer Size (mm)	Total length (m)	CCTV cost per m ($)	Total cost ($)
<=750	2,532,560	$ 10.50	$ 26,590,000
750 to 1200	320,851	$ 13.75	$ 4,410,000
>1200	226,826	$ 25.00	$ 5,670,000
		TOTAL COST	**$ 36,670,000**

The cost above is considered a low-end cost as it assumes ideal conditions (favorable weather, no traffic restrictions, no accessibility or visibility issues, etc.). Furthermore, we understand that a significant portion of sewers upstream of outfalls are submerged and/or influenced by Lake Ontario. These sewers would require more advanced inspection technology, such as underwater Remote Operated Vehicles (ROVs) equipped with sonar, that is much more expensive and time-consuming than traditional CCTV. Since the preliminary estimated cost figure is already impractically high under ideal conditions, it was not necessary to perform a detailed evaluation of the length of submerged pipes or add other costs for accessibility issues, poor weather, re-inspections (due to poor visibility), etc. We expect the actual cost to complete this inspection program to be at least 35% higher, **approaching $50M**.

The total estimated cost as shown in **Table 3-2** is broken down to show the estimated cost per area for each of the six community areas. This information will be included in the quantitative legend of the GIS figure maps in **Appendix A**, in addition to expected staffing costs and total cost with contingency.

Table 3-2: Detailed In-Pipe Inspection Cost Estimate Breakdown Per Area

Area	Cost Breakdown Per Area
Flamborough	$2,280,000
Dundas	$1,910,000
Ancaster	$3,250,000
Glanbrook	$1,965,000
Stoney Creek	$6,065,000
Hamilton	$21,200,000
Total	**$36,670,000**

3.4 Program Duration and Resource Requirements

Table 3-3 below presents the number of CCTV Contractor crews that would be required, performing continuous inspections simultaneously year-round (working days only), to complete the inspection program within various time-frames (5-years, 10-years and 20-years). The additional City staff required for each scenario is presented as well as the estimated cost for those resources.

Table 3-3: Contractor and City Resources Required to Complete Program in X Years

# of Years to Complete	CCTV Contractor Crews Required	Additional Full-Time City Staff Required	Total City Resource Cost
5	4	6	$ 3,200,000
10	2	4	$ 3,700,000
20	1	2	$ 4,700,000

As discussed in the assumptions and inputs section above, the duration of the program is limited by the number of excess full-time CCTV crews the local industry can supply. CCTV contractors must maintain adequate resources (trucks and staff) for other works, such as ongoing condition assessments, operational sewer maintenance work and construction verifications. For this analysis, it was assumed that each of the three main local CCTV contractors (PipeFlo, Pipetek, and Empipe), could each secure 1 additional CCTV crew for this special program (3 crews in total), which is a reasonable assumption. A fleet of three (3) CCTV crews could theoretically complete the inspections in 7 years, however this would require hiring an additional 5 full-time employees, which could be considered excessive. Based on this limitation, the program would be expected to take over 10 years using 2 CCTV crews in tandem and would require the hiring of 4 additional City staff members (at an estimated City resourcing cost upwards of $4M).

3.5 Discussion

Based on the analysis presented above, a City-wide in-pipe inspection program would be prohibitively expensive. Furthermore, to complete the program within a reasonable timeframe (under 10 years), it would require a significant number of additional full-time City staffing resources. These are low-end estimates and do not account for many of the challenges and limitations that will inevitably be encountered as the program progresses through the City's complex system.

Additionally, completing in-pipe camera inspections is not likely to provide the most benefit in identifying spills or unauthorized discharges, as the vast majority of these conditions are expected to occur at a maintenance hole (MH) or structure, aside from sewer lateral cross-connections, which would occur most commonly along smaller local sewers in separated areas. Unknown critical regulators would be discovered by first opening MH covers, while mainline sewer cross-connections are most likely to occur due to a sanitary or combined sewer being connected to the wrong MH (i.e. into a storm MH).

For these reasons, conducting a city-wide detailed in-pipe inspection program for the purposes of identifying unauthorized discharges is not recommended.

4 Feasibility of Completing a Risk-Based Inspection Program (MECP Order 5.2)

This section outlines the components of a programmatic approach and risk-based assessment methodology that is based on Industry Good Practices and deemed to be a feasible approach to address the risk of unauthorized discharges impacting water quality at CSO and storm drainage outfalls within the City of Hamilton. The framework for Industry Good Practices was compiled using the Illicit Discharge Detection and Elimination (IDDE) Manual by the US Environmental Protection Agency (EPA), as well as inquires to subject matter experts within Stantec's internal outreach throughout North America, and informal communications with various municipalities. It is important to note that the City has, in fact, been following many of these practices over the past 10 years since they have initiated a program to address cross-connections within their separated sewer system and have begun to focus their efforts within the combined sewer system with pilot area studies.

The City has currently implemented a number of programmatic initiatives that are designed to locate and address unauthorized discharges and spills within various areas of the City (discussed further within **Section 5**). In the second part of this section, we describe how the City's current programmatic elements will integrate within and follow the overall programmatic framework of a feasible risk-based approach. A new overall risk-based management program (SUDRIP) is presented along with recommended enhancements to the City's current inspection programs for the combined and separated system and anticipated resource requirements for managing all three.

Within **Section 5**, we provide a review of the City's other programmatic initiatives and compare them with each of the components of the recommended risk assessment-based framework with the purpose of evaluating their consistency with Industry Good Practice and identifying any gaps and/or opportunities for enhancements. Based on this assessment, recommended program enhancements and or additions are described along with terms of reference for their further development outside of the scope of this response to the MECP's order.

4.1 Industry Good Practices for a City-Wide and Risk-Assessment Based Inspection Program

Problem Description: Polluted stormwater drainage from outfalls with unauthorized discharges and spills can have a dramatic impact on receiving waters, and cause exceedances of water quality objectives and recreational use standards. The need for investigation of a drainage area tributary to an outfall exhibiting signs of pollution typically arises as a result of a recorded pollution incident, reporting from a member of the municipal/utility operating group, another agency, the public, or a developer.

Finding unknown sources of spills and unauthorized discharges is often described as trying to find a needle in a haystack on a limited budget. Monitoring and sampling are often assumed to be the most effective means of identifying sources but it is usually the most expensive component of any spills/unauthorized discharge program. It is therefore of key importance to understand the infrastructure and characterize the risk of various sources of pollution to then be strategic in the approach to investigating, detecting, and finding the combinations of sources that create the greatest risk for unauthorized discharges at each outfall location.

A Risk-Assessment Based approach to investigating and addressing unauthorized discharges and spills is consistent with the Industry Standard approach and provides a sustainable means of investing in the works necessary to mitigate the risk of measurable impacts to the community and the environment. A risk-based approach, informed by both a desktop risk assessment and screening-level investigations is first employed to develop a prioritized list of outfalls requiring detailed investigation along with the prioritized basin-specific action plans that are then deemed most effective for locating and removing the identified sources of pollution that impact the outfall and its receiving waters.

A Programmatic Approach: Every community will develop a unique spills control and unauthorized discharge detection program that reflects its environmental impacts, size and complexity, development history, land use, and legacy infrastructure types (combined, partially separated, previously combined systems that have been separated, or fully separated systems). Nevertheless, there are many commonalities between municipalities in the nature of the problem and in the methods that can be employed to understand its likely extent and potential impacts to then be able to feasibly locate and address the sources of unauthorized discharges having an impact. Recognizing these commonalities, the City of Hamilton has looked to Industry Good Practices to provide a basis to guide the development and implementation of an effective and well-managed spills management and unauthorized discharge elimination program.

This section describes a feasible programmatic and operational approach for investigation and resolution of systemwide pollution risks stemming from sewage systems affected by unauthorized discharges and spills to outfalls within both combined and separated sewer systems. This is an approach that is based on proven Good Practice guidance documents and methodologies followed by agencies in both North America and the UK in tackling this problem, which is common to most operational systems.

It is important to note that most of the guidance documents available within the industry are mainly focused on addressing unauthorized discharges to storm drainage systems within separated sewer systems and/or systems that were once served by combined sewer or septic systems but were subsequently converted to separated sewer systems. The detection of unauthorized sources of continuous discharges, and especially intermittent or transitory discharges, within combined sewer systems is complicated by the fact that relief sewers and combined sewer outfalls most often contain background concentrations of all the typical constituents that are used as indicators of pollutant sources from wastewater sources. While the good practice programmatic approach and the associated risk-based assessment methodologies are perfectly valid, the investigative strategies within separated and combined sewer systems will vary in accordance with the site-specific conditions.

Program Components: (Good Practices from Industry Guidelines) The key components of an unauthorized discharge removal and spills control program are described below.

1. **Problem Definition and Program Goals:** An understanding of the nature and impact of unauthorized discharges and spills in urban watersheds is essential in defining the extent of the problem and in setting realistic and sustainable goals to then be able to develop implementation strategies designed to find, fix, and prevent them. This must be established in context of regulatory requirements and measurable impacts to both the community and the environment. The implementation of the program and the timelines to meet the established goals at a system-wide level must consider the prioritization of efforts and the corresponding allocation of resources based on meeting the goals and deriving the greatest benefit in a manner that is affordable to the community and sustainable by the operating entity.

   The terms “unauthorized discharge” and “spills” can be interpreted to have many meanings within both the regulatory and operational context, which then extends to the definition of a broad range of potential sources of pollution. It is important that the terminology and the scope of the definitions be well defined to be able to classify those types of discharges that fall within the scope of the program and thus the control techniques that will be employed.

   The sources of unauthorized discharges and potential spills that fall within the context of this program are limited to direct cross-connections of sewage from the wastewater collection system to the storm drainage and/or combined sewer outfall system. The terminology describing the pertinent systems as well as the relevant types and modes of discharges and spill events that are pertinent to this order are defined in **Section 2.2** (incl. Terminology).

2. **Program Governance Structure** (Roles and Responsibilities, Support programs and integration)

   The development, implementation, and operation of a systemwide unauthorized discharge/spills control program will require consideration that the initiative may be managed as a distinct program and, at minimum, as an integral and specific component of the City’s operations. It also establishes the local legal authority to regulate unauthorizes discharges by third parties, either by amending an existing by-law or developing a new unauthorized discharge or spills by-law, if required.

   Critical to its successful implementation and operation is the establishment of a program governance structure that identifies and assigns both accountability and responsibility for each of the key roles that are necessary to lead and support the Planning, Implementation and Operation of a program. The planning, implementation, and operation of a systemwide program requires a multi-disciplinary team that possesses the diverse skills and knowledge needed for the program, ranging from legal analysis, GIS, monitoring, stakeholder management and pipe repairs. Implementation of the program requires on-going inter-divisional collaboration within the City’s water and wastewater operations department (Hamilton Water) as well as collaborations with other departments and external agencies.

3. **System Characterization:** For very large systems that include a variety of legacy system types, like the City of Hamilton, the level of inherent risk of cross-connections that result in continuous or intermittent discharges will vary considerably from one system type to another. Compared to newer separated sewer areas, older legacy systems such as combined sewers retrofit with storm relief sewers and/or having numerous flow regulating structures (both mechanically operated and static) inherently have an increased likelihood of having cross-connections or system failures that could lead to unauthorized discharges and/or spills. This includes the consideration of formerly combined areas that were subsequently separated though the addition of storm sewers as well as older partially separated areas where storm sewers were constructed to replace former ditch drainage.

   The characteristics of the drainage area to each outfall can, and is often, a key screening factor in prioritizing efforts at a systemwide level. It is therefore important to have access to mapping and data within GIS systems, maintenance management systems, system models, as well as system drawings that provide the ability to readily characterize and describe the connectivity of the systems tributary to each outfall in order to prioritize areas of focus within the system. This understanding can be further enhanced with access to system monitoring and operational data, historical records. and institutional knowledge.

   Similarly, it is important to consider that the effectiveness of various investigation strategies will vary considerably from one system type to the other and that system owners must be strategic in their approach in order to achieve their goals in a cost-effective and affordable manner.

4. **Strategic Risk-Based Prioritization Process:** When considering the programmatic structure at a systemwide level, it may be deemed preferable to structure distinct streams of work for combined and separated sewer system outfalls given that the inherent risks and investigation strategies for each will differ. **Figure 4-1** outlines the process by which a system-wide program can be feasibly managed by employing a risk-based prioritization and strategic source identification methodology. The process is designed to prioritize and focus efforts on outfalls at greatest risk of being impacted and by addressing those sources that have the potential for causing the greatest impact on those outfalls. The process described herein is applicable to various forms of combined and separated sewer systems and can be used to set priorities and applicable investigation strategies while recognizing these distinct differences.

   Table 4-1 Illustrates the relative risks of encountering various types of unauthorized discharges and/or spills within various system types. This depicts the rational and typical result that, compared to separated sewer systems, combined and previously combined sewer systems inherently possess a greater likelihood of having legacy cross-connections and/or flow control regulator malfunctions (e.g. failures, improper settings) that could result in continuous and/or intermittent unauthorized discharges. This high-level desk-top assessment would typically sway priorities towards the investigation of outfalls within combined, partially combined, and previously combined sewer system areas. While this may be the case, the process described herein provides the ability to also elevate priorities within separated sewer systems and/or shift priorities to other parts of the system when all reasonable efforts in a priority area have been suitably addressed. The key steps in the process are described as follows:

a. Outfall Risk Assessment and Prioritization

The first phase of the systemwide prioritization process consists of conducting a desktop risk assessment of unauthorized discharge and spills potential at each outfall in order to prioritize sub-catchment areas for further investigation. This can be assessed both holistically as well as further prioritized on the basis of system type (i.e. with distinct prioritization streams and investigation strategies for combined and separated sewer systems).

The desk-top assessment evaluates risk on the basis of understanding the sensitivity of the receiving water body, historical records, and the characteristics of the tributary sub-catchment area. It is also informed by conducting a field reconnaissance inventory at each outfall (and stream reach) where the objective is to confirm the geospatial location or identify undocumented outfalls, record basic characteristics of individual storm drain outfalls, evaluate suspect outfalls, and assess the severity of unauthorized discharge problems in each basin. In addition to observing visual evidence and scent indicators of unauthorized discharges or spills, water quality samples may be collected for analysis where unauthorized discharges are suspected or are likely to occur. Within combined sewer areas, sampling for the purposes of source detection is only recommended for storm relief sewers discharging separately from CSO outfalls or at CSO outfalls where significant amounts of continuous discharge is observed under dry conditions.

The order in which the field inventories are conducted can be prioritized on the basis of the initial desk-top risk assessment. The results of the field inventory are subsequently factored into the outfall risk assessment that will then inform the prioritization of tributary areas for further investigation.

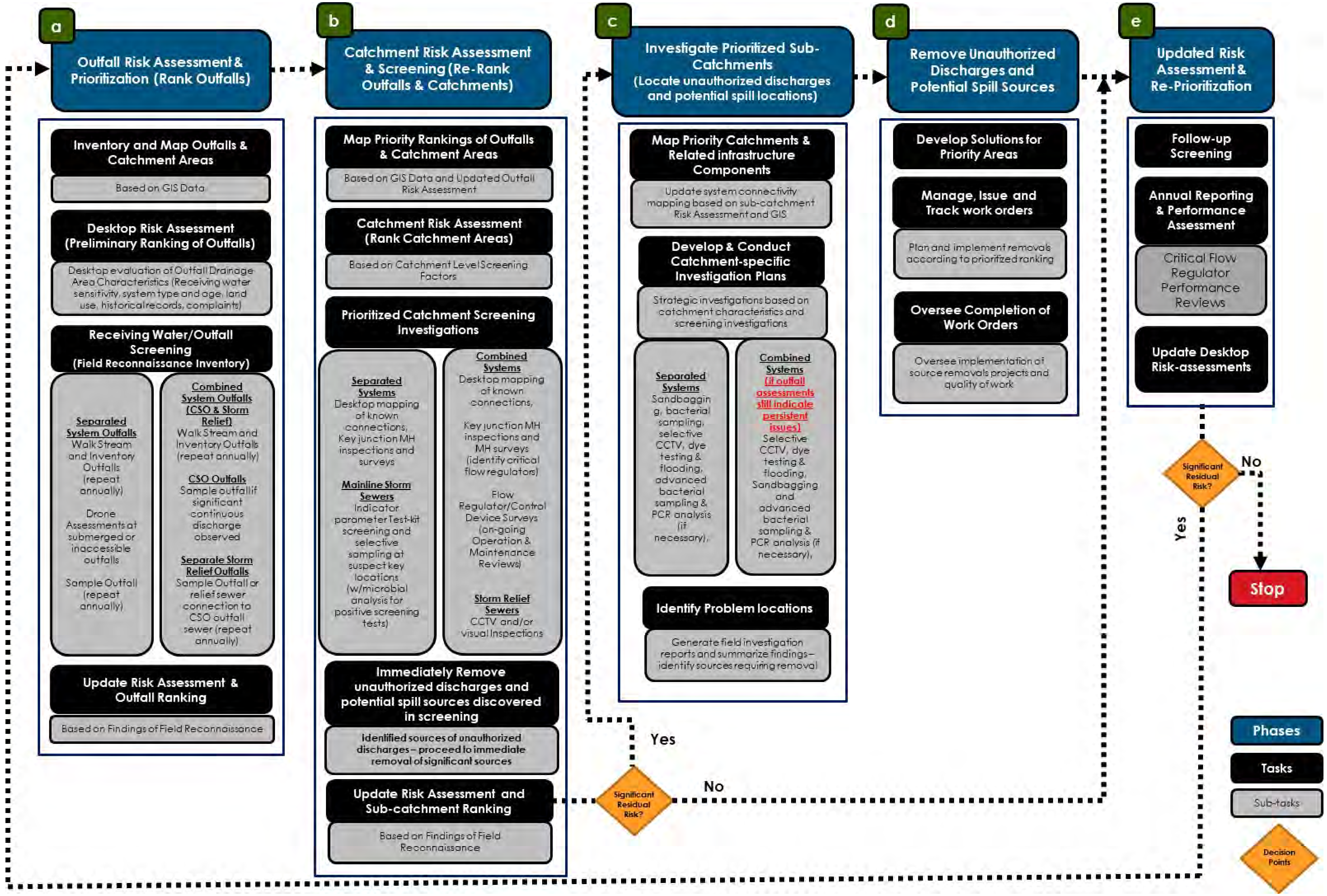


Figure 4-1: Systemwide Risk-based Prioritization and Source Investigation/Removal Methodology

Table 4-1: Illustrative Example of Inherent Relative Risks of Unauthorized Discharges and/or Spills in Various System Types

		System Level Risks														
		Combined Sewer System Outfalls						Storm Sewer Outfalls								
		Combined Sewers Only			Partially Combined with Storm Relief Sewers			Previously Combined but Subsequently Separated			Partially Separated Sewers (older ditched systems with piped storm drainage added)			Separated Sewer System (constructed with separate sanitary and storm sewers)		
Type	Description	Likelihood	Impact	Risk	Likelihood	Impact	Risk	Likelihood	Impact	Risk	Likelihood	Impact	Risk	Likelihood	Impact	Risk
1	Mainline Sewer Cross- Connection (Continuous Discharge)	L	H	LH	M	H	MH	M	H	MH	L	H	LH	L	M	LM
2	Sewer Lateral Cross-Connection (Continuous Discharge)	L	M	LM	L	M	LM	L	H	LH	L	H	LH	L	H	LH
3	Mainline Sewer Relief Connection / Unknown or Unauthorized Critical Regulator (Intermittent Spill)	M	M	MM	M	M	MM	L	M	LM	L	M	LM	L	M	LM
4	Critical Flow Regulator Malfunction (Transitory Spill)	M	H	MH	M	H	MH	L	M	LM	L	M	LM	L	M	LM

Likelihood of: Having unknown sources based on legacy system
Impact of: Degrading receiving water quality and/or environment based on the frequency and relative magnitude of the discharge

Table 4-2 lists typical screening factors used in the outfall risk assessment. For each of the screening indicators, the table also provides a perspective on typical level of risk by indicating the relative likelihood of finding issues and sources within various classifications of sub-catchment types. It must be noted that this is indicative of typical findings and what may be expected from the perspective of program implementation planning. However, each system is unique and there will be exceptions.

Table 4-2: Typical Screening Factors for Outfall Risk Assessment and Prioritization

Screening Factors	Combined and Partially Combined Sewer Systems		Separated Sewer Systems		
	CSO Outfalls	Storm Relief Outfalls	Formerly Combined Outfalls	Partially Separated Outfalls	Separated Storm Outfalls
Desk-top Risk Assessment Impact Factors					
Sensitivity of Receiving Water at Outlet (ecological & habitat classification or biological stream indicators, recreational value/use)	Site dependent impact	Site dependent impact	Site dependent impact	Site dependent impact	Site dependent impact
Desk-top Risk Assessment Likelihood Factors					
Outfall & Tributary Area	**Relative Likelihood of Finding Issues and Sources (typical)**				
Past Discharge Complaints and Reports	H	H	H	M	L
Prevalent Type of Sewer System	H	H	H	M	L
Historical and Current Configuration of Tributary System	H	H	M	M	L
Age and General Condition of Tributary Sewer System	H	H	H	M	L
Prevalence of Critical Flow Regulating Structures in Tributary Area	H	H	M	L	L
Post Site Reconnaissance Risk Assessment Likelihood Factors					
Observed Water Quality at and in the vicinity of the Outfall (flow, odor, color, or visual indicators)	Site specific findings	Site specific findings	Site specific findings	Site specific findings	Site specific findings
Sampled Dry Weather Water Quality at Outfall	Site specific findings	Site specific findings	Site specific findings	Site specific findings	Site specific findings
Temperature Zones	H	M	L	L	L

b. Catchment Risk Assessment and Screening:

Upon developing a prioritized list of outfalls, the focus of the risk assessment is then expanded to conducting a more in-depth assessment of the prioritized area's tributary sub-catchment characteristics along with strategic in-system investigations that are designed to isolate likely problem areas and/or locate the largest sources. This is designed to cost-effectively identify locations within the collection system where there is a higher potential for encountering unauthorized discharges or spills and, where necessary, will prioritize more expensive follow-up investigations to further isolate and locate the remaining sources.

As depicted in **Figure 4-1**, typical investigations at this stage will include inspections of all flow control/regulating structures, inspections of all key junction chambers and documented connections, as well as in-pipe investigations in those areas of elevated potential of finding sources. For storm sewers/drains within separated or partially separated areas, these follow-up investigations typically include in-field water quality sampling with test kits during dry weather conditions for detection of possible contamination along with the collection of samples for microbial analysis where the test kits indicate a high likelihood of contamination.

Within combined sewer catchments, the screening level in-field water quality testing and sampling methods are not reliable or effective given the high likelihood of contamination from background concentrations of the typical indicator constituents. Indicative sampling efforts should be limited to upstream reaches of storm relief sewers where there are no known relief connections/diversions from the combined sewer system and where the storm relief sewer does not connect back into the combined sewer upstream of a flow regulating structure. Flow regulator inspection, junction chamber inspections, and CCTV inspections within the storm relief and the CSO outfall sewers downstream of any flow control structure provides a more effective means of identifying cross-connections and unauthorized discharges within the combined sewer system.

Any cross-connections identified during the sub-catchment screening process will proceed immediately to the development and implementation of solutions for removal. Upon completion of all screening level investigations and where it can be demonstrated that completed removals have likely addressed the identified issues, the work within that sub-catchment can be considered complete and proceed to on-going maintenance and operational conditions monitoring. Where the screening level investigations result in the identification of highly likely or other potential sources needing further investigation, the process will continue with the development and implementation of catchment specific investigation plans.

c. Prioritized Sub-Catchment Strategic Investigations

The screening level in-system investigations in the previous step will either have identified the problem sources of discharges and spills and/or helped isolate the location and likely sources. This next step consists of developing sub-catchment specific investigation plans and implementing more focused and potentially more advanced investigative techniques to confirm and locate sources for subsequent removal. **Table 4-3** provides an overview of the recommended investigation techniques designed to locate various potential sources of discharge or spill potential at each stage of the investigations process.

Table 4-3: Recommended Sub-Catchment Investigation Strategies for Various Sources of Discharge or Spill Potential to Priority Outfalls

		Recommended Sub-Catchment Investigation Strategies for Priority Outfalls	
Description of Sources	**Stages of In-System Investigation**	**Combined and Partially Combined Sewer Systems**	**Separated Sewer Systems**
Type 1: Mainline Sewer Cross-Connection (Continuous)	Initial Source Isolation Investigations	1) Desktop screening & assessment of system connectivity 2) Junction Chamber Inspections 3) MH Inspections within storm-relief sub-catchments 4) CCTV of storm relief sewers & tracking of connections (prioritize storm relief sewers discharging directly to outfalls)	1) Desktop screening & assessment of system connectivity 2) Junction Chamber and MH Inspections (with Test-kit sampling and sandbagging where required)
	Targeted Follow-up Investigations	1) Complete CCTV of storm relief sewers & tracking of connections (storm relief sewers re-connecting to combined sewer U/S of flow control chamber) 2) Complete MH inspections in priority sub-catchments (survey connections) <u>If necessary:</u> 1) Follow-up microbial and human waste indicator (e.g. caffeine) sampling (with sandbagging where required) 2) CCTV of adjacent mainline combined sewer and tracing of connections (if necessary) 3) Follow-up Dye Testing and tracing of sources (where CCTV is inconclusive) 4) Advanced microbial sampling and genetic tracing (where sampling results are inconclusive)	1) Follow-up microbial and human waste indicator (e.g. caffeine) sampling (with sandbagging where required) 2) CCTV of isolated storm sewer sections and tracing of connections (where testing results are conclusive) 3) CCTV of adjacent mainline sanitary sewer and tracing of connections (if necessary) 4) Follow-up Dye Testing and tracing of sources (where CCTV is inconclusive) 5) Advanced microbial sampling and genetic tracing (where sampling results are inconclusive)

		Recommended Sub-Catchment Investigation Strategies for Priority Outfalls	
Description of Sources	**Stages of In-System Investigation**	**Combined and Partially Combined Sewer Systems**	**Separated Sewer Systems**
Type 2: Sewer Lateral Cross-Connection (Continuous)	Initial Source Isolation Investigations	Same as Type 1 above	Same as Type 1 above
	Targeted Follow-up Investigations	1) Where outfall or storm relief sampling (if deemed necessary) indicates contamination and minimal to no continuous flow observed during DWF, use sandbagging to capture and sample for possible lateral cross connections 2) Where positive result recorded, follow same procedures as Type 1 above	1) Where outfall sampling indicates contamination and minimal to no continuous flow observed during DWF, use sandbagging to capture and sample for possible lateral cross connections 2) Where positive result recorded, follow same procedures as Type 1 above
Type 3: Mainline Sewer Relief Connection (Intermittent)	Initial Source Isolation Investigations	Same as above	Same as Type 1 above
	Targeted Follow-up Investigations	Same as above	1) Where outfall sampling indicates contamination and no continuous flow observed during DWF, use sandbagging to capture and sample for possible spills 2) Where positive result recorded, follow same procedures as Type 1 above
Type 4: Critical Flow Regulator Malfunction (Transitory)	Initial Source Isolation Investigations	1) Desktop screening & assessment of system connectivity 2) Critical Flow Regulator inventories, surveys and operational reviews 3) Junction Chamber Inspections 4) MH Inspections within storm-relief sub-catchments 5) CCTV of storm relief sewers	1) Desktop screening & assessment of system connectivity If necessary 2) Critical Flow Regulator inventories, surveys and operational reviews (if high level relief to storm is present)
	Targeted Follow-up Investigations	Monitoring and/or regular inspection (depending on risk of malfunction)	If critical regulators are present in the system 1) Monitoring and/or regular inspection (depending on risk of malfunction)

d. Prioritized Source Removals

Once a source of unauthorized discharge or potential spill has been identified, steps should be taken to fix or eliminate the discharge as soon as possible. Sources of discharges or spills will either be on the publicly owned and operated system or located on private property. Sources located on the public system fall under the jurisdiction of the system owner and can thus be readily addressed using public funds. Access to investigate and then remove sources on private can be challenging, costly, and require significant time and resources to complete. Some of the greatest challenges to removing sources from private property are not technical; rather, they are related to legal and policy issues, enforcement of by-laws, engaging the property owner in the program through education, and establishing equitable means of funding of private side remedial measures. **Figure 4-2** provides an example decision-making process for removing or correcting unauthorized discharges and is based on a similar graphic provided in the USEPA's Illicit Discharge Detection and Elimination (IDDE) Guidance Manual for Program Development and Technical Assessments (2004).

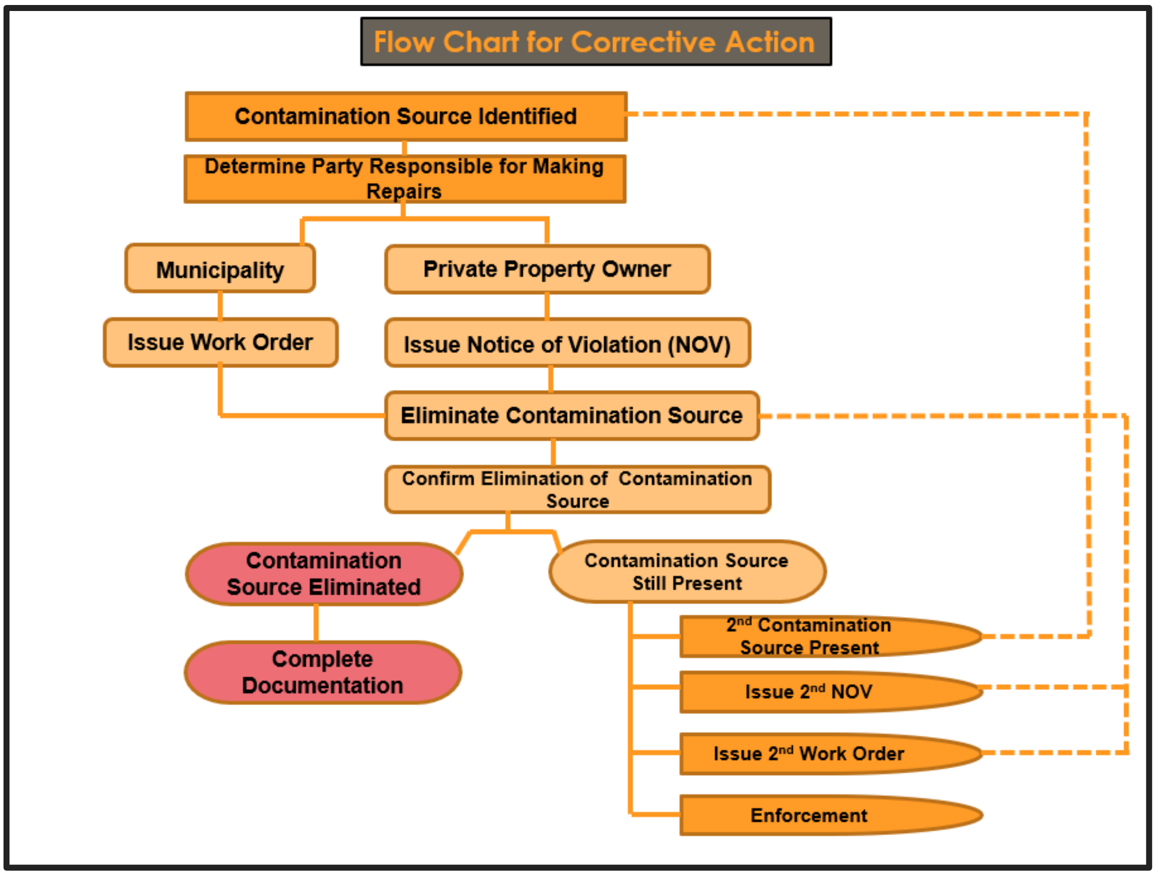


Figure 4-2: Example Decision-making Process for Removing or Correcting Unauthorized Discharges or Sources of Potential Spills (adapted from USEPA IDDE Guidance Manual 2004)

e. Re-assessment and Re-prioritization

After a few years of analysis and field surveys, communities get a good handle on the actual severity and residual risk of their unauthorized discharge problems. In some communities, outfalls and storm drains will be relatively clean, whereas others may have persistent problems. Effective and sustainable programs are flexible and adaptive, and shift program resources to the management measure that will reduce the greatest amount of pollution where it has the most benefit to the community and the environment.

5. **Program Management Tools (For Future Consideration):** An effectively managed unauthorized discharge and spills control program requires effective data management and reporting tools to be able to monitor and track progress on the program, log all program findings, as well as facilitate the reporting on the overall performance for the purposes of both compliance reporting, decision-making on priorities and work plans, along with justifying recommendations on priorities, program revisions, and adaptation strategies (as required). The City currently utilizes a number of internal document management and work order tracking tools for data management. For consideration in the future, the City may wish to explore the creation of an integrated tracking system for the overall program that consolidates these items into a consistent platform.

   Within the industry, more and more water utilities and municipalities are leveraging digital technologies to deliver better outcomes in a timely manner through better decision-making processes that are informed by better access to better data. The technological advances in cloud computing and communications, coupled with analytic capabilities, are enabling system owners to better use the data they already have as well as plan and execute new ways of collecting data that lead to improving the efficiency of their programs and operations. The ideal tracking system consists of a web-based portal that provides an interactive window to a relational database (on-premise or cloud-based) that is linked to a GIS system, which can be used to ingest, store, and analyze data from multiple sources and produce maps. Through cloud-based data collection and data management platforms, field collected observations and data collected by system operators can be accessed and/or input directly to the program's supporting databases. The web-portal can also integrate or link to the risk assessment framework tools that document the risk evaluation process and decisions on priorities that are made therein.

6. **Resources** (Staff and budget) Most programs are challenged by having sufficient resources to perform the amount of investigation and remediation work necessary to fully eliminate all sources of continuous, indirect, and transitory discharges in their community. Consequently, effective programs target their discharges of greatest concern, with continuous discharge sources as a priority, and spend their scarce dollars in the outfall and catchment areas, neighbourhoods or business sectors most likely to generate them.

4.2 Feasibility and Recommendations for Implementing a City-Wide and Risk-Assessment Based Inspection Program

As discussed under **Section 5**, the City already accomplishes the majority of the elements discussed in the above framework for risk-assessment based inspections. These elements are covered effectively and thoroughly by activities completed within a variety of ongoing City programs (refer to **Table 5-2** for summary). While there appears to be effective communication between the programs, they each operate and report individually on the type of spill or unauthorized discharge source that the program is designed to uncover. There appears to be a need for a centralized task-force overseeing inspection and information on the City's collection system as it relates to potential spills and unauthorized discharges.

It is therefore recommended that the City implement a new overall risk-assessment based program using the framework described above. This new program (referred to herein as the System-wide Unauthorized Discharge Removal and Inspection Program, aka SUDRIP) will be used to inform and serve as an information hub between individual inspection programs. This will take shape over a number of years as the City continues to investigate its collection systems in detail and evaluates its ongoing needs for inspections. As such, it is difficult to define the long-term requirements for SUDRIP, however, a reasonable place to start is to establish the new program mandate and use it to propose expansions and potential refocusing of the City's current Sewer Lateral Cross-Connection Program and the Risk-Based Proactive Pilot Program.

Expansion and completion of these programs will serve as the initial inspection activities for the separated system and the combined system, respectively. The outfall and sub-catchment prioritization process has already been completed by the City while developing and executing these programs. When these expanded programs are complete, the City can re-initiate the outfall and sub-catchment prioritization phase and determine the next steps for the overall program. This initial conception of SUDRIP is described and evaluated in this section for the purposes for completing a feasibility analysis in response to MECP Order Item #5.2.

The other purposes of SUDRIP will be to serve as a hub for the City's various departments and their ongoing activities on the collection system to share information and maintain a common objective of identifying and correcting potential sources of spills and unauthorized discharges. Several other ongoing City programs and activities will continue to exist outside of SUDRIP but should develop a formal communication protocol and consider using feedback from one-another to incorporate potential sources of spills and unauthorized discharges into their prioritization methodology and budgetary planning. This includes, but may not be limited to:

1. Regulator inspections;
2. Sewer condition assessments;
3. Operational sewer maintenance; and
4. Construction pre- and post- inspection procedures.

4.2.1 COMBINED SYSTEM INSPECTION PROGRAM

The City has a number of current programs and activities that may be useful in identifying sources of spills and unauthorized discharges within the combined system, including those listed above. Aside from the routine regulator inspections, which are essential to help prevent spills from failure of a known regulator, these other programs and activities generally have other primary objectives than identifying spills and unauthorized discharges, though they can be useful to that end. Prior to 2022, there was not a program in place that specifically targeted potential mainline sewer cross-connections or the discovery of unknown regulators / mainline relief connections (refer to **Section 5.3** for a summary and gap analysis of which current City programs are designed to target various sources of spills and unauthorized discharges).

This missing link is now being addressed as the City has undertaken a Risk-Based Proactive Pilot Program (aka The Pilot Program) in response to issues that were discovered in 2022. The Pilot Program objective is to locate and identify other spills due to mainline sewer cross connections, specifically within the combined sewer area. The Pilot Program has focused primarily in the combined sewer area along the flow paths of the following four “critical subcatchments” for: Wentworth, Birch, Ottawa, and Kenilworth outfalls. The methodology of this program revolves around MH structure inspections along the critical flow paths (i.e. subcatchments to the four critical outfalls) to identify potential mainline cross-connections. Note that these particular subcatchments are considered “critical” because any sanitary sewage that enters these sewer sub-networks will ultimately flow into the Hamilton Harbour. Further details on the Pilot Program are provided in **Section 5**.

To date, the Pilot Program has completed inspections on all MHs on storm sewers that are 600mm in diameter or smaller within the four critical flow paths, as well as any combined sewer MHs directly adjacent to these. This program has been very effective to date, having identified several mainline cross-connections and unknown regulator structures and gained valuable knowledge on where in the combed sewer area these structures may exist. In addition to expanding the Pilot Program to inspect all remaining MHs within the critical storm catchments areas, as per **Table 4-3** it is also recommended that the City complete CCTV videoing of the entire storm sewer network within these critical areas to complement the chamber inspections. The purpose of the CCTV inspections within these critical areas will be to provide a robust, thorough review of these areas to minimize the chance of a missed cross connection. The CCTV reports along with the City’s MH inspection reports should be combined into an overall summary report prepared by the City that will summarize the results of the investigation, number of issues identified, and remedial plans or actions taken.

In addition to completing inspections on the larger MHs and CCTV video along the critical flow paths (222 MHs outstanding), we recommend that this program be expanded in the future to cover more outfall subcatchments within the combined sewer area. Most of the other outfalls in the combined system are configured such that any unexpected upstream dry weather flow is directed to the treatment facility (these outfalls generally serve as wet weather relief points). However, in combined sewer areas identified for future sewer separation projects, it would be prudent during the planning and engineering phases of these projects to proactively search for and identify unknown cross connections and regulators within the target subcatchment areas, so that future separation of the combined system does not result in unintended dry weather spills or discharges. This phase of the program in the combined sewer area would be considered low priority and can be re-assessed in the future after the investigations into the higher priority areas are completed.

Some potential improvements to the Pilot Program methodology could also be considered as it progresses towards inspecting larger diameter storm sewer MHs (i.e. on sewers greater than 600mm) within the critical flow path, and potentially into other geographic areas. These improvements incorporate some observations from the Gap Analysis discussed in **Section 5** and some additional inspection methodologies available as discussed in **Section 6**. Some potential improvements that will be considered for completion and expansion of the Pilot Program, include the following:

- Formalize documentation procedures:
    - Prepare standard data collection forms / templates;
    - Standardize methods of identifying & recording discrepancies from GIS / as-built records.
- Consider zoom-camera to confirm pipe alignments / flows / potential inflow within pipe span;
- Complete storm MH inspections during dry weather only to better identify unexpected flows;
- Complete newly found regulator inspections during wet weather to evaluate regulator behavior; and
- Conduct sampling and testing of any dry weather flow observed from storm sewers.

4.2.2 SEPARATED SYSTEM INSPECTION PROGRAM

The City's separated sewer area is unlikely to have many (if any) mainline cross-connections and by definition, will not have any regulators. The primary expected source of spills and unauthorized discharges (at least of those that can be easily identified through inspection) in these areas is cross-connections of sanitary sewer laterals into stormwater sewers. To identify and correct these issues, the City has a Sewer Lateral Cross Connection (SLXC) Program that has been ongoing since 2009. The program has evolved to become very robust and effective over the years. The inspection methodology is MH-to-MH CCTV of all local sewers within the separated area where outfall sample results indicate the possibility of cross connections. The program is limited to the separated area as lateral cross-connections are much less likely within the combined area. When residences in the combined area were originally constructed, they would have only had one sewer lateral into the combined sewer system. Storm sewer trunks that were later installed were most likely only capturing roadway runoff and included only leads from catch basins or ditch inlets (i.e., not modifying the existing laterals to the combined sewers).

To prioritize subcatchments, the outfalls are sampled and tested for E. Coli and caffeine, used as human waste indicators. To date, the SLXC program has inspected approximately 75% of the City's separated sewer areas, expecting to be complete the remaining 25% by 2025 (first round inspections of the separated system). Further details on the SLXC Program are provided in **Section 5**.

As the CCTV inspections for this program approaches full coverage of the separated sewer area, it is recommended that the City promptly complete follow-up sampling and testing of the outfalls (and select MHs within the subcatchments) as a means to verify that issues have been corrected. This activity would serve as the “Follow-Up Screening” step in the “Updated Risk Assessment and Re-Prioritization” phase of the process outlined in **Figure 4-1**. This will inform decision-making on the need to re-inspect areas for cross-connections that were missed or other types of spill and unauthorized discharge sources that may not have been expected in these areas.

4.2.3 RESOURCES AND TIMING

Overall Program (SUDRIP):

Since creation and implementation of SUDRIP is primarily a management and administrative assignment, this is expected to require office staff only. We believe this could reasonably be managed by one full-time employee (FTE) and 50% time support from a junior staff or co-op student. The initial focus of the program could be to implement more robust communication protocols between other programs, as they relate to identifying and correcting sources of spills and unauthorized discharges, and to recommend and oversee expansion of the combined sewer and separated sewer inspection programs described above. The FTE’s responsibilities would be expected to evolve over time.

Combined System:

The continuation of the Risk-Based Proactive Pilot Program is assumed to require completely new staff (as the original push was conducted exclusively during overtime hours). The first leg of this program involves completing inspections on the larger storm MHs and adjacent combined MHs along the four critical flow paths (222 storm MHs, and an estimated 186 adjacent combined MHs based on previous ratio of storm vs combined MH inspection: 0.84).

The secondary (and more extensive) expansion of this program will be to conduct inspections on all the remaining storm MHs and adjacent combined MHs within other outfall catchments in the combined sewer area (approximately 2,874 storm MHs and an estimated 2,414 adjacent combined MHs). However, as described previously, since these storm catchment areas typically have downstream control structures in place to keep flows within the combined sewer network and flowing to the WWTP during dry weather conditions, we would recommend the City initially prioritize areas that are identified for future sewer separation projects. In addition, the City will be able to leverage the knowledge gained through MH investigations and sampling work in the four critical flow path areas, to help inform and improve the MH inspection approach the remainder of the combined sewer area moving forward.

Information from the City on the Pilot Program to date suggests that one crew of 2 field staff can generally inspect 1 MH per hour on the smaller sewers. This number should be expected to increase for larger sewers, especially as many of them may require confined space entry. A more reasonable estimate for larger MHs (on sewers > 600mm diameter) may be 2hr per MH, with a blended rate of 1.5hr per MH for the remaining outfall catchments. The following table outlines the remaining requirements and expected duration. The number of years assumes crews are working 8 hours in the field per day for an average of

200 days per year (250 working days accounting for inclement weather, vacation, sick days and office requirements).

Table 4-4: MH Inspections and Estimated Durations for Expanded Pilot Program

	Storm MHs	Combined MHs (estimated)	Total Hours	Estimated Years (1 crew)	Estimated Years (2 crews)
Larger MHs on critical flow paths	222	186	816	0.5	0.25
Remaining MHs in combined sewer area	2,874	2,414	7,932	5	2.5

As shown in the table above, it would take approximately 5 years for a single crew to complete the MH inspections within the combined sewer area.

<u>Separated System:</u>

The SLXC Program is currently expected to complete its first round of inspections in 2025. The City staff and CCTV contractor costs required to complete this is assumed to be already budgeted and available to the City. An added cost for sampling and testing is assumed for completing follow-up outfall sampling at a similar rate as in recent years ($40,000/year based on 70 locations every 2 years, 3 samples per location). CCTV Contractor costs for any re-inspection will be extra to this, but we recommend that some of the budget and resources available after the completion of the first round of the SLXC program in 2025 be retained for re-inspecting subcatchments that have persisting indicators and for repairing new issues where necessary. Ultimately this program is expected to evolve and subside as more issues are identified and corrected.

<u>Summary:</u>

Table 4-5 below provides a summary of the resourcing needs as a high level annual budget to complete the program expansions outlined above and to implement the new overall program.

Table 4-5: Summary of New and Expanded Program Resource Requirements and Interim Completion Dates

<table>
<tr><th></th><th>Overall Program Management</th><th>Combined System Program</th><th>Separated System Program</th></tr>
<tr><td>Description of Needs</td><td>Establish and oversee new program, including reporting and ongoing improvements</td><td>Complete remaining storm / adjacent combined MH inspections within combined sewer area</td><td>Begin follow-up screening of previously inspected outfalls / subcatchments</td></tr>
<tr><td>Additional Staff Requirements (FTEs)</td><td>1 Program Manager FTE</td><td colspan="2">3 WW Collection Staff FTEs shared among programs</td></tr>
<tr><td>Additional Support Staff</td><td>0.5 Co-op / Junior Staff</td><td colspan="2">1.5 Co-op / Junior Staff</td></tr>
<tr><td>Estimated Additional City Staffing Costs</td><td>$110,000 / yr</td><td colspan="2">$310,000 / yr</td></tr>
<tr><td>CCTV Contractor Costs (in addition to current budget)</td><td>N/A</td><td>$100,000 / yr</td><td>$40,000 / yr</td></tr>
<tr><td>Additional Sampling and Analytical Costs (in addition to current budget)</td><td>N/A</td><td>$20,000 / yr</td><td>$20,000 / yr</td></tr>
<tr><td>Interim Completion Date</td><td>On-Going</td><td>2028-2029</td><td>On-going</td></tr>
</table>

It is understood that the City is anticipating spending approximately $250,000 annually on CCTV and $40,000 annually on sampling to support the existing SLXC program. The additional resourcing needs provided in **Table 4-5** are in addition to the City's existing continuing programs, such as their SLXC program needs.

In summary, and to support the additional resourcing in **Table 4-5**, we expect the City would need to **hire or reassign an additional 4 full-time employees and 2 junior engineers or co-op students** to carry out the new and expanded inspection programs described in this section, at an estimated annual program cost of **$600,000 / year**, in addition to current budgets for the existing programs.

5 Gap Analysis of City’s Current Programs, Procedures & Measures (MECP Order 5.3)

The existing programs that are currently implemented by the City of Hamilton that pertain to identifying the previously noted potential sources of spills and unauthorized discharges are described below within the context of geographic coverage, methodology, potential to miss spills/unauthorized discharges, progress to date, and execution speed / inspection frequency. As per the outlined framework above, these key programs will then be evaluated against the components of the Industry Good Practice Framework to develop the Gap Analysis.

A second component of the Gap Analysis, which is presented later in this section, is to review the collection of current programs and their potential for identifying each of the potential sources of spills or unauthorized discharges. This will provide a clearer understanding of which of these sources are well-covered under current or future initiatives and which the City should dedicate more resources towards tracing.

5.1 Summary of Current Programs and Initiatives

The following four (4) existing programs have been identified for review and evaluation based on their relevance in identifying/remediating the potential spills and unauthorized discharges as characterized in Section 2.2. As such, the work contained within these programs will be considered as the primary source of contribution to the City’s existing approach in the Gap Analysis in **Section 5.2**. Other routine City sewer works, such as sewer condition assessments, operational sewer maintenance and pre/post construction inspections, also provide incidental identification opportunities. Updates have been made to the standard procedures for these activities to notify the wastewater team and in the future, the SUDRIP program manager.

5.1.1 RISK-BASED PROACTIVE PILOT PROGRAM

Prior to the issuance of the MECP Order, the City of Hamilton initiated a Risk-Based Proactive Sewer Inspection Pilot Program to locate and identify other spills, specifically due to mainline sewer cross-connections. This section provides a description and evaluation of the City’s current pilot program and recommends improvements to the program before analyzing the feasibility of expanding it across a larger area of the City.

5.1.1.1 Geographic Coverage and Prioritization

The Pilot Program is focused within the combined sewer area of the City, specifically along the flow paths (upstream sewer catchments) of four critical outfalls: Wentworth, Birch, Ottawa and Kenilworth (see **Figure 5-2** for CSO point locations and these critical flow paths). Any dry weather flow that enters these upstream catchments will discharge directly to the Hamilton Harbour. Therefore, these four outfalls were identified by City staff as the most vulnerable to cross-connections (i.e., having the greatest likelihood of an upstream cross-connection resulting in an environmental spill). Conversely, many other storm sewers within the combined system serve as storm relief sewers and end up discharging back into the collection system during dry weather where all flow is directed to the Woodward Wastewater Treatment Plant.

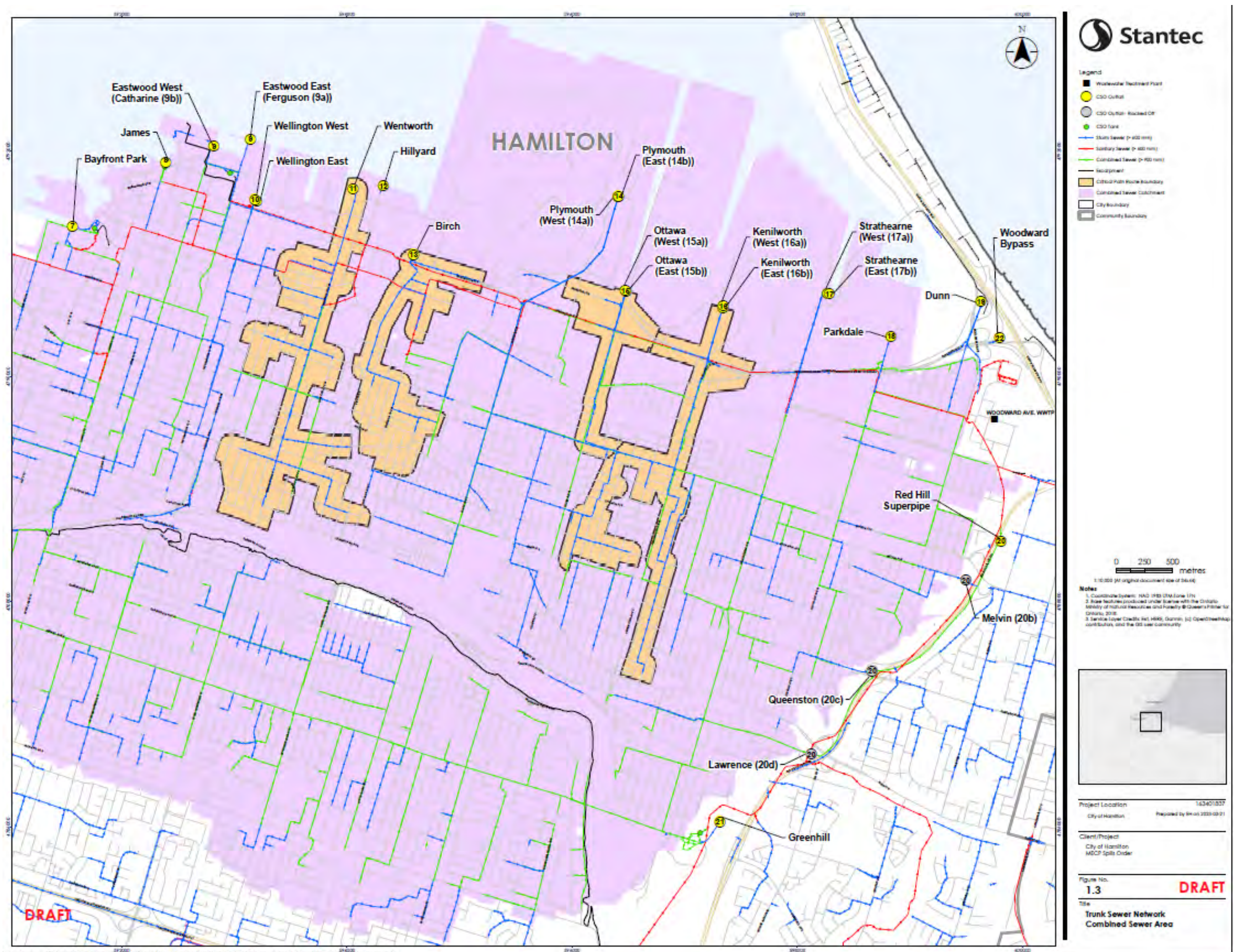


Figure 5-1: Flow Paths for Critical CSO Outfalls

The program is being conducted using City staff only and consists of MH structure inspections along these critical flow paths. As noted above, mainline cross-connections are unlikely to occur along a pipe span as connections of larger pipes (tees, wyes, crosses, etc.) are almost always done at a structure with an access point. All storm sewer MHs along the flow paths are being inspected, as well as any adjacent combined sewer MHs that are within a few meters of the main storm MH's. Only MHs on smaller diameter storm sewers (up to 600mm) along the critical flowpaths are inspected for the pilot program, while there is no restriction on the size of adjacent combined sewer MHs.

5.1.1.2 Inspection Methodology

Before entering the field, City staff review the City’s sewer network GIS data and any available as-built drawings on record for the structures to determine expected sewer sizes, types, alignments and number of connections. The storm MH structure inspections are generally completed from surface - hence why only smaller MHs were inspected as the larger sewers are generally deeper and darker, having higher flows and are likely to have intermediary structures such as staged landings. City field staff remove the MH covers and look into the structure to confirm the number of connections to compare with the expectations from GIS and drawings. Approximate sizes and alignments of the connections are also verified. Any signs of live flow in a storm sewer (which is not expected during dry weather conditions) is noted, as well as any other indications of sanitary or combined sewage, such as strong sewage smells or staining. Inspections are completed during all weather conditions, on weekends during daytime hours. No samples of flow are taken for analysis and no video recording or person-entry into the structure is performed.

For the often-larger combined sewer MHs, City field staff completed a video inspection of the MH after visually inspecting. A Go-Pro camera is lowered into the MH using an extendable pole. Video is reviewed in real-time on site to record information and determine whether further inspection is required before proceeding to the next MH location. The video inspection of the combined sewer MHs is also used to find regulators (if present). If visibility is compromised due to depth, darkness or live flow, a follow-up person-entry inspection is performed at a later date. Videos are later reviewed in further detail in the office.

5.1.1.3 Results

A total of 346 storm sewer MHs and 292 adjacent combined sewer MHs have been inspected. During these inspections, nine (9) previously unknown critical regulators were identified, which have the potential to discharge to the environment during rainfalls events. These discharges would be considered unauthorized as the unknown regulators are not currently covered under an Environmental Compliance Approval issued by the MECP. These were added to the City’s regulator database and will be incorporated into the biannual regulator inspection program. Additionally, three (3) previously undocumented mainline sewer cross-connections were discovered. These were subsequently repaired.

With these findings, the Pilot Program has been quite effective to date. The methods used and areas targeted in this in this Pilot Program can be considered the start of a subcatchment-specific investigation of the City’s combined system that can be effective in identifying spills and unauthorized discharges within the combined sewer area. This program should be adopted under the new overall Risk-Assessment Based framework (the SUDRIP program) as it is progressed and expanded. Recommendations for expansion of this program, along with a feasibility analysis of such, is provided in the following section. Although it cannot be confirmed whether any cross-connections or other potential spill sources may have been missed within the program area, we believe that these are unlikely as the program focused on smaller diameter sewers with MH’s that are generally visible from surface.

5.1.2 SEWER LATERAL CROSS CONNECTION PROGRAM (SLXC)

Between 2001 and 2009, Hamilton Water's Public Works department completed investigations to identify storm sewer outfalls of concern and to isolate sources of E. coli contamination based on the Ministry of Environment's Orders regarding the unauthorized discharge of E. coli contaminated storm water. It was concluded that all storm sewer outfalls within the separated sewer system presented a risk of having improperly (cross) connected sewer laterals to them. In 2009, an official pilot program was initiated for the Sewer Lateral Cross Connection Pilot Program. The objective of this program was to find and repair complete cross connections in the separated sewer system between residential sanitary outputs to storm sewer laterals and thus storm sewer mains, to address the sources of E. coli. In 2016, the program was extended to a permanent Sewer Lateral Cross Connection Program (SLXC) with FTE's assigned to the program.

The program focused on the separate sewer areas of the City and as of 2022, covered most of Hamilton Mountain, parts of Dundas, Ancaster, and Stoney Creek. The prioritization sequence which steers the SLXC program is through the results of the storm sewer outfall sampling assignments as described in the following sections. The following figure depicts the SLXC program activities as of February 2022.

Figure 5-2: Sewer Lateral Cross-Connection Activity Map – February 2022

The SLXC Program identifies outfalls of concern based on sample results for E. coli and caffeine. Based on the results of the outfall sampling, upstream storm sewers of the flow path are inspected via CCTV. Signs of sanitary flow (staining of the pipe walls, visible wastewater flow, etc.) are captured along the storm sewer network and are traced upstream to a residential source. Homeowner participation is requested and once confirmed, a dye test is used to confirm the improper connection and complete cross connections are repaired. As of March 2023, the SLXC has repaired 471 cross connections, successfully diverting over an estimated 105 million liters of sewage, annually, from discharging out to the environment and back into the wastewater collection system for treatment. In addition, effective January 2016, new subdivision agreements require a dye test to ensure that all sanitary drains in newly constructed dwellings have been properly connected to the sanitary sewer system.

The SLXC program is still currently underway, and the completion of its first inspection round of the separated system will be dictated by the remaining sample results and the corresponding need for further investigation (first inspection round expected to be completed in 2025). A key limitation of the current program is regarding partial cross connections (improper connection of a single sanitary fixture to the storm sewer lateral), which stems from the lack of enforcement and financial incentive for homeowners to repair the misconnection (the repair must be made internally on private plumbing). It should be noted that changes are forthcoming to the Sewer and Drain Bylaw (estimated to be October 2023) specifically for identifying complete and partial cross connections as contraventions with enforcement being added under the Municipal Act.

5.1.3 OUTFALL INSPECTION PROGRAM

The outfall inspection program (outfall sampling assignments) is a component of the SLXC program implementation. However, it has been broken out as an individual program for evaluation as outfall inspections and sampling are a crucial first step in allocating the limited resources for the SLXC program. Since the permanent implementation of the SLXC program in 2016, outfall and associated MH sampling works were scoped and conducted by consultants and contractors. A summary of the information obtained to date by the City of Hamilton is presented in **Table 5-1** below.

Table 5-1: Summary of Outfall / MH Sampling Projects

Outfall/MH Sampling Project	Date of Sampling and Company	Scope	Results
City of Hamilton Upper Ottawa Outfall Dry Weather Sampling	May 2016 – Oct 2017 Calder Engineering Ltd.	812 storm MHs Inspected for E. coli (visual and laboratory test) in Central Hamilton (between Garth Street, Upper Ottawa Street, Mohawk Rd East, and Rymal Rd West)	Cases of Contamination: 52 – via visual inspection 36 – via laboratory testing (10.8% of total)
City of Hamilton 2018/2019 Outfall Sampling Program	March 2019 – March 2020 Calder Engineering Ltd.	Dry weather sampling of 101 storm sewer outfalls for E. coli/caffeine in the City of Hamilton (all over Hamilton, Stoney Creek, Flamborough, Dundas, and Ancaster)	Outfalls with detected E. coli concentrations above 10,000 CFU/100mL (or 5,000 + CFU/100mL E. coli & 0.5+ positive caffeine indication): 24 of 101 (2 of which were noted with sewage odor)
City of Hamilton Storm Sewer Outfall Sampling for E. coli –	Nov 2021 – June 2022 Aquafor Beech Ltd.	Inspections and variable weather monitoring of 61 storm sewer outfalls	9 cases of Positive Human marker (HF183)

Outfall/MH Sampling Project	Date of Sampling and Company	Scope	Results
Sewer Lateral Cross Connection Program		primarily within Ancaster and Dundas	
City of Hamilton Storm Sewer Outfall Sampling and Monitoring Program Category 9 Roster Assignment	2022 – 2024 WSP	Inspections and sampling of 80 storm sewer outfalls across Flamborough, Glanbrook, and Stoney Creek to determine if cross-connections are likely within the upstream sewer shed area	Efforts are currently on-going

Sampling of storm outfalls have taken place all throughout the City of Hamilton, however, most of the effort was focused in the separated sewer system area as aligned with the primary objective of the SLXC program.

5.1.4 CRITICAL REGULAR INSPECTION PROGRAM

As previously mentioned, the combined sewer system area features 195 known critical regulators, which divert excess combined sewage from the wastewater collection system towards one of the City's twenty-two (22) authorized combined sewage outfall locations. It is worth noting that 2 of the 4 potential sources of spills and unauthorized discharges are directly related to the state of the critical regulars (failed/unknown), as described in **Section 2.2**. The asset management of these combined sewer flow regulators was initiated in 2019, in which asset information was gathered on any structure that functioned as a flow regulator in the combined sewer system. Over 900 regulators were identified, and the flow path of each asset was traced to determine whether a regular was deemed critical (overflow correlates to outflow to natural environment) or non-critical (overflow ends up back in combined collection system). There are currently 751 non-critical regulators recorded and subject to an annual inspection schedule, and the 195 identified critical flow regulators are inspected twice a year for condition and flow characteristics.

The City of Hamilton maintains a critical regulator log that contains the asset name, associated outfall, street address location, and the type of structure. Within the City of Hamilton collection system, a majority of the critical regulators are within Hamilton, as previously shown in **Table 2-1**.

In response to the findings of the on-going inspection program which utilizes confined space entries as well as Go Pro inspections, 23 structural weir repairs were completed between January 2020 and as recently as February 2023. The types of repairs included the full replacement of corroded boiler plate weirs (metal) with PVC, rehabilitation of deteriorating weir walls via parging with hydraulic cement, and parging of leaking inlet/outlet connections to seal off spilling.

5.2 Gap Analysis between Current Programs / Initiatives and Industry Good Practices Framework

As stated previously, the City of Hamilton has looked to Industry Good Practices to provide a basis to guide the development and implementation of an effective and well-managed spills management and unauthorized discharge elimination program. This is evident through the summary of the various programs in the above section.

Section 4.1 describes an approach that is based on proven good practice guidance documents and methodologies followed by agencies in both North America and the UK in tackling the problem of combating spills and unauthorized discharges, which is common to most operational systems. The following table is a qualitative summary of the evaluation of the current programs and initiatives analyzed against the components of the Industry Good Practices framework.

A summary of the recommendations from this evaluation is provided until Section 5.3.

Table 5-2: City of Hamilton's Existing Programs Evaluated Against Industry Good Practices

Program Components of Industry Good Practices	City of Hamilton's Current Approach	Recommendations
1. Problem Definition and Program Goals	The City of Hamilton Public Works Department has been diligently searching for and correcting potential unauthorized discharges and spills through a variety of programs over the past decades. As per the Surface Water Quality Program – A Framework Report Outlining the Program Details (June 2022), "This Surface Water Quality Program (SWQP) Framework is the starting point for the City in gaining a holistic understanding of its receiving waters and the potential impacts from various City assets within the storm and wastewater collection and treatment system. Hamilton's goal is to build a baseline understanding of ambient surface water conditions over time, develop open communications and transparency with various partners, and respond to and investigate any water quality anomalies that may be due to infrastructure malfunctions and standard operating conditions. Based on this overarching objective, the Hamilton Water Division has been operating programs such as the SLXC and Risk-Based Pilot Program, as well as performing routine inspections at critical regulators and outfalls.	As shown in Table 5-3, the current efforts by the Hamilton Water Division collectively contribute to identifying/remediating all the various potential sources of spills and unauthorized discharges. The four (4) types of spills and unauthorized discharges in question are described in Section 2.2. It is recommended that current efforts and programs be consolidated into sub-branches of a new holistic Hamilton Water program that identifies the four (4) previously described types of spills and unauthorized discharges as the Problem Definition (the main targets of focus), and define the Program Goals to create, enhance, and implement on-site programs to identify and repair the targeted spills and unauthorized discharges. More suggestions regarding the new holistic program are mentioned in the recommendations pertaining to Program Governance Structure.
2. Program Governance Structure	The City of Hamilton Public Works Committee currently oversees the operations of the Hamilton Water Division. Within this structure, standards and programs such as the Wastewater Quality Management System (WWQMS), SLXC, and SWQP, are developed and implemented. However, within the context of field-investigation programs, there is a need for improvement to consolidate the combined sewer system and separated sewer system efforts into one umbrella that is governed with an objective to combat all types of spills and unauthorized discharges in the City of Hamilton.	It is recommended that the City of Hamilton, under the governance of Hamilton Water, organize the capital resources, time, and FTE staff into one "mother program" that focusses on the investigation and remediation of spills and unauthorized discharges, as previously noted in the recommendations pertaining to the Problem Definition and Program Goals. Under one unified umbrella, the existing programs (e.g., SLXC, Risk-Based Pilot Program, Outfall Inspections, and Critical Regular Inspections, etc.) may become the main branches that make up the mother program, as described in Section 4.2. Having one unified mother program that is dedicated towards the one main objective (combating spills and unauthorized discharges in the City of Hamilton) will enhance clarity associated with staffing, planning operations, and coordination with multi-disciplinary works. The mother program should be championed with a FTE staff member to oversee, prioritize, and delegate reconnaissance/repair fieldworks. Suggested title of the mother program: **System-wide Unauthorized Discharges Removal and Inspection Program (SUDRIP).**
3. System Characterization	The City of Hamilton has a strong understanding of their current system and how it operates. The overall sewer system is generally divided into the combined sewer area (urban core) and the separated sewer area (peripheral areas). Based on the characterization of the system, varying sources of spills and unauthorized discharges are expected (e.g., efforts to find failed critical regulators would be focused in areas with a need for critical regular – combined sewer system). The City's current programs and activities to identify these sources use knowledge of their sewer system to focus their efforts. Further description of the system is provided in Section 2.	Having a well-defined and characterized system allows municipalities to maximize efficiency in terms of the scope of the program and the desired outcomes. This is achieved through a thorough evaluation of what can be done and what should be done within the scope of the defined program. The effectiveness of the implemented investigation strategy will vary considerably from one system type to another. In the case of the proposed System-wide Unauthorized Discharges Removal and Inspection Program (SUDRIP), the various activities (made up of current and future programs) should continue to target the areas of the City that are most relevant to the type of spill and/or discharge source that the activity is intended to identify. As these programs and the overall system evolve, system characterization should be re-investigated to ensure efforts can continue to prioritize the proper areas.
4a-c. Strategic Risk-Based Prioritization Process – Outfall Risk Assessment and Prioritization to Prioritized Sub-Catchment Strategic Investigations	The City currently follows a risk-based outfall and sub-catchment prioritization process. It has been noted by the Hamilton Water Division staff that the Outfall Sampling Program prioritization has evolved over time. The program first started in the Chedoke Creek sub-watershed area due to local water quality concerns and then moved to Red Hill Creek Watershed for the same reasons. From there, the program filled in the remaining areas on the Hamilton Mountain and lower Stoney Creek as they had a similar infrastructure profile to those initial areas of concern. From 2019 onwards, the outer areas were sampled (Ancaster, Dundas) and then prioritized based on sample results as the focus shifted toward completing a first "low hanging fruit" type pass through the entire separated system. In 2023, it is planned to finish sampling the system by looking at the newest development areas (Binbrook, Waterdown, S/E Hamilton Mountain) and prioritized CCTV inspections are likely to be complete during/by 2025.	Figure 4-1 outlines the process by which a system-wide program can be feasibly managed by employing a risk-based prioritization and strategic source identification methodology. The process is designed to prioritize and focus efforts on outfalls at greatest risk of being impacted and by addressing those sources that have the potential for causing the greatest impact on those outfalls. It may be preferable to structure distinct streams of work for combined and separated sewer system outfalls given that the inherent risks and investigation strategies for each will differ. While, the City currently appears to follow this approach informally, the implementation of a new SUDRIP program would allow it to formalize this strategy. The City of Hamilton currently aims to finish the sampling the system in 2023. Therefore, the outfall risk assessment and prioritization strategies laid out in Section 4.1 are recommended to be adopted for future prioritization efforts, and within the SUDRIP. In essence, a "Plan-Do-Check-Act" feedback loop is created and maintained, starting from the desktop risk assessment of the outfall risk assessment and prioritization step, to the updated risk and re-prioritization step in which follow up screening, annual reporting, and other field reconnaissance data is used to update the desktop risk assessments.

Program Components of Industry Good Practices	City of Hamilton's Current Approach	Recommendations
4d. Prioritized Source Removals	The City's current programs include a source removal strategy. In the case of the existing SLXC program, once the source of contamination has been identified, the following four steps are taken: • Letters to Homeowners Requesting Participation • Dye-Testing and Sewer Lateral CCTV Inspections • Engineering Investigations for Corrective Action • Sewer Lateral Cross Connection Corrections The Pilot Program identified several previously unknown critical regulators and led directly into efforts for inspection and rehabilitation.	It is recommended that the City continue their source removal strategy and formalize it into the new SUDRIP program. The flowchart as depicted in Figure 4-2 is recommended to be followed once a source of unauthorized discharge or potential spill has been identified (Flow Chart for Corrective Action). Sources of discharges or spills will either be on the publicly owned and operated system or located on private property. Sources located on the public system fall under the jurisdiction of the system owner and can thus be readily addressed using public funds. Access to investigate and then remove sources on private can be challenging, costly, and require significant time and resources to complete. Some of the greatest challenges to removing sources from private property are related to legal and policy issues, enforcement of by-laws, engaging the property owner in the program through education, and establishing equitable means of funding of private side remedial measures.
4e. Re-assessment and Re-prioritization	In the case of the existing SLXC program, once a correction has been made, the case is deemed complete and closed. In summary, the SLXC currently lacks a "repeat sampling" or validation step in its current process. The Pilot Program is too new to comment on this step.	The SLXC program doesn't focus on the re-assessment & re-sampling of the sewer network to confirm the elimination/reduction of unauthorized discharge from areas previously covered. As per the flowchart for Corrective Action (Figure 4-2), it is imperative that a step to "confirm elimination of contamination source" is conducted after the actual work to eliminate the source. This step either allows for the confirmation of the contamination source being fully eliminated, or provides for an opportunity to issue the second Work Order or Notice of Violation (NOV). Once again, the essence of the process would be to create the "Plan-Do-Check-Act" feedback loop and reinforce the process such that the loop is maintained.
5. Program Management Tools	As previously noted, the existing City of Hamilton programs that are directly relevant to identifying and remediating spills and unauthorized discharges are independently operated by the Hamilton Water Division under the Public Works Department. However, as made evident by the recommendation to unite the programs under one umbrella, the programs are operated independently, and without the use of established data management tools that combines the data derived from investigating/remediating the combined and separated sewer systems.	It is recommended that the SUDRIP consider adopting established enterprise data management and analytics platforms. Business insights beyond system operations can now be generated in real-time through computer assisted analytics that can be applied to multiple and disparate data sets. Such systems enable the integration of data source and interoperability of applications for near-real-time decision making. This includes integrating business (IT-GIS/CMMS/CRM/AMI/LIMS) and operational (OT-SCADA) technologies for application use. The key benefits are listed below: • Enables a connected & insightful workforce • Enhances the ability to abstract, share, and visualize information • Enhances the ability to analyze and interpret data • Provides for better informed decision making and program/project execution
6. Resources (Staff and Budget)	As previously noted, the existing City of Hamilton programs that are directly relevant to identifying and remediating spills and unauthorized discharges are independently operated by the Hamilton Water Division under the Public Works Department. However, as made evident by the recommendation to unite the programs under one umbrella, the programs are operated with the resources available at the time of implementation under the Hamilton Water Division's control and staff are generally not fully dedicated to the programs (not FTEs for the program).	Under the SUDRIP team structure, it is recommended that an FTE program manager is dedicated to the program to oversee and manage all branches of the program. Under the dedicated program manager/leader, it is recommended to create a team of 3 FTE SUDRIP staff that can assist with leading the sampling efforts, coordination of inspections, CCTV work, and be the information controllers to help maintain consistency in documentation and record keeping. In addition to full-time City staff, co-op students can be incorporated into the team to reduce labour costs. This model can be compared to the City of Toronto's (Toronto Water) Outfall Monitoring Program (OMP), in which the program is championed by a dedicated supervisor and is operated by a staffing team of 1 manager, 2 FTEs, and 3 co-op students. The recommendation to build on the existing SLXC and Pilot Programs and the staffing upgrades needed to maintain those programs under the SUDRIP umbrella are explored in Section 4.2.3.

5.3 Gap Analysis between Current Programs / Initiatives and Potential Sources of Spills & Unauthorized Discharges

Table 5-3 below summarizes the relevant inspection-related programs and initiatives and scores them in terms of their potential to identify each type or source of potential spill or unauthorized discharge. This Gap Analysis is under development. A discussion will follow on the types of spills and unauthorized discharges that are most or least likely to be discovered through the City's current programs. This will be used to recommend focus of programs and future allocation of resources.

Table 5-3: Overview of City's Current Inspection-Related Programs and Initiatives (Scores: 0 – Ineffective, 5 – Most Effective)

					Potential to Detect Spills and Discharges			
Program	**Years Active**	**Areas Covered**	**% of City Covered**	**% of Program Complete**	**Main Line XC**	**Lateral XC**	**Failed Regulator**	**Unknown Regulator**
Risk-Based Proactive Pilot Program	2022-current	Hamilton Core	~40%	100%	4	1	1	5
Sewer Lateral Cross-Connection	2009-current	Hamilton Dundas Ancaster Stoney Creek	~80%	~75%	1	5	0	1
Outfall Inspection Program	2016-current	Hamilton Flamborough Dundas Ancaster Stoney Creek	~90%	~80%	2	2	2	2
Critical Regulator Inspection Program	2019-current	Hamilton Flamborough Dundas Ancaster Stoney Creek	~90%	2x annually	0	0	5	1
- Sewer Condition Assessments - Operational Sewer Maintenance - Construction Pre / Post Inspection	Ongoing	Entire City	100%	Ongoing	1	1	1	1
				Total Scores	**7**	**7**	**8**	**7**

As shown by the total scores presented in **Table 5-3**, when all the individual programs are considered together in the context of their potentials to detect spills and discharges, there is no apparent blind spot (collectively speaking, all sources of spills and discharges have a strong way to be found and repaired). A limitation of this quantitative gap analysis table is that the effectiveness of past and current inspection programs to identify spills and unauthorized discharges cannot be verified because the true number of these conditions is unknown. Unless multiple programs were completed in quick succession, there is no way to confirm whether spills or unauthorized discharges were missed by the inspection program, or whether they simply did not exist.

In summary, there is no specific need for a new program to target one of the spills/discharge types, however, as presented in **Table 5-2**, it would seem natural to unite all the existing programs under one umbrella. The above is essentially an evaluation of the proposed System-wide Unauthorized Discharges and Removal Inspection Program (SUDRIP). Under the SUDRIP, each of these programs should be reinforced with a Plan-Do-Check-Act feedback loop (within the outfall prioritization process, as well as within the re-assessment and re-prioritization processes), as noted in **Table 5-2**. In summary, under the proposed SUDRIP:

- Each main branch (i.e., current programs) should undergo a system characterization evaluation to ensure that each program is defined and scoped in a way that makes the most efficient use of available resources and geographical coverage (Table 5-2, Item 3 – System Characterization)
- Incorporate a reiterative components of the program to re-prioritize outfall and catchment / sub-catchments as detection and removal efforts continue (Table 5-2, Item 4e – Re-assessment and Re-prioritization)
- A team of FTE SUDRIP staff should operate these programs with an assessment / re-assessment, prioritization/ re-prioritization framework (Table 5-2, Item 7 – Resources)
- Make use of established enterprise data management and analytics platforms (Table 5-2, Item 6 – Program Management Tools).

6 Additional Physical and Analytical Inspection Programs (MECP Order 5.4)

As part of the gap analysis in **Section 5.3**, Stantec completed a holistic review of the City's ongoing programs to identify potential spill(s) and unauthorized discharges from the City of Hamilton sewage system. The purpose of the section herein is to review additional physical and analytical inspection programs that the City may consider for enhancements or additions to their existing programs, procedures and measures to inspect, monitor and identify spills and unauthorized discharges. Stantec consulted with internal Stantec staff with extensive experience in Illicit Discharge Detection and Elimination (IDDE) approaches, methodologies and technologies, inclusive of experience in Canada, the United Kingdom, and the United States. Stantec also reached out to a municipality who has used one of the techniques mentioned herein (canine scent tracking), for further clarification on their experience using this technique. Stantec compiled a list of potential physical and analytical inspection technologies, measures and methods for the City's further review and consideration. The following provides a general overview of each technology that was reviewed.

6.1 Field-Based Sampling

6.1.1 QUANTITATIVE POLYMERASE CHAIN REACTION (QPCR)

Traditional fecal indicator bacteria (FIB) tests that culture total coliforms, fecal coliforms, E. coli, or Enterococci is widely recognized. However, there are limitations as the traditional FIB tests are not specific or sensitive and can have a high percentage of false positive and false negative results. Specific organisms can be detected using Polymerase Chain Reaction (PCR). Quantitative PCR (qPCR) is performed by amplifying DNA using fluorescent tags, which can be more sensitive and specific compared to the traditional FIB tests to determine the presence of fecal or sewage contamination. To date, the most promising use of qPCR technology is to test for total Bacteroides, human Bacteroides, and human Polyomaviruses (HPyVs). Bacteroides species are anaerobic bacteria that only presents in fecal contamination with a huge concentration in feces, unlike E.coli and Enterococcus species which are not specific to feces only. The enormous concentration of Bacteroides in feces also make testing more effective and easier than using FIB culture tests. HPyVs are even more specific than Bacteroides, since it can only be found in human urine. QPCR testing results can be available within 24 hours or less, it is much also much quicker than cultured-based testing, which typically require 10-14 days to complete testing. To track illicit discharge within a stormwater system, qPCR appears to be much more effective compared to traditional FIB tests, however, it can be costly, so there is a need for better approaches to strategically select the testing locations. If not already used, the City may consider using qPCR testing to enhance their sampling program.

6.2 Field-Based Physical Investigations/Test

6.2.1 DRY WEATHER SAND BAGGING

Where outfall sampling indicates contamination and minimal to no continuous flow is observed during DWF, sandbags can be placed in storm MHs from upstream and proceed downstream to capture and sample for possible lateral cross connections. If flow captured by the sandbag was tested and has results that identify no contamination, then the upstream segments are assumed to be clear of contamination and field crews can proceed to the next strategic MH. Field test kits are used to determine if sewage is contaminated, as indicated by detection of ammonia, surfactants, or total residual chlorine greater than 3.4 ppm. MH should be strategically selected until it is possible to isolate a section with illicit connection(s) to identify source(s) of contamination. Note that sand bagging may not be appropriate due to standing water when there is too much flow in storm drains to allow sandbagging, then dye testing can be used instead, however, dye testing would cost more than sandbagging and require a greater level of effort as the field crew will need to coordinate to get access to the buildings.

6.2.2 DYE FLOODING

Dye flooding involves the isolation of a segment of mainline sewer to find cross connections between storm and sanitary, as opposed to dye testing which injects dyed water in a potential source of cross-connection (e.g. lateral, drain, etc.). Dye flooding is typically done in conjunction with CCTV where a segment of the storm sewer is isolated and flooded with dyed water to see if it comes out in the sanitary (or in the City's case, between the combined and storm relief sewers). This method could be used as a follow-up test to find or confirm intermediate sources of cross-connection that are not visible from surface and suspected based on CCTV results.

6.2.3 CANINE SCENT TRACKING

Canine scent tracking involves using trained dogs to scent the human sources of bacterial (e.g., E. coli) in a storm drain system or waterbody. Environmental Canine Services (ECS) in the United States has trained dogs to identify and track illicit sewage discharges. This method is cost-efficient and provides a rapid result in the field, however, this program currently may not be available in Canada. Dogs can indicate the presence of human waste by either barking or sitting. One literature review of diverse scent source types reports high specificity (82 to 100%; most sources .96%) and sensitivity (75 to 100%; most sources .87%) for canines and their trained target sources (Helton, 2009). Stantec contacted a municipality in the United States who has used canine scent tracking as a pilot as part of Illicit Discharge Detection and Elimination program. The following pros are identified with using canine scent tracking for detection of illicit discharges including:

- Cost-efficient.
- Provides immediate rapid results (i.e., detection of human waste) in the field.
- Ability to quickly investigate locations and help prioritize which locations to complete sampling.

- More successful for screening outfalls for human waste where the outfalls are spread apart from each other.
- Dogs have strong sensitivities and can detect low levels of human waste. Dogs typically become more animated when higher levels of human waste are detected.

Several challenges were identified by this municipality with using canine scent tracking to detect illicit discharges, which included:

- Dogs can make mistakes and can be distracted by outside influences, particularly in noisy, busy and urban areas.
- Dogs have varying sensitivities and cannot determine what they are identifying in the field, only that they have identified something.
- The level of sewage cannot be measured, this methodology detects if sewage is present or not.
- Sampling may still be required to verify results.
- Dogs get sick which can cause delays.
- Trained and experienced canine handlers are required.
- Water Environment Research report titled "The Canine Scent Detection and Microbial Source Tracking of Human Waste Contamination in Storm Drains" dated June 2014, noted that the dogs accurately identified human waste which was verified by PCR testing. However, there were some false positives by the dogs, later verified by PCR testing. In addition, the report noted that no false negatives were identified in this study (i.e., where dogs indicated that human waste was not present, the PCR testing verified these results). In conclusion, the report noted that canine scent tracking provides immediate field results, unlike other methods and that the quantitative approach can greatly assist in locating contamination problems at a low expense (Van De Werfhorst, 2014).

6.2.4 CCTV ON STORM RELIEF SEWERS

Within the formerly combined areas, the City of Hamilton has numerous storm relief sewers that are connected to combined sewers. Those storm relief sewers are critical as they have high likelihood of cross-connections or system failure of unauthorized discharges and/or spills. The use of mobile video cameras that are guided remotely through those storm relief sewers to observe and note possible illicit discharges can be effective for finding continuous potential illicit discharges and/or unaccounted for connections, however, it will be difficult to identify "blind cross-connection" (e.g. between two MHs with no surface access/visibility). While this tool is definitive as it provides real-time data and high-quality images/videos back, but when used in isolation it can be relatively costly and time consuming when compared to other source isolation techniques. Ideally, targeted CCTV videoing is used in conjunction with sampling and MH investigations where cross connections are suspected to exist.

6.2.5 CHEMICAL INDICATORS

Although the most common source of contamination in illicit discharge is wastewater, other sources, such as washwater (contains detergents), can contribute as well. It is also useful to identify tap water presence in the storm system to identify water system leaks and reduce chlorine and fluorine that discharges to the environment. Chemical indicators (such as Fluorescein or Rhodamine Dye) can be used to identify a specific type of discharge and potential cross-connections. Samples collected from outfalls or pipes, along with techniques to store and preserve them for subsequent laboratory analysis will identify the presence of chemical parameters. The following are the typical chemical field parameters that can identify potential illicit discharges. No single indicator is perfect, a combination of testing different parameters is often the best approach. List below are several indicators and what they can detect, as described in the Detection of Wastewater Contamination Technical Paper dated 2019 (Barker et. al., 2019):

- Ammonia – Good indicator of wastewater, however, volatilizes easily.
- Boron – Potential indicator of any discharge containing detergents.
- Chlorine – Can identify tap water presence.
- Fluorine – Since tap water is fluoridated in most communities, fluoride can often distinguish tap water from groundwater.
- Nitrogen/Phosphorus – An in-stream parameter to identify large-scale wastewater contamination.
- pH – Identifies some industrial discharges.
- Potassium – Excellent indicator of industrial discharges.
- Detergents – Surfactants: Surfactants (found in detergents) can distinguish an illicit discharge from other natural water or tap water because surfactants are not typically found in groundwater.

6.2.6 FLOW MONITORING ON STORM RELIEF SEWERS

The sewer monitoring programs provide real-time flow, depth and velocity measurement at different time intervals at MHs. Typically, a third-party vendor will be responsible for overall data QA/QC, including daily review, maintenance, and activity logs, and sensor verification measurements. The selection of the MH for monitoring station also need to consider site access, hydraulics (i.e. avoid bends, drop structures), upstream land use and size of drainage area, known construction/ maintenance conflicts, and the identification of back-up secondary/tertiary sites to optimize installation time. The City of Hamilton can consider putting flow monitoring stations at the critical regulators next to the storm relief sewers that diverts combined sewage overflow to the CSO outfalls to identify any potential unknow critical regulator failures. Storm relief sewers typically should only discharge combined overflow during rainfall events, monitoring critical regulators could identify any dry weather (sanitary) flow that occurs at the cross-connections. Additionally, the monitoring data can also be used for model calibration.

6.3 Microbiological

6.3.1 RAPID COLIFORM TEST

Rapid Coliform test is a fast test to simultaneously detect both total coliforms and E.coli in water samples to provide results within 18 hours (Xebios Diagnostics GmbH, n.d.). According to research, suppliers that carry rapid coliform testing kits to test water contamination are Colikat Rapid and 3M™ Petrifilm™ Series, which uses either a plate or a tray to put the water sample into that will turn sample into yellow if coliforms are presented, if it shows fluorescence under UV-light E.coli is presented (Xebios Diagnostics GmbH, n.d.). The number of coliforms or E.coli in the sample can be estimated by counting the number of the squares that turned yellow or showed fluorescence under UV-light (Xebios Diagnostics GmbH, n.d.). Colikat Rapid is designed to test the surface water and wastewater samples, however it appears that it is only available in Germany. 3M™ Petrifilm™ is available to purchase in Canada but it is more direct to be used within the food safety industry, using it for the purpose of stormwater contamination testing should be verified with 3M™ Petrifilm™.

6.3.2 LAB-BASED MICROBIOLOGICAL

Lab-based microbiological is widely used procedure that sampling water and applying testing techniques to identify and quantify microbiological organisms in a water sample. One of the most effective ways to check water sample for fecal contamination is microbiological analysis, instead of carrying out separate tests for each potential pathogens, viruses, or parasites that might be in the water (Rapid Microbiology, n.d.). Coliform has the characteristics of allowing for “easy isolation, detection and enumeration in the lab and are good standard for microbial water testing” (Rapid Microbiology, n.d.). The microbiologist typically would look for count of fecal coliforms such as E. coli, whose only habitat is the intestine as the ideal indicator of fecal contamination (Rapid Microbiology, n.d.). “The presence of fecal streptococci/Enterococci is also evidence of fecal contamination” (Rapid Microbiology, n.d.). “Conventional testing methods may also give false positive, in that case, additional testing may be required” (Rapid Microbiology, n.d.).

6.3.3 SEQUENCE-BASED GENETIC

Sequence-based genetic has been developed to establish evidence of fecal contamination in surface freshwaters through alternative DNA-based indicators (Tan et. al., 2015). Sequencing methods targeting small subunit (SSU) rRNA hypervariable regions have allowed identification of signature microbial species that serve as bioindicators for sewage contamination (Tan et. al., 2015). The microbiomes associated with sewers were predominantly unique compared to those associated with animal hosts, surface freshwaters and other environmental sources (Tan et. al., 2015). For example, qPCR, analysis of profiles of microbial SSU rRNA genes, and use of bacterial taxonomic groups identified through next-generation sequencing (NGS)-based surveys are the few methods that has been used for detecting human microbial species in sewer system (Tan et. al., 2015). Since this is one of the newer technologies in the market, it is recommended that the City confirm which laboratories, if any provide this type of analysis in Ontario.

6.4 Summary

These technologies were reviewed based on Stantec's experience and knowledge of the industry as well as high level desktop research completed as part of this assignment. **Table 6-1** provides a summary of each technology and analytical inspection program, and a high-level summary of its local availability, effectiveness/timeline and cost impact. Stantec has also provided recommendations on which technologies to carry forward as part of SUDRIP. It is noted that the details provided are based on high-level review, and it is recommended that the City further review these technologies for suitability in the City's existing programs as well as validate the availability and accessibility of these technologies should the City be interested in pursuing these further.

Table 6-1: Potential Physical and Analytical Inspection Program Summary

Program	Previously Implemented by the City	Locally Available	Effectiveness/ Timeline	Cost	Comments	Recommended for Implementation
Field-Based Physical Investigations						
Dry Weather Sand Bagging within storm sewer MHs	Yes	Yes	Effective	$	As noted in Table 4-3, sandbagging can be used as part of a follow up investigation if necessary.	✓
Dye Flooding	Yes	Yes	Moderately Effective	$	The City may consider implementing dye flooding as a trial as part of the SLXC program.	✓
Canine Scent Tracking	No	Unlikely	Less Effective	$	Cost-efficient and provide rapid results in the field, however, likely not currently available in Canada.	✗
CCTV Storm Relief Sewers	No	Yes	Less Effective	$$	Low likelihood but high severity if major sewer cross-connection is found. The City may consider completing CCTV of storm relief sewers within critical within storm outfall areas.	✓

Program	Previously Implemented by the City	Locally Available	Effectiveness/ Timeline	Cost	Comments	Recommended for Implementation
Chemical Indicators	No	Likely	Moderately Effective	$$	Most tests are simple and provide quick results, however, some of the chemical parameters can be difficult to detect. The City may consider implementing chemical indicators as part of a pilot project and trial as part of either the SLXC program or the combined sewer area investigation.	✓
Flow Monitoring on Storm Relief Sewers	No	Yes	Less Effective	$$$	Provides real-time flow, depth and velocity measurement at critical regulator locations.	✓
Microbiological Lab Based Testing						
qPCR	No	Likely	Effective	$$$	More sensitive and specific than the traditional culture-based FIB testing method, but it can be costly.	✗
Rapid Coliform Test	No	Yes	Effective	$	Can be done in the field and test results can be ready within 18 hours. However, these tests do not appear to be either readily available in Canada or are currently used for different applications.	✗
Lab-based Microbiological	Yes	Yes	Moderately Effective	$	Widely used, non-specific. The City should continue with their lab-based microbiological testing.	✓

Program	Previously Implemented by the City	Locally Available	Effectiveness/ Timeline	Cost	Comments	Recommended for Implementation
Sequence-Based Genetic	No	Likely	Effective	$$$	Rapid and accurate, relatively new, limited resources available. High cost. As noted in Table 4-3, genetic tracing can be used where other sampling results are inconclusive.	✓

7 Conclusions and Recommendations

Stantec has prepared this report in response to MECP Order No. 1-142403769 issued to the City of Hamilton. This report summarizes our review of the City's collection system and its current inspection-related programs and initiatives and provides our recommendations to improve the City's ability to identify spills and unauthorized discharges, in compliance with MECP Item No. 5 (specifically sub-items I to IV – also referred in this report to herein as MECP Order Items 5.1 to 5.4), as follows:

Item No. 5 Compliance Due Date: 05/12/2023

Identify recommendations for enhancements to the City's sewer inspection programs to better identify identifying Spill(s) and unauthorized discharges of untreated sewage within the City of Hamilton sewer system. These recommendations shall include at a minimum but not limited to:

I. An analysis of the feasibility of conducting a detailed in-pipe inspection of the City of Hamilton's sewer system.

II. An analysis of the feasibility of conducting risk-based inspections of the City of Hamilton's sewer system.

III. The Terms of Reference for an assignment to complete a gap-analysis review of current programs, procedures, and measures to inspect, monitor and identify Spill(s) and unauthorized discharges from the City of Hamilton's sewer system.

IV. A review of additional physical and analytical inspection programs to identify Spill(s) and Spills(s) and unauthorized discharges from the City of Hamilton sewage system.

Item 5.5 (V) was completed by the City of Hamilton staff:

V. Procedures for updating City of Hamilton's current digital mapping system when discrepancies are determined.

In summary and based on our review of the City's on-going sewer inspection programs, this report concludes the following in response to MECP Order Items 5.1 to 5.4:

- As noted in Section 3, completing a city-wide detailed in-pipe inspection program is not likely to provide the most benefit in identifying spills or unauthorized discharge.
- The City has many ongoing inspection-related programs that have proven to be very effective in identifying various types of spills and unauthorized discharges.
- Collectively, these programs and other activities cover many of the elements of Industry Good Practices for identifying and eliminating illicit discharges.
- The City could benefit from establishing a centralized task-force / overall program, namely the System-wide Unauthorized Discharges Removal and Inspection Program (SUDRIP) to

connect efforts within these various inspection-related programs, activities and initiatives with an integrated prioritization process.

- It is recommended that the current Risk-Based Proactive Pilot Program be expanded to inspect the remaining MHs within the combined sewer area.
- It is recommended that the Sewer Lateral Cross-Connection Program adopt a verification exercise to re-sample outfalls and sub-catchments that previously showed signs of sanitary sewage and evidence of potential cross-connections.
- It is recommended that the City proceed with implementing field-based physical investigations defined in Section 6. In addition, it is recommended the City continue with microbiological lab-based testing and consider sequence based genetic testing where other sampling results are inconclusive.

8 References

Pitt, R., & Center for Watershed Protection. (2004, October). *Illicit discharge detection and elimination (IDDE) guidance manual ...* Retrieved April 18, 2023, from https://www3.epa.gov/npdes/pubs/idde_chapter-8.pdf

Barker, D. B., DeMaria, A. D., P. E., Caraco, D., P. E., R. Corsi, S. R., Kinzelman, J. K., Ph. D. ,. M. S. ,. M. T., Liner, B. L., Ph. D. ,. P. E., L. McLellan, S. M., Ph. D., McFadden, L., & Nenn, M. S. (2019). *Detection of Wastewater Contamination*. In *https://www.wef.org/globalassets/assets-wef/2-resources/topics/a-n/intelligent-water-systems/technical-resources/usgs_uwm_wef_detection_of_wastewater_contamination_2019---4printing.pdf. Water Environment Federation.*

Van De Werfhorst, L. C., Murray, J. L. S., Reynolds, S., Reynolds, K., & Holden, P. A. (2014, June). *Canine Scent Detection and Microbial Source Tracking of Human Waste Contamination in Storm Drains*. Research Gate. Retrieved April 14, 2023, from *https://www.researchgate.net/publication/262733946_Canine_Scent_Detection_and_Microbial_Source_Tracking_of_Human_Waste_Contamination_in_Storm_Drains*

Barker, D., DeMaria, A., Caraco, D., Corsi, S.R., Kinzelman, J., Liner, B., McLellan, S.L., McFadden, L., & Nenn, C.(n.d). *Detection of Wastewater Contamination*. Retrieved March 30, 2023, from *https://www.wef.org/globalassets/assets-wef/2-resources/topics/a-n/intelligent-water-systems/technical-resources/usgs_uwm_wef_detection_of_wastewater_contamination_2019---4printing.pdf*

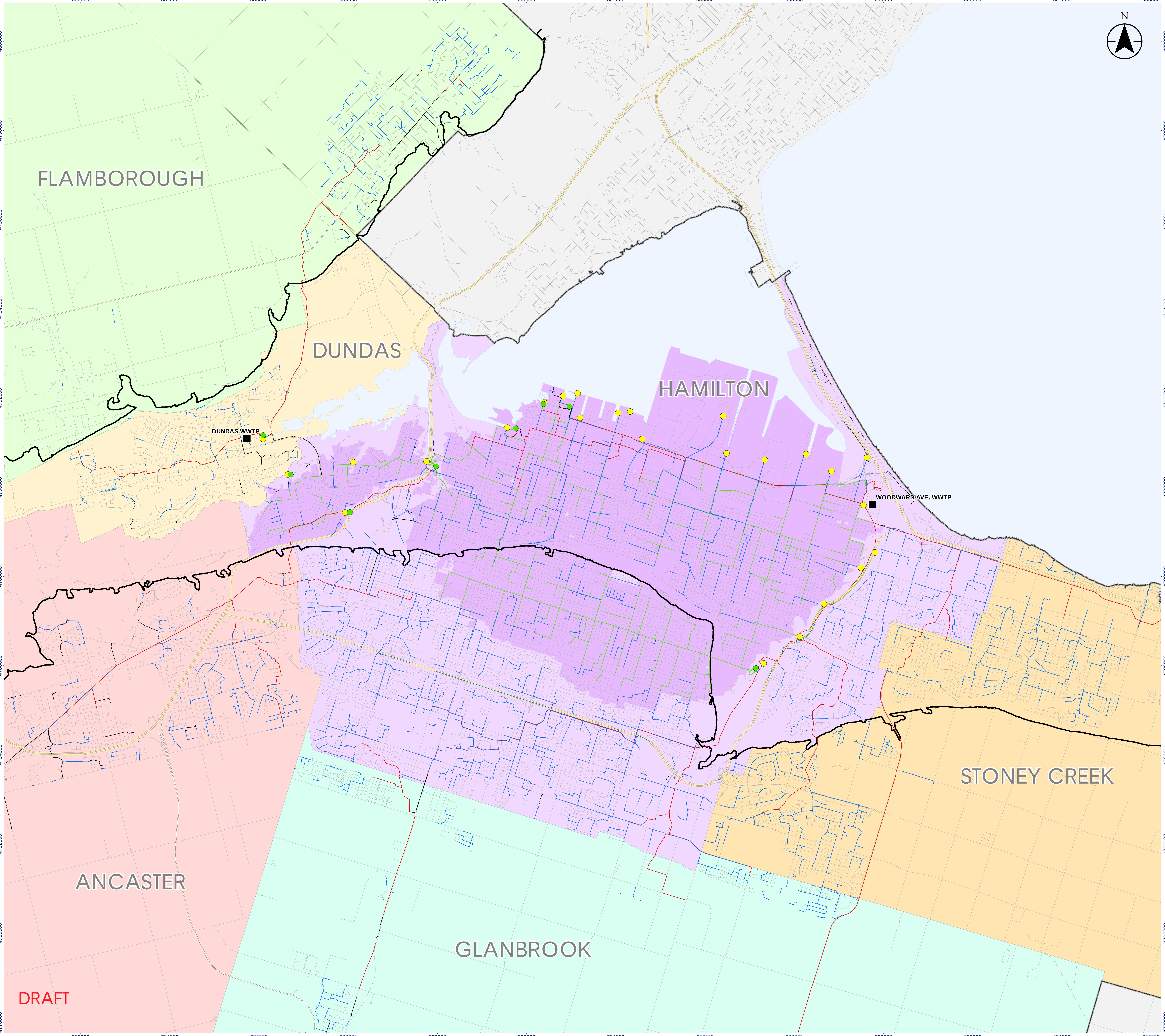
EMSL. (2021, March 17). Using qPCR to Detect Sewage Contamination.

Pitt, R. (2004). Illicit Discharge Detection and Elimination A Guidance Manual for Program Development and Technical Assessments by the Center for Watershed Protection. Retrieved from *https://www3.epa.gov/npdes/pubs/idde_tableofcontents.pdf*

Tan, B., Ng, C., Nshimyimana, J. P., Loh, L. K., Gin, K. Y., & Thompson, J. R. (2015). Next-generation sequencing (NGS) for assessment of microbial water quality: current progress, challenges, and future opportunities. Frontiers in Microbiology, 6. *https://doi.org/10.3389/fmicb.2015.01027*

Xebios Diagnostics GmbH. (n.d.). COLIKAT RAPID. COLIKAT RAPID. https://www.colikat.com/Water - Microbiological Analysis Test Method Guide. (n.d.). Rapid Microbiology. *https://www.rapidmicrobiology.com/test-method/theory-and-practice-of-microbiological-water-testing*

APPENDIX A GIS MAPS



Stantec

Legend

- Wastewater Treatment Plant
- CSO Tank
- CSO Outfall
- Storm Sewer (> 600 mm)
- Sanitary Sewer (> 600 mm)
- Combined Sewer (> 900 mm)
- Escarpment
- Combined Sewer Catchment
- City Boundary

Community Boundary

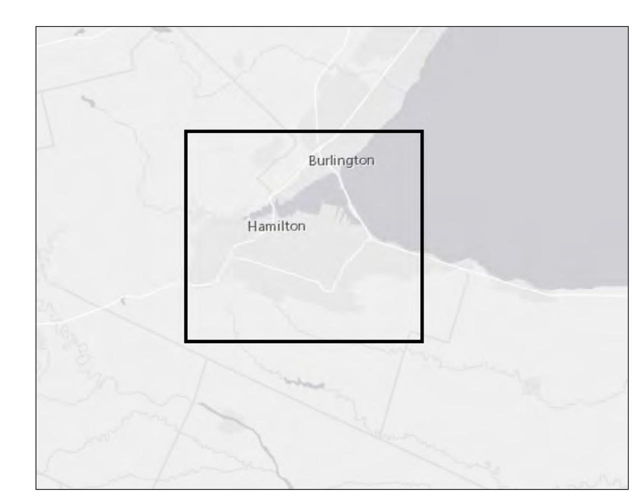
- Ancaster
- Dundas
- Flamborough
- Glanbrook
- Hamilton
- Stoney Creek

0 1,000 2,000 metres

1:28,000 (At original document size of 34x44)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Project Location 163401837

City of Hamilton

Prepared by EH on 2023-03-21

Client/Project

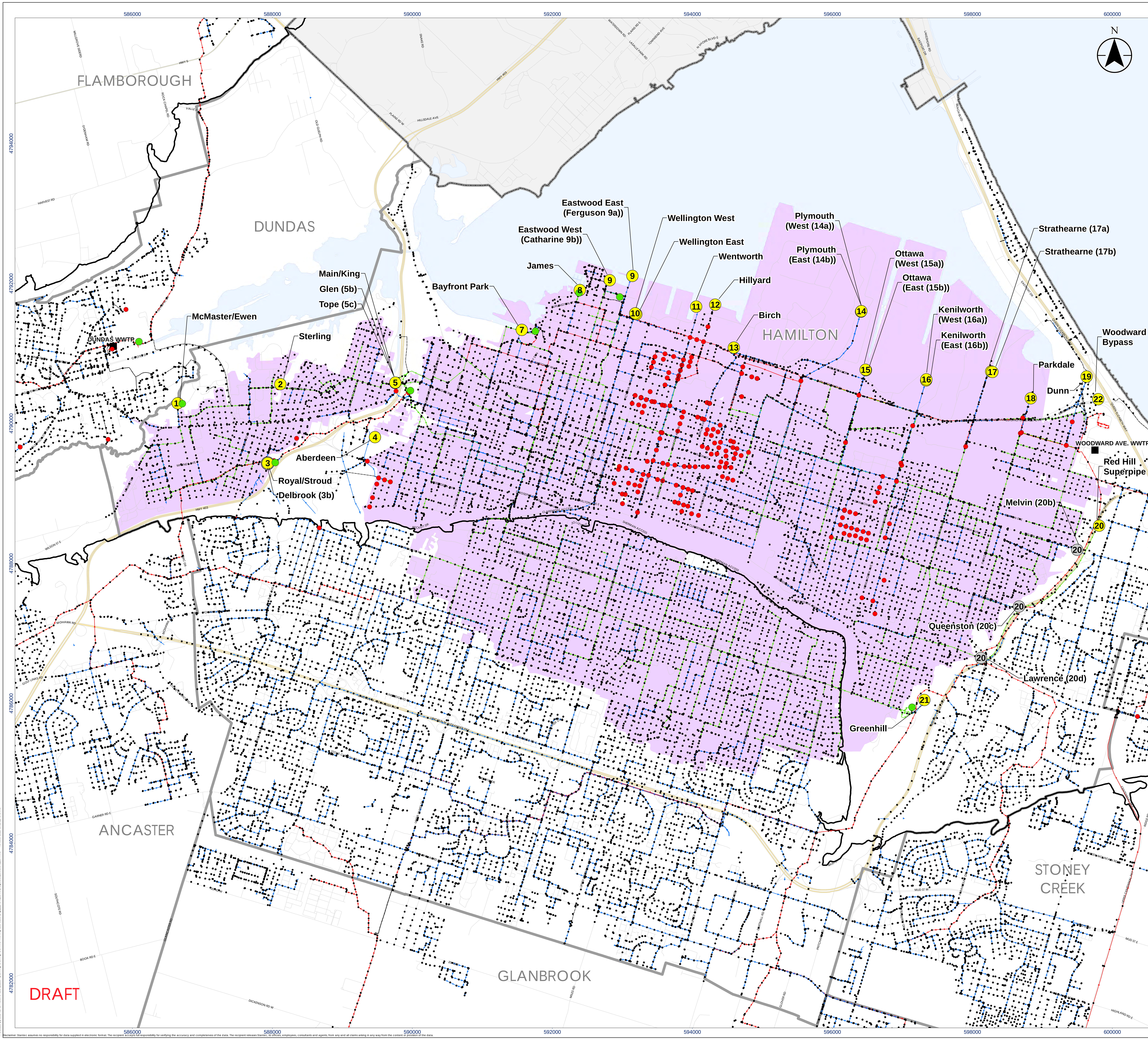
City of Hamilton
MECP Spills Order

Figure No.

1.1 DRAFT

Title

Trunk Sewer Network



Stantec

Legend

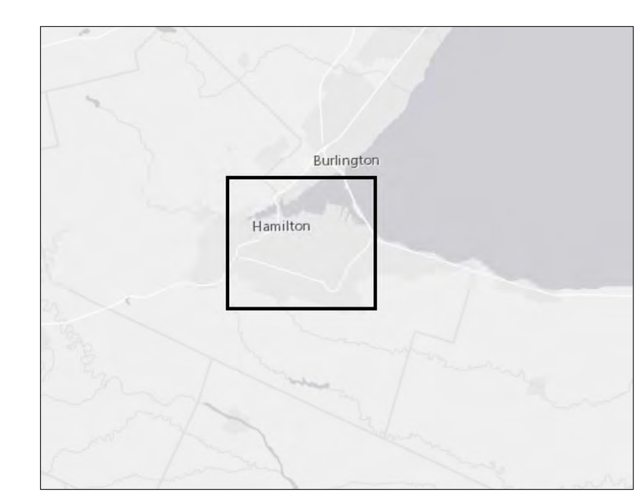
- Wastewater Treatment Plant
- CSO Outfall
- CSO Outfall - Blocked Off
- CSO Tank
- Critical Regulator
- Non-Critical Regulator
- Storm Sewer (> 600 mm)
- Sanitary Sewer (> 600 mm)
- Combined Sewer (> 900 mm)
- Escarpment
- Combined Sewer Catchment
- City Boundary
- Community Boundary

0 500 1,000 metres

1:17,500 (At original document size of 34x44)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

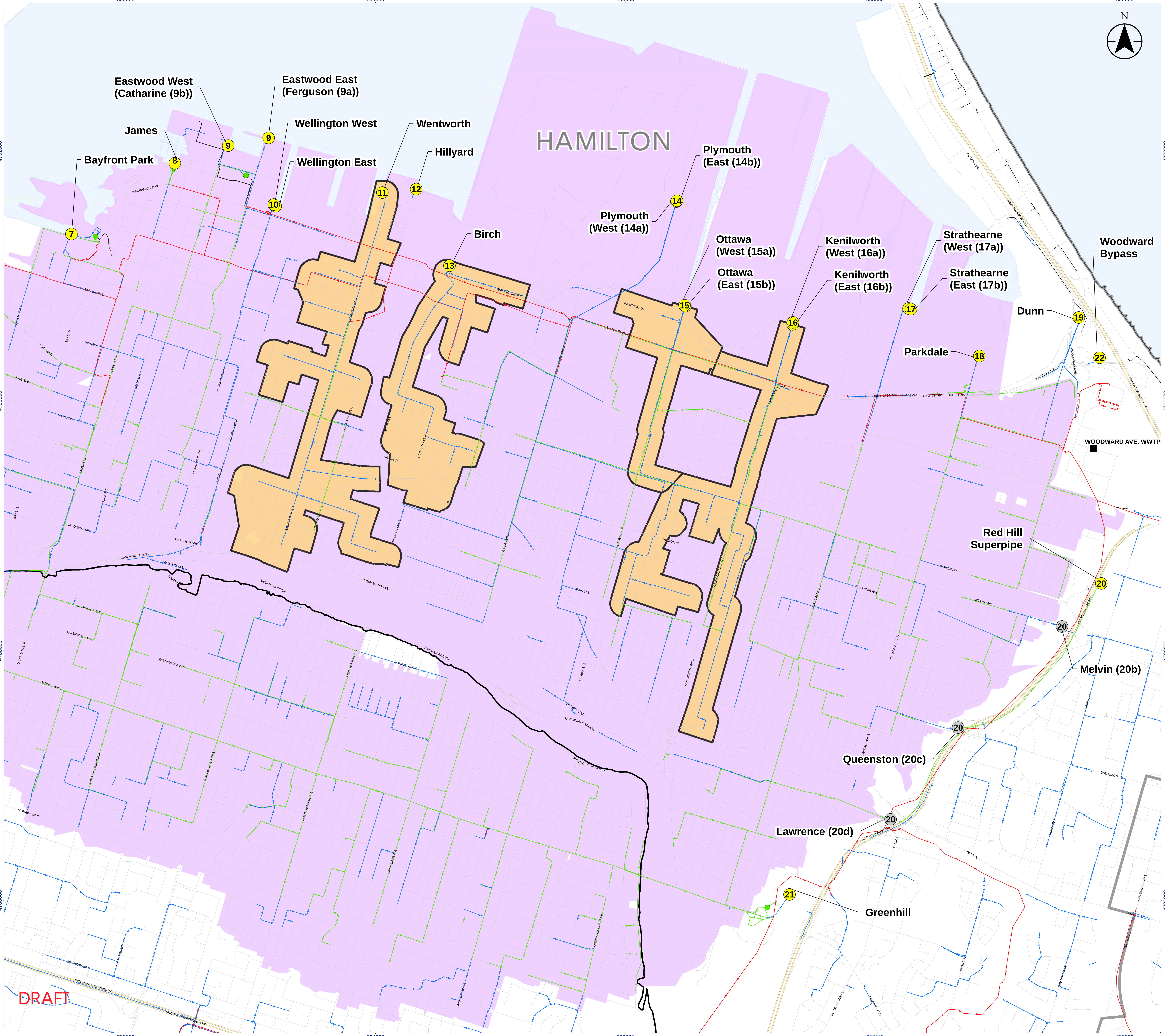


Project Location: City of Hamilton — 163401837 — Prepared by EH on 2023-03-21

Client/Project: City of Hamilton, MECP Spills Order

Figure No. 1.2 — DRAFT

Title: Trunk Sewer Network Critical Regulator Locations



Stantec

Legend

- Wastewater Treatment Plant
- CSO Outfall
- CSO Outfall - Blocked Off
- CSO Tank
- Storm Sewer (> 600 mm)
- Sanitary Sewer (> 600 mm)
- Combined Sewer (> 900 mm)
- Escarpment
- Critical Path Route Boundary
- Combined Sewer Catchment
- City Boundary
- Community Boundary

0 250 500 metres

1:10,000 (At original document size of 34x44)

Notes
1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Project Location: City of Hamilton

163401837

Prepared by EH on 2023-03-21

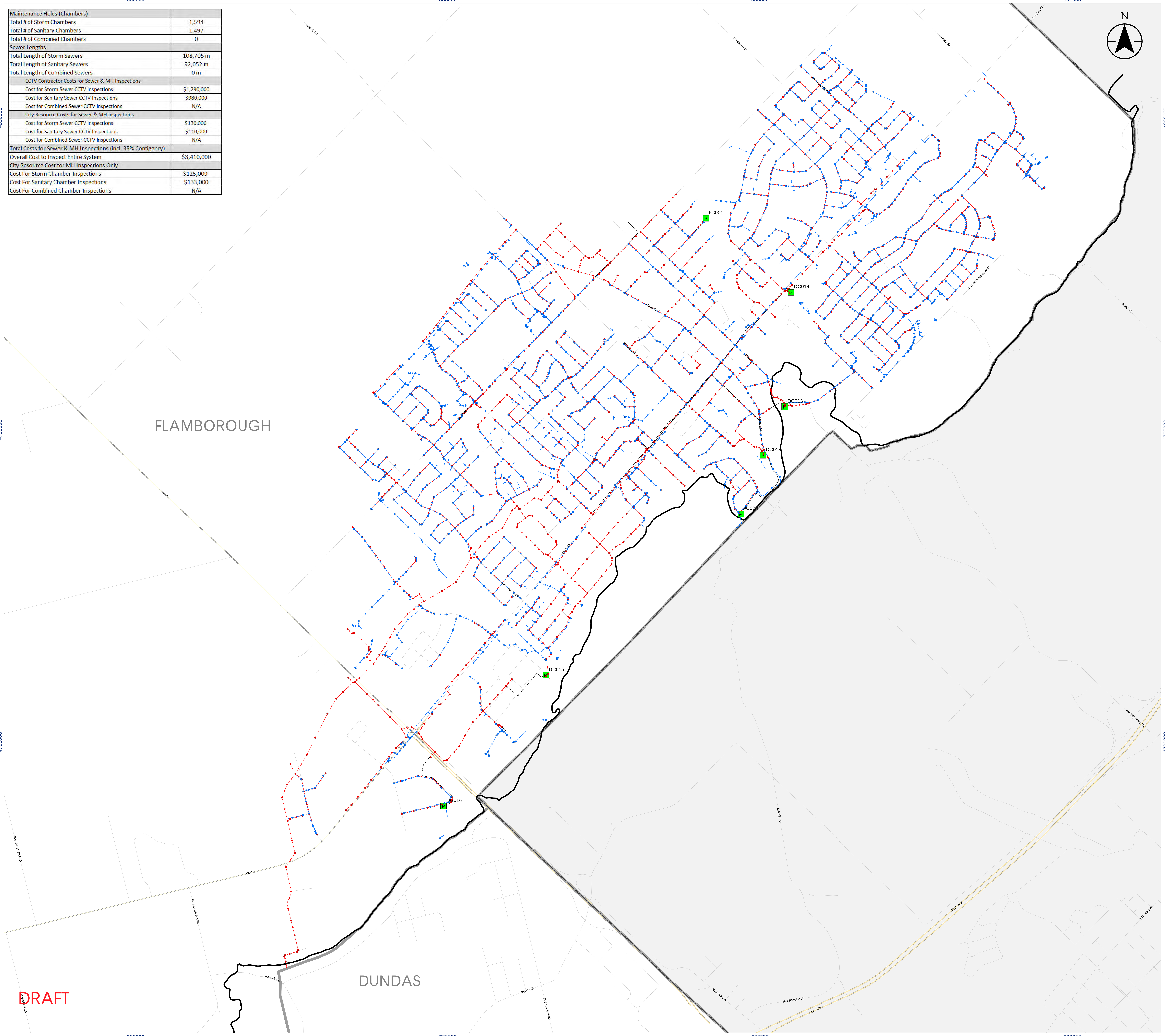
Client/Project: City of Hamilton, MECP Spills Order

Figure No. 1.3

DRAFT

Title: Trunk Sewer Network Combined Sewer Area

Maintenance Holes (Chambers)	
Total # of Storm Chambers	1,594
Total # of Sanitary Chambers	1,497
Total # of Combined Chambers	0
Sewer Lengths	
Total Length of Storm Sewers	108,705 m
Total Length of Sanitary Sewers	92,052 m
Total Length of Combined Sewers	0 m
CCTV Contractor Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$1,290,000
Cost for Sanitary Sewer CCTV Inspections	$980,000
Cost for Combined Sewer CCTV Inspections	N/A
City Resource Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$130,000
Cost for Sanitary Sewer CCTV Inspections	$110,000
Cost for Combined Sewer CCTV Inspections	N/A
Total Costs for Sewer & MH Inspections (incl. 35% Contigency)	
Overall Cost to Inspect Entire System	$3,410,000
City Resource Cost for MH Inspections Only	
Cost For Storm Chamber Inspections	$125,000
Cost For Sanitary Chamber Inspections	$133,000
Cost For Combined Chamber Inspections	N/A



Stantec

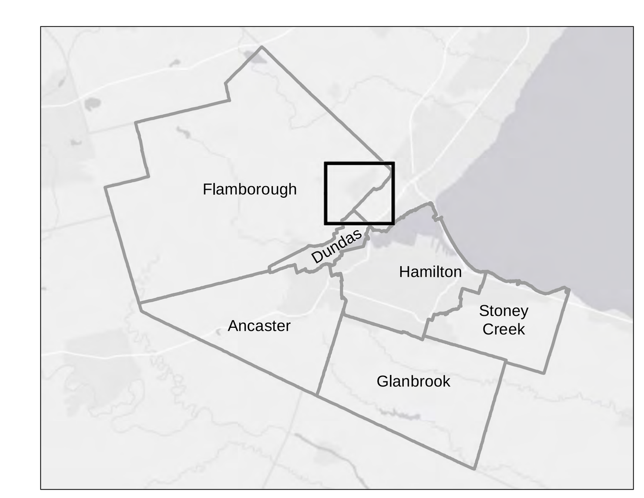
Legend

- Storm Manhole
- Sanitary Manhole
- Sanitary Pumping Station
- Storm Sewer
- Sanitary Sewer
- Escarpment
- City Boundary
- Community Boundary

0 200 400 metres

1:8,000 (At original document size of 34x44)

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



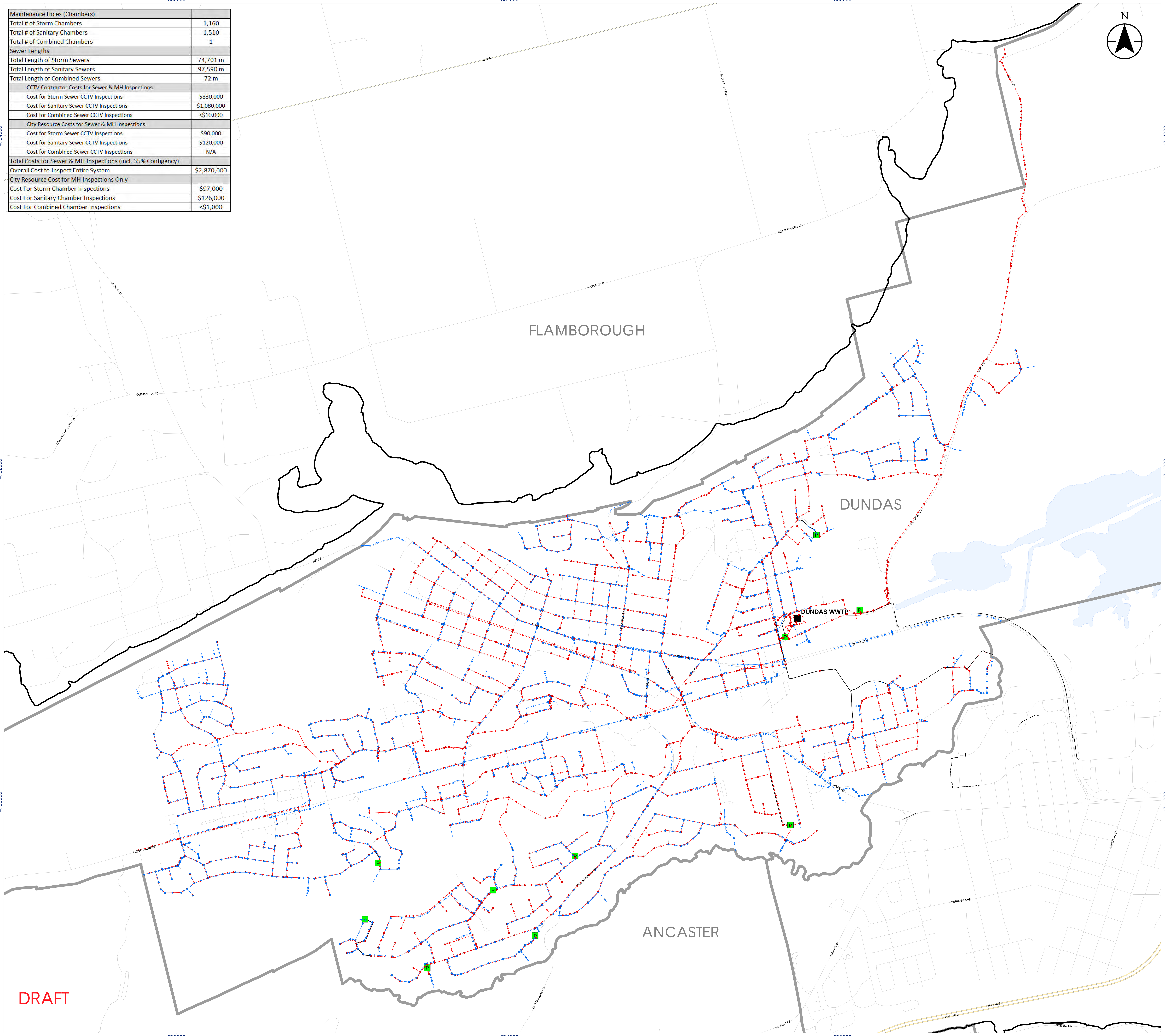
Project Location 163401837
City of Hamilton
Prepared by EH on 2023-04-24

Client/Project
City of Hamilton
MECP Spills Order

Figure No.
2.1
DRAFT

Title
Community Sewer Network
Flamborough

Maintenance Holes (Chambers)	
Total # of Storm Chambers	1,160
Total # of Sanitary Chambers	1,510
Total # of Combined Chambers	1
Sewer Lengths	
Total Length of Storm Sewers	74,701 m
Total Length of Sanitary Sewers	97,590 m
Total Length of Combined Sewers	72 m
CCTV Contractor Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$830,000
Cost for Sanitary Sewer CCTV Inspections	$1,080,000
Cost for Combined Sewer CCTV Inspections	<$10,000
City Resource Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$90,000
Cost for Sanitary Sewer CCTV Inspections	$120,000
Cost for Combined Sewer CCTV Inspections	N/A
Total Costs for Sewer & MH Inspections (incl. 35% Contigency)	
Overall Cost to Inspect Entire System	$2,870,000
City Resource Cost for MH Inspections Only	
Cost For Storm Chamber Inspections	$97,000
Cost For Sanitary Chamber Inspections	$126,000
Cost For Combined Chamber Inspections	<$1,000



Stantec

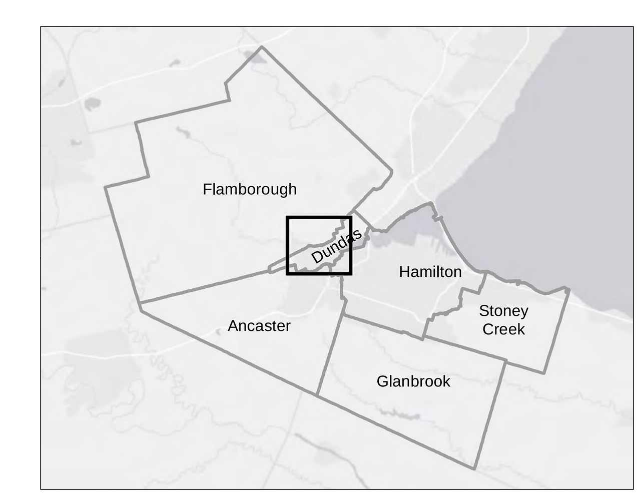
Legend

- Wastewater Treatment Plant
- Storm Chamber
- Sanitary Chamber
- Combined Chamber
- Sanitary Pumping Station selection
- Storm Sewer
- Sanitary Sewer
- Combined Sewer
- Escarpment
- City Boundary
- Community Boundary

0 200 400 metres

1:7,500 (At original document size of 34x44)

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Project Location 163401837

City of Hamilton

Prepared by EH on 2023-04-24

Client/Project

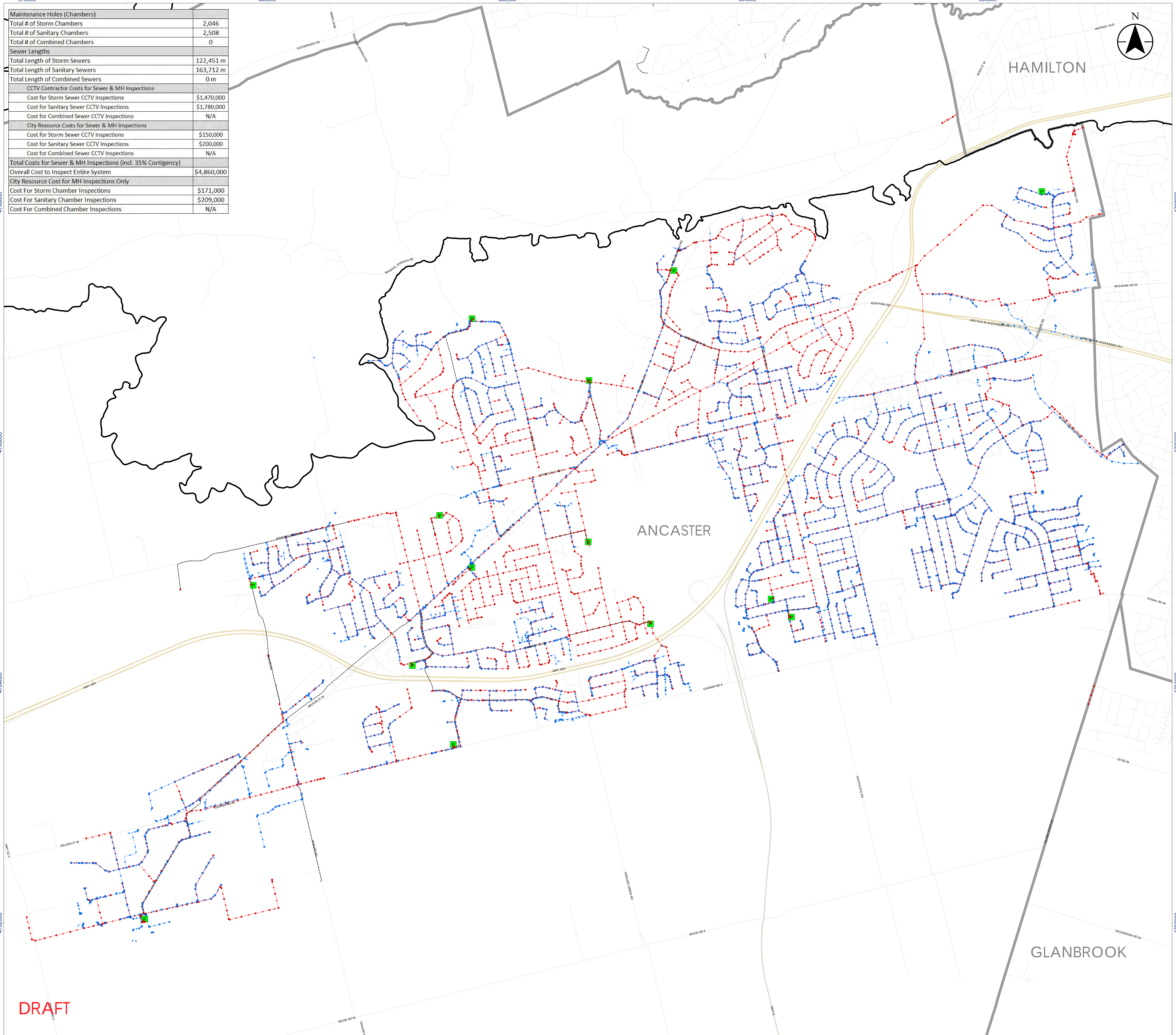
City of Hamilton
MECP Spills Order

Figure No.
2.2

DRAFT

Title
Community Sewer Network
Dundas

Maintenance Holes (Chambers)	
Total # of Storm Chambers	2,046
Total # of Sanitary Chambers	2,508
Total # of Combined Chambers	0
Sewer Lengths	
Total Length of Storm Sewers	122,451 m
Total Length of Sanitary Sewers	163,712 m
Total Length of Combined Sewers	0 m
CCTV Contractor Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$1,470,000
Cost for Sanitary Sewer CCTV Inspections	$1,780,000
Cost for Combined Sewer CCTV Inspections	N/A
City Resource Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$150,000
Cost for Sanitary Sewer CCTV Inspections	$200,000
Cost for Combined Sewer CCTV Inspections	N/A
Total Costs for Sewer & MH Inspections (incl. 35% Contigency)	
Overall Cost to Inspect Entire System	$4,860,000
City Resource Cost for MH Inspections Only	
Cost For Storm Chamber Inspections	$171,000
Cost For Sanitary Chamber Inspections	$209,000
Cost For Combined Chamber Inspections	N/A



Stantec

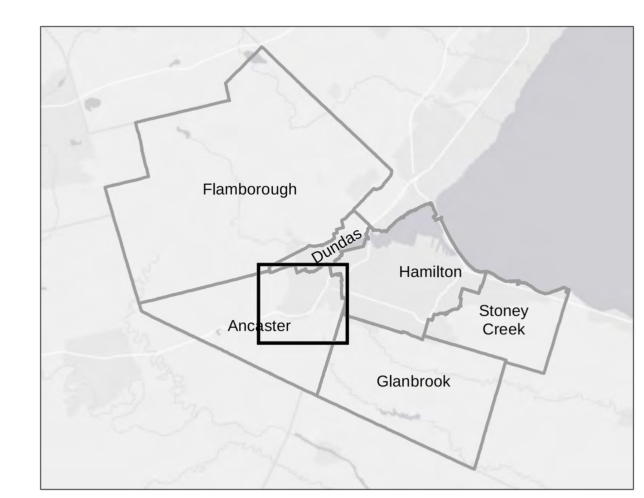
Legend

- Storm Chamber
- Sanitary Chamber
- Sanitary Pumping Station
- Storm Sewer
- Sanitary Sewer
- Escarpment
- City Boundary
- Community Boundary

0 200 400 metres

1:10,500 (At original document size of 34x44)

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



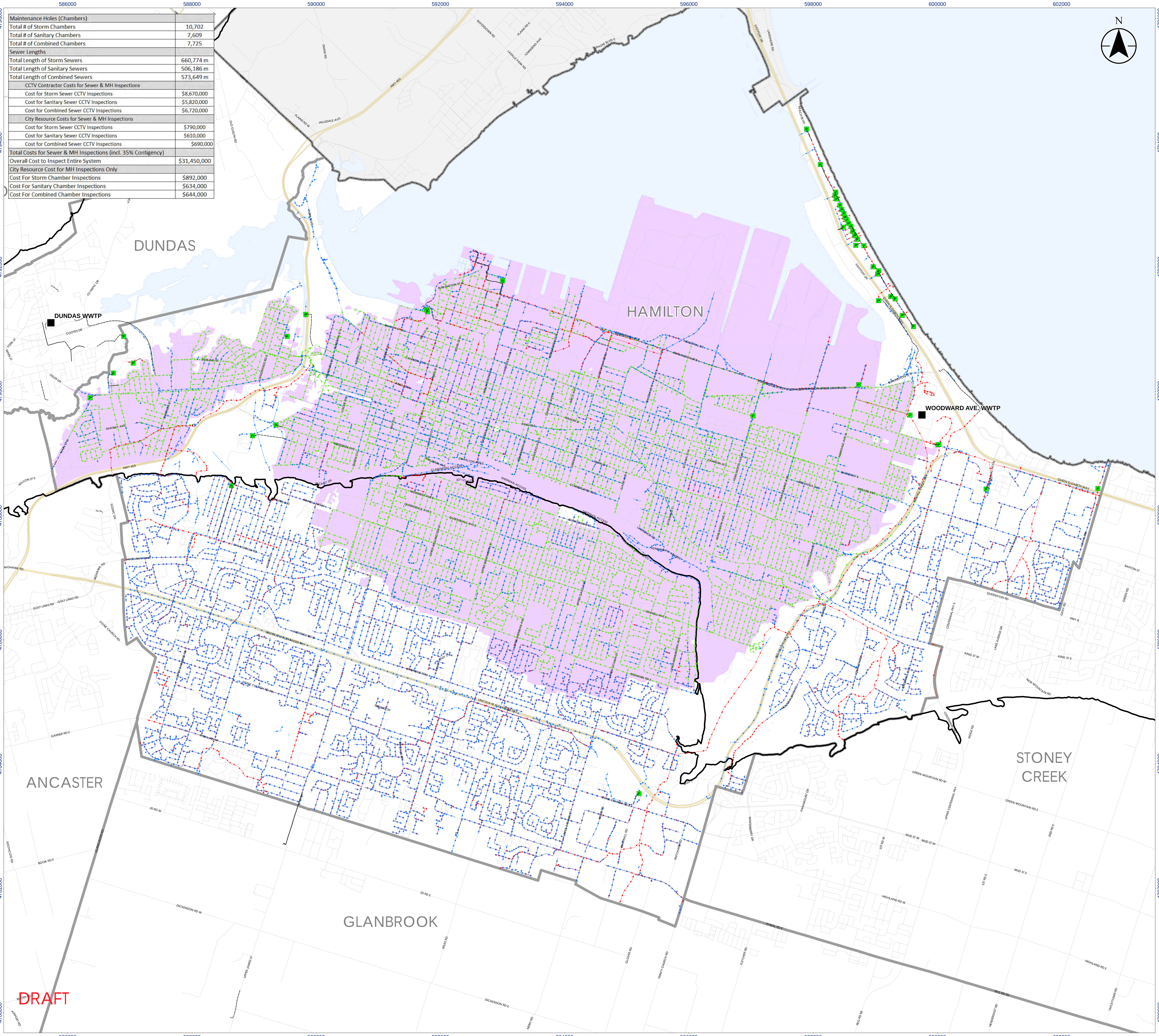
Project Location: City of Hamilton | 163401837 | Prepared by EH on 2023-04-24

Client/Project: City of Hamilton, MECP Spills Order

Figure No. 2.3 DRAFT

Title: Community Sewer Network Ancaster

Maintenance Holes (Chambers)	
Total # of Storm Chambers	10,702
Total # of Sanitary Chambers	7,609
Total # of Combined Chambers	7,725
Sewer Lengths	
Total Length of Storm Sewers	660,774 m
Total Length of Sanitary Sewers	506,186 m
Total Length of Combined Sewers	573,649 m
CCTV Contractor Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$8,670,000
Cost for Sanitary Sewer CCTV Inspections	$5,820,000
Cost for Combined Sewer CCTV Inspections	$6,720,000
City Resource Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$790,000
Cost for Sanitary Sewer CCTV Inspections	$610,000
Cost for Combined Sewer CCTV Inspections	$690,000
Total Costs for Sewer & MH Inspections (incl. 35% Contigency)	
Overall Cost to Inspect Entire System	$31,450,000
City Resource Cost for MH Inspections Only	
Cost For Storm Chamber Inspections	$892,000
Cost For Sanitary Chamber Inspections	$634,000
Cost For Combined Chamber Inspections	$644,000



Stantec

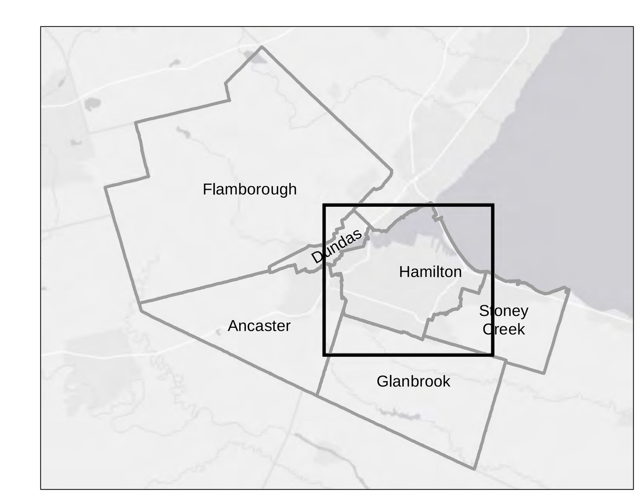
Legend

- Wastewater Treatment Plant
- Sanitary Pumping Station

0 500 1,000 metres

1:20,000 (At original document size of 34x44)

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



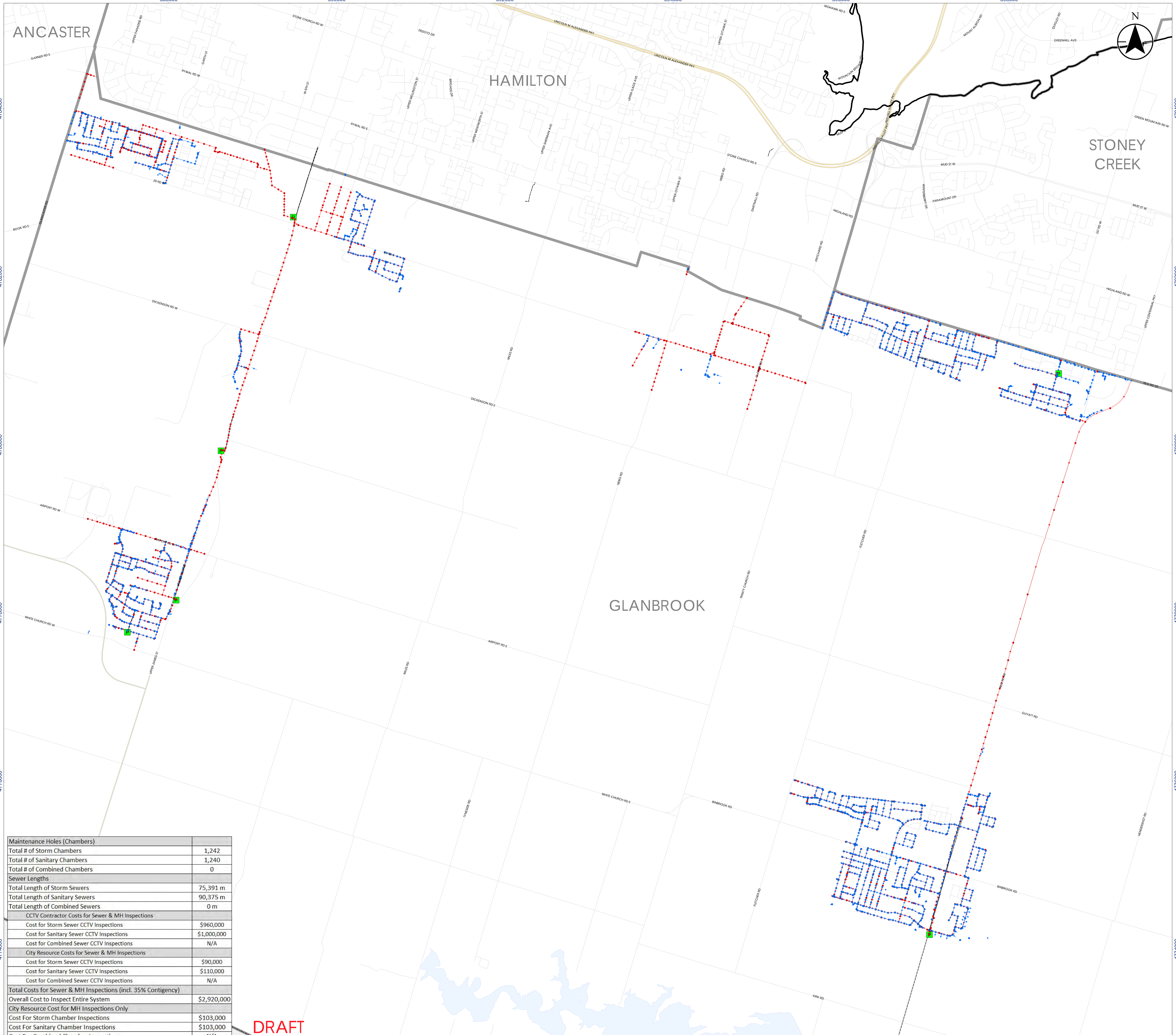
Project Location: City of Hamilton — 163401837

Prepared by EH on 2023-04-24

Client/Project: City of Hamilton, MECP Spills Order

Figure No. 2.4 — DRAFT

Title: Community Sewer Network Hamilton



Maintenance Holes (Chambers)	
Total # of Storm Chambers	1,242
Total # of Sanitary Chambers	1,240
Total # of Combined Chambers	0
Sewer Lengths	
Total Length of Storm Sewers	75,391 m
Total Length of Sanitary Sewers	90,375 m
Total Length of Combined Sewers	0 m
CCTV Contractor Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$960,000
Cost for Sanitary Sewer CCTV Inspections	$1,000,000
Cost for Combined Sewer CCTV Inspections	N/A
City Resource Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$90,000
Cost for Sanitary Sewer CCTV Inspections	$110,000
Cost for Combined Sewer CCTV Inspections	N/A
Total Costs for Sewer & MH Inspections (incl. 35% Contigency)	
Overall Cost to Inspect Entire System	$2,920,000
City Resource Cost for MH Inspections Only	
Cost For Storm Chamber Inspections	$103,000
Cost For Sanitary Chamber Inspections	$103,000
Cost For Combined Chamber Inspections	N/A

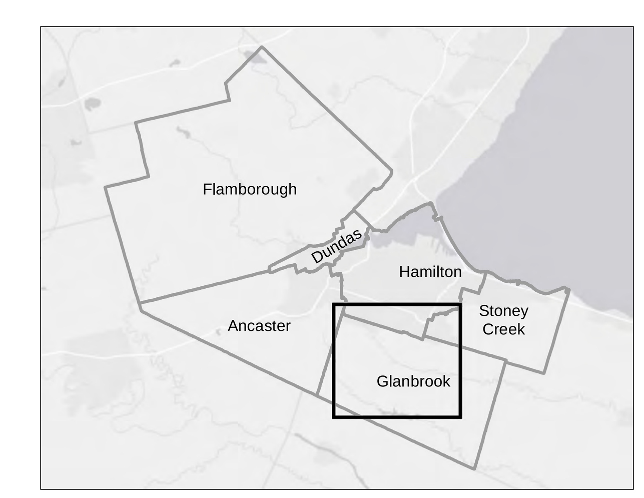
Stantec

Legend
- Storm Chamber
- Sanitary Chamber
- Sanitary Pumping Station
- Storm Sewer
- Sanitary Sewer
- Escarpment
- City Boundary
- Community Boundary

0 500 1,000 metres

1:15,000 (At original document size of 34x44)

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Project Location: 163401837
City of Hamilton
Prepared by EH on 2023-04-24

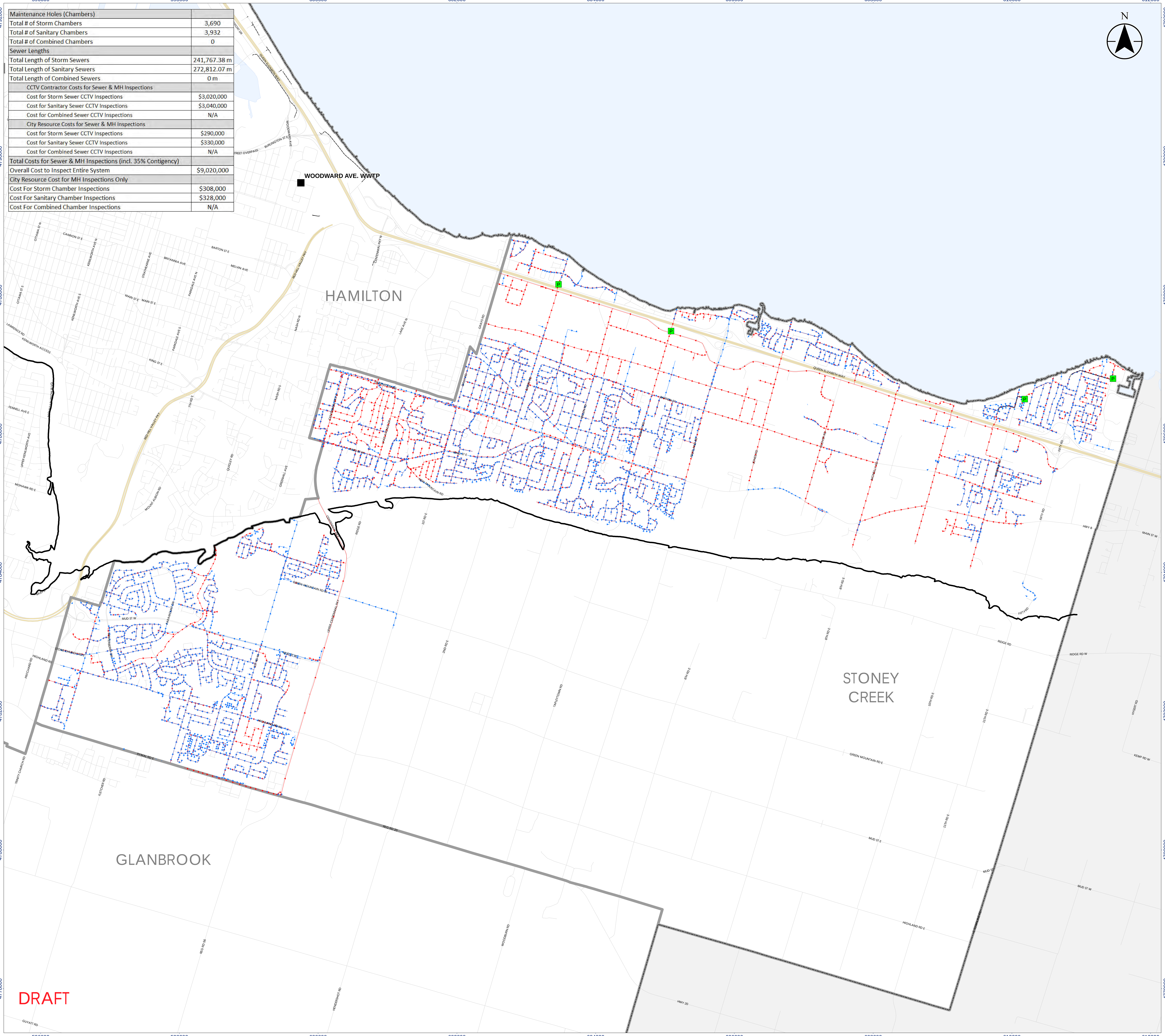
Client/Project
City of Hamilton
MECP Spills Order

Figure No.
2.5 DRAFT

Title
Community Sewer Network
Glanbrook

\\Ca0218-ppfs01\01-634\active\1634_01837\planning\drawing\GIS\mxd\working\163401837_Fig2_5_Glanbrook.mxd Revised: 2023-04-24 By: ehewko

Maintenance Holes (Chambers)	
Total # of Storm Chambers	3,690
Total # of Sanitary Chambers	3,932
Total # of Combined Chambers	0
Sewer Lengths	
Total Length of Storm Sewers	241,767.38 m
Total Length of Sanitary Sewers	272,812.07 m
Total Length of Combined Sewers	0 m
CCTV Contractor Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$3,020,000
Cost for Sanitary Sewer CCTV Inspections	$3,040,000
Cost for Combined Sewer CCTV Inspections	N/A
City Resource Costs for Sewer & MH Inspections	
Cost for Storm Sewer CCTV Inspections	$290,000
Cost for Sanitary Sewer CCTV Inspections	$330,000
Cost for Combined Sewer CCTV Inspections	N/A
Total Costs for Sewer & MH Inspections (incl. 35% Contigency)	
Overall Cost to Inspect Entire System	$9,020,000
City Resource Cost for MH Inspections Only	
Cost For Storm Chamber Inspections	$308,000
Cost For Sanitary Chamber Inspections	$328,000
Cost For Combined Chamber Inspections	N/A



Stantec

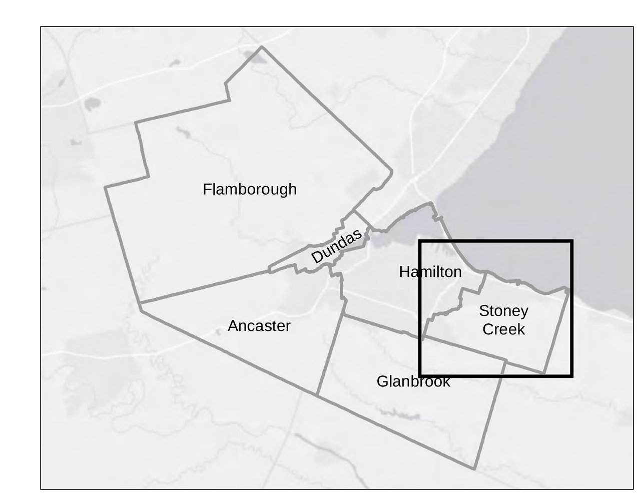
Legend

- Wastewater Treatment Plant
- Sanitary Pumping Station
- Storm Sewer
- Sanitary Sewer
- Escarpment
- City Boundary
- Community Boundary

0 500 1,000 metres

1:18,000 (At original document size of 34x44)

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



Project Location 163401837
City of Hamilton
Prepared by EH on 2023-04-24

Client/Project
City of Hamilton
MECP Spills Order

Figure No.
2.6
DRAFT

Title
Community Sewer Network
Stoney Creek