INTEGRATED SANITARY MASTER PLAN
Municipal Class Environmental Assessment –
Volume 2 (Technical Memorandums)

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Prepared for:
City of Kitchener

Prepared by:
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City of Kitchener Integrated Sanitary Master Plan – Technical Memo #5: Design Criteria & Level of Service

TM 5

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Sign-off Sheet

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1.0 Introduction

The City of Kitchener (City) is completing an Integrated Sanitary Master Plan (ISAN-MP). The purpose of the ISAN-MP is to develop an overall master plan to guide the future needs of the City for growth development and infrastructure renewal to account for updated population and employment growth projections to the 2051 planning horizon, building on the work/studies previously completed and integrating available information from ongoing studies/programs. Following the Municipal Class Environmental Assessment (EA) Process, priority and strategic projects will be evaluated to continue to efficiently and effectively operate the system, implement best management practices (including growth tracking and digital innovation), and sustainable staging and funding of wastewater capital projects.

The following tasks are being carried out for the completion of the ISAN-MP, including a series of Technical Memoranda (TM) that will comprise the content of the final Master Plan document (note that Task 3, 4 and 6 have been consolidated into a single TM#3):

Task 1: Background Data Review (TM#1)
Task 2: Hydraulic Analysis (TM#2)
Task 3: Sanitary Servicing Analysis (TM#3)
Task 4: Capital Infrastructure Funding and Risk Analysis (TM#3)
Task 5: Design Criteria, Level of Service & Sensitivity Analysis (TM#5)
Task 6: Growth Management and Implementation Plan (TM#3)
Task 7: Communications and Community Engagement
Task 8: Sanitary Servicing Master Plan / Innovation Strategy

1.1 Overview of TM#5

The work of the preceding Technical Memoranda #1 and #2 provide the background and basis for hydraulic assessment in the ISAN-MP, establishing the updated hydraulic model for use in evaluation of system capacity over existing and future growth scenarios in Task 3. Task 5 involves a review of the current design criteria documents / sources of information used to guide the sizing of new / replaced sanitary infrastructure, and for the assessment of system performance relative to a preferred service level provided to municipal customers with consideration to sensitivity analysis for resiliency to impacts of climate change.

This document summarizes the available data sources and current sanitary sewer / pump station design criteria, and level-of-service (LOS) considerations typically applied in the City and Ontario municipalities. The information is contrasted against the Ministry of Environment (MECP) criteria, with recommendations for improvements where required. In this document, there is a distinction between design criteria as applied to new developments and the sizing of new pipes (i.e., typical design sheet methodology), versus system-wide LOS performance and Master Planning triggers for infrastructure upgrades as assessed with the City's dynamic hydraulic model. Section 2 speaks to standard design sheet methodologies in support of development applications and pipe sizing and pump station capacity, while Section 3 speaks to the metrics used in this Master Plan for pipe and pump station assessment and triggers for upgrades.

2.0 Sanitary Collection System Criteria

The following subsections outline the specific criteria reviewed pertaining to sanitary sewer and pump station design. The referenced sources are listed in **Table 2-1**, complete with reference ID that is used throughout this document.

Table 2-1: Sanitary Collection System Criteria Documents

Ref. ID	Title	Author	Year
KDM	Kitchener Development Manual	City of Kitchener	2021
DGSSMS	Region of Waterloo and Area Municipalities Design Guidelines and Supplemental Specifications for Municipal Services	BMP Technical Sub-Committee, Region of Waterloo	2023
KSS	Kitchener Standard Specifications	City of Kitchener	2020
KPF	Kitchener Design Standards and Procedures Manual: Wastewater Pumping Facilities	City of Kitchener	2022
MECP (2008)	Design Guidelines for Sewage Works (for Pump Stations only)	MECP	2008
MECP (2023)	Design Criteria for Sanitary Sewers, Storm Sewers and Forcemains for Alterations Authorized under an Environmental Compliance Approval	MECP	2023

It is noted that the KDM refers to the DGSSMS for all criteria and only indicates specific values where the City deviates from the DGSSMS. Since 2021, the MECP has adopted a Consolidated Linear Infrastructure Permissions Approach (CLI) for low-risk projects related to sanitary collection and stormwater management, which replaces the previous "pipe by pipe" Certificate of Authorization (CoA) approach. Effectively, the CLI is a pre-authorization that allows municipalities to proceed with certain collection system alterations without first obtaining individual Ministry permission, as long as the work is carried out in accordance with the requirements of the municipality's CLI Environmental Compliance Approval (ECA), including meeting MECP design criteria (Version 2.0, dated May 31, 2023), found at the following City of Kitchener link: (https://www.kitchener.ca/en/resourcesGeneral/Documents/INS_SSU_Design_Criteria.pdf).

The City of Kitchener ECA number is 019-W601, granted January 29, 2023, which is found at the following link: https://www.kitchener.ca/en/resourcesGeneral/Documents/INS_SSU_ECA_019-W601.pdf

2.1 Design Sewage Flows

2.1.1 Local vs. Trunk System

The City of Kitchener designates trunk sewers as pipes with 375 mm diameter and larger. Therefore, local sewers are less than 375 mm diameter. The City's GIS Asset data provides an indication of the sub-drainage area related to the defined trunk sewersheds (e.g., Upper Schneider – Sandrock), which helps to communicate tributary connectivity and location within the trunk sewershed.

2.1.2 Drainage Area

There is limited reference to the basis of establishing drainage areas in the background documents. As noted in TM2, the definition of the drainage area is a critical component for both the establishment of consistent assessment for sanitary flow generation and infiltration and inflow unit rates. Typically, drainage areas are assessed for new or re-development based on the parcel fabric with extension across road right-of-ways, based generally on a maintenance hole-to-maintenance hole delineation. With the modifications to the system-wide hydraulic model set-up, which is based on Parcel-Based subcatchments for development and a Buffer-Based subcatchment for rainfall-derived infiltration and inflow (RDII), there is opportunity to promote consistency in the application of area extents for both private and system-wide assessments. At the development application level, use of the Parcel-Based subcatchments is recommended for both population and RDII design sheet calculations. Depending on the type of development (greenfield vs. infill), there may be cases where an area less than the parcel size is more appropriate for generating reasonable RDII (e.g., around trunk sewers with no service connections), and the Buffer-based area approach of using 45 m surrounding gravity pipes should be used.

2.1.3 Domestic Sewage Flows

Table 2-2 presents a comparison of the domestic (residential) sewage generation rate criteria within the reference documents, with section numbers indicated.

Table 2-2: Domestic Sewage Generation Rates

Criterion	**MECP** (2023)	**DGSSMS** (B.3.1.2.1)	**KDM** (E.1.1)
Per Capita Rate (L/c/d)	2.1.1: 225-450	275[1]	305
Population	Not referenced	Actual or Projected based on data (zoning or other) from City[1]	Table 4 by Zoning Category, in People/ha[2] Persons/unit densities are not to be used
Peaking Factor	2.1.6: Harmon or Babbitt Min. PF = 2	Harmon	Harmon

1. Kitchener Deferred to Chief Municipal Engineer (KDM)
2. See Appendix A for Table 4 of the KDM

The value selected by Kitchener (305 L/c/d) is within the acceptable range of the MECP, and is higher than the DGSSMS. For reference, the Region of Waterloo indicates an average flow per capita at the Kitchener Wastewater Treatment Plant (WWTP) in the 250 L/c/d range. However, this includes factors such as RDII and industrial commercial institutional (ICI) contributions that can skew the resulting per capita rate, and therefore cannot be directly compared to domestic sewage generation. Flow monitoring data was compared as part of this ISAN-MP revealing a range of rates from 60 to 200 L/c/d, which is generally less than the design value. It is noted that this rate assumes the removal of dry weather groundwater infiltration, which along with population assumptions are variables subject to uncertainty and change over time. While the KDM value is relatively high, it is recommended that in the interest of continuity and defining a factor of safety in the sizing of new infrastructure, that the City maintain 305 L/c/d for new design purposes.

The difference between conservatism for sizing new pipes and being over-conservative in the assessment of the downstream impacts is an important consideration. For intensification projects, some municipalities apply a lower more reasonable per capita rate in the assessment of downstream capacity, while sizing the internal sewer infrastructure per the full rate. Given the intended use of the hydraulic model for development applications and designs, the calibrated per capita parameters will be used for the existing system, and new developments will apply a design per capita rate.

Population data is available through the City’s planning group, at the parcel level, which was used to establish the hydraulic model set-up. For development applications, the method of population calculation through the use of per hectare Zoning allocations is reasonable for greenfield development. For intensification, consideration for using more refined unit rates on a gross floor area (GFA) basis may be warranted, which accounts for the site-specific buildings independent of their parcel size.

Use of the Harmon Peaking Factor can remain for sizing of new sewers. For assessing the impacts to the overall downstream collection system, the dynamic hydraulic model should be used with direct population input as indicated in Section 3.

2.1.4 ICI Sewage Flows

Table 2-3 presents a comparison of industrial-commercial-institutional (ICI) generation rates.

Table 2-3: ICI Sewage Generation Rates

Criterion	MECP[1] (2023)	DGSSMS (B.3.1.2)	KDM
Industrial	2.1.4: Actual sanitary flow monitor data for min. 2-years; otherwise, average flow of 0.20 to 0.64 L/s/gross ha	0.40 L/s/ha	Defers to DGSSMS
Commercial - Core	2.1.2: Actual sanitary flow monitor data for min. 2-years; otherwise, minimum 28 m^3/gross ha/day	0.95 L/s/ha	
Commercial – Mall		0.30 L/s/ha	
Commercial - General		0.50 L/s/ha	
Institutional	2.1.3: Historical water use for min. 2-years of similar facility. Table 1 of MECP can be used. Designer to use professional judgment	0.25 L/s/ha	
Institutional – Hospital Bed		0.015 L/s/bed	
1. See Appendix A for Table 1 of the MECP with Various Commercial/Institutional Rates			

For design sheet analysis, the area-based flow rates in the DGSSMS may be used; however, it is recommended that where available the equivalent population approach be maintained for consistency of input with the hydraulic model. Exceptions may be required for known specific high-water users with return to the collection system, depending on location and sensitivity of the receiving sewer.

2.1.5 Extraneous Flow

Extraneous flow is a catch-all term for any storm or groundwater related input into the sanitary sewer system. When discussed in the design context, this relates to an allowance for the long-term leakage that can be expected to occur towards the end of service life for the pipe. It is not intended as an acceptable allowance for this flow to occur immediately after pipe construction. New sewer construction should not be susceptible to major extraneous or illicit sources of water that would have occurred in historic construction that predates the 1980s. Roof downspouts, private drains and foundation drainage are not permitted to be connected to the sanitary sewer system. However, replacement sewers in older parts of the system that predate 1980 may still receive foundation drainage via sump pump discharge. **Table 2-4** presents the comparison of published values.

Table 2-4: Extraneous Flow Generation Rates

Criterion	MECP (2023)	DGSSMS	KDM
Extraneous Flow	2.1.5: up to 0.28 L/s/ha	B.3.1.2.5: 0.25 L/s/ha	E.1.2: 0.15 L/s/ha
Foundation Drainage	Foundation drains are not permitted to be connected to the sanitary sewer system		

Kitchener's allowance is less than the DGSSMS and MECP, but it is important to contrast that against the higher per capita rate used for flow generation. With the use of the hydraulic model calibrated to flow monitoring data, the importance of the impact of the allowance on the overall system is reduced since extraneous flow is captured more directly and associated with varying rainfall. For design purposes, and if using the overall parcel as the basis for the area calculation, the use of 0.15 L/s/ha is recommended to remain. See discussion on drainage areas in Section 2.1.2.

2.2 Design of Sewers

In general, the design of sewers is captured by the MECP Guidelines that provide the overarching minimum standard that is superseded by the Regional and Municipal guidelines. The Mannings equation is uniformly recommended for use in Ontario for the sizing of sewers and assessment of pipe capacity.

2.2.1 Pipe Criteria

Table 2-5 compares the sanitary pipe design criteria from the reference documents. In general, the sewer design criteria are similar to the MECP Guidelines. The flow velocities comply with the MECP Guidelines, with additional considerations for subcritical flow.

Table 2-5: Comparison of Sanitary Pipe Design Criteria

Criterion	**MECP** (2023)	DGSSMS	KDM
Min. Pipe Size	2.3: 200 mm (150 mm is acceptable if it is demonstrated in the design that there is no risk of clogging, and the design is accepted by the Owner)	B.3.1.4: Per MECP	Defer to DGSSMS
Min. Pipe Slope	-	B.3.1.6: 1st Reach: 1.0% All Other Pipes: 0.5%	E.1.3: 1st Reach: per DGSSMS All Other: As a function of flow velocity
Velocities	2.4: Min: 0.6 m/s when flowing full Max: 3.0 m/s	B.3.1.7: Per MECP	E.1.4: Min: 0.8 m/s when flowing full Max: 3.0 m/s
Pipe Depth	2.8: Installed at sufficient depth to prevent freezing, considering traffic load and manufacturer recommendations	B.3.1.10: Min. 2.8 m to Obvert > 5.0 m may require secondary shallow sewer	E.1.5: Per DGSSMS
Capacity Ratio	-	-	E.1.2: Local: <95% Pipe Full Capacity Trunk: <85% Pipe Full Capacity
Roughness	2.2: 0.013	B.3.1.5: 0.013	Defer to DGSSMS

Considerations:

- Add that the pipe should be ideally designed to convey the peak design flow at no greater than 80% d/D, to allow for air movement in the open channel.
- Adding clarity that velocities should also be checked against Actual Flow velocity in addition to theoretical Pipe Full, to flag potential operational issues when pipes do not frequently flow full.
- Adding a section related to Construction Dewatering requirements, and assessment of impact on downstream collection system.
- Systemwide Level of Service is discussed further in Section 3

2.2.2 Maintenance Hole Criteria

Table 2-6 presents a comparison of the maintenance hole (MH) criteria.

Table 2-6: Comparison of Sanitary MH Design Criteria

Criterion	**MECP** (2023)	DGSSMS	KDM
Minimum Invert Drops	2.10.4: Based on bend angle: 0˚: 0.025 m 45˚ Turn: 0.03 m 90˚ Turn: 0.05 m Sewer grade may be maintained across maintenance holes provided minimum required flow velocity is maintained	B.3.2.6: 0˚ – 45˚: 0.030 m 45˚ – 90˚: 0.060 m	Defer to DGSSMS
Change in Flow Direction	-	B.3.2.9: Must be less than 90˚ Pipes 675mm or greater must be less than 45˚	Defer to DGSSMS
Benching	-	D.3.3.4: All sanitary MHs benched to springline Slope: 8%	Defer to DGSSMS
Drop Structures	2.10.6: Drop should be provided for sewer entering ≥610mm above MH invert External drop connection preferred; internal drops if necessary to be secured to interior wall of MH for access and cleaning Where drop not feasible, alternative methods of energy dissipation and minimizing air entrainment and odour problems to be specified	B.3.2.4: Defers to MECP Only external drops allowed	Only external drops allowed
Change in Pipe Size	2.10.5: When smaller sewer joins larger one, invert of larger sewer should be lowered sufficiently to maintain the same energy gradient, or pipe obverts are matched	-	-

Criterion	**MECP** (2023)	**DGSSMS**	**KDM**
Minimum Diameter	2.10.11: 1200mm Maintenance holes shall be designed based on the pipe size, alignment, and inspection and maintenance needs; minimum access diameter of 610mm required	B.3.2.3: 1200mm	Defer to DGSSMS
Maximum Spacing	2.10.1: 400mm = <120 m 450mm-750mm = <150m	B.3.2.2: 200mm – 450mm = 90 m >450mm – 900mm = 120 m >900mm = at approval of Chief Municipal Engineer	Defer to DGSSMS
Lids	2.10.7: Located away from any route or ponding area. Grading around MH to shed water away from lidd	B.3.2.8: Where there is a possibility of surface flood water ingress, watertight lids shall be installed	-

The following recommendation are proposed:

- Benching standard be extended to the top of the pipe, to improve flow hydraulics through the MH.
- Consider adding section in KDM re: location of maintenance lids: Siting of sanitary maintenance holes shall consider the possibility of excess surface water ingress either from surface ponding due to a pre-existing local drainage condition, a planned stormwater management strategy, or position within a floodplain or area subject to frequent flooding. Where there is risk of surface water ingress and there is no opportunity to realign the sewer, sanitary maintenance hole design shall mitigate the potential for inflow through watertight lids and/or raising of the maintenance hole above the floodplain if feasible.

2.3 Design of Pump Stations

There are many facets to pump station design criteria as outlined in the KPF. Select criteria relative to this Master Plan are presented in **Table 2-7**.

Table 2-7: Pump Station Criteria

Criterion	**MECP** (7.2.3) (2008)	**KPF**
Design Flow	Multiple pumps should be provided. Where only two pumps, they should be of equal size and provide a Firm Capacity (one pump out of service) to handle at least the 10-yr peak hourly flow	2.1: Pumping Facilities should be able to pump 10-yr peak flows with the largest capacity pump out of operation. For a two-pump station, each pump should have sufficient capacity to handle the peak flows. For three-pump stations or larger, with the largest pump out of operation, the remaining pumps operating in parallel should convey the peak flows.

Criterion	**MECP** (7.2.3) (2008)	KPF
Pump Sizing	Min. Dia. = 80 mm Min. Dia. Suction & Discharge Opening=100 mm	2.7.1: Min. Dia. = 75 mm
Hazen-Williams C-Factor	Low Sewage Level: C = 120 Median Sewage Level: C = 130 Overflow Sewage Level: C = 140	Same as MECPP
Protection	Pumps receiving flow from >= 750 mm pipes to be protected by bar racks Pumps receiving flow from smaller pipes to be protected from clogging	2.7.10: Grinders to be installed to protect pumps from clogging or damage. Where size warrants, a mechanically cleaned bar screen with grinder or compaction device is recommended.
Forcemain Sizing	Firm design capacity should be based on design peak instantaneous flow and should be adequate to maintain a minimum velocity of 0.6 m/s in the forcemain	2.6.5: ≥ 100 mm 2.6.1: Velocities should be in the range of 0.8 to 2.5 m/s, with the lower limit preferred for the initial phase
Emergency Storage	7.7.3: Controlled, high-level wet well overflow to be provided for use during possible periods of extensive power outage or uncontrollable emergency conditions	2.2.3: Storage to be provided for 1-hr time to overflow, calculated under peak flow (10-yr) conditions

3.0 Sanitary Collection System Level of Service

The design criteria presented informs and provides preferred direction for new or infill development related infrastructure. It is also very important to understand how new or increased flows impact the performance of existing infrastructure. This type of capacity assessment can be referred to as a Level of Service (LOS) analysis.

Level of Service, however, is not a universally defined term in the collection system industry. The USEPA defines LOS as: "Characteristics or attributes of a service that describe its required level of performance. These characteristics typically describe how much, of what nature, and how frequently about the service." LOS is intrinsically tied to Asset Management (AM), where various levels of LOS targets are established to roll up to meet higher level municipality-wide strategic targets, such as Kitchener's Strategic Plan or Corporate Climate Action Plan. AM is an integrated and data-driven approach to effectively manage existing and proposed assets. Generally, AM is intended to maximize benefits, reduce risk, and provide expected LOS to the community in a sustainable manner.

Ontario's Asset Management legislation, O. Reg. 588/17, provides a definition for legislated Community and Technical levels of service for core assets as follows:

- Community LOS: qualitative descriptions, images or maps that describe the end-user experience.
- Technical LOS: quantitative metrics that describe what the municipality provides.

From a sanitary servicing perspective, Community LOS takes the form of drainage area and sewer coverage mapping, publicly available educational materials on the collection system purpose and operation, and an explanation on the reliability of the service (i.e., resiliency to RDII). In this regard, the City's website provides general information on the sanitary sewer system:

- https://www.kitchener.ca/en/water-and-environment/sanitary-sewer-system.aspx
- https://www.kitchenerutilities.ca/en/rates/water-and-sewer-rates.aspx

From a Technical LOS perspective, the ISAN-MP seeks to establish appropriate metrics to inform the triggers for capital planning investment and phasing, factoring in resiliency to aging infrastructure, the effects of infiltration and inflow on sewer infrastructure performance, and impacts of climate change. The following sub-sections outline the current capacity-related LOS metrics for the sanitary utility.

The City's Corporate Asset Management Policy provides the following discussion on LOS:

> *An important component of developing detailed asset management plans is to correlate the cause and effect of operational and maintenance activities to the infrastructure and to what degree the activities need to continue to meet the agreed upon level of service. As well, sustainability/lifecycle cost performance indicators are crucial to embed into on-going operational activities and measurements. A balance must be struck between maintaining the current condition/health of the asset versus activities directly related to providing services. Not having*

effective levels of service lead to reactive management and potentially to high social, environmental and financial costs. The emphasis is to define, develop and implement a level of service framework that results in a consistent set of expectations across infrastructure categories that support the city's sustainability and resiliency targets.

The City's Sanitary Asset Management Plan (Phase 2) Final report (2018) describes that LOS falls into a number of categories; qualitative customer expectations, legislated obligations, and technical standards. LOS is in the context of this document refers to Technical Standards. As of 2017, the Core Service Key Result Indicators (KRI) are provided on an annual basis from the Sanitary Utility, which include:

1. % of length of sanitary sewer pipes flushed
2. # of kilometers of sanitary sewer pipe replaced/rehabilitated
3. % sanitary sewer pipes inspected
4. # of sanitary main blockages per 100 km of pipe
5. # of spills that reach the environment/total # of spills

These are operational metrics to provide long-term measuring of system performance over time. A legislated obligation is based on Provincial guidelines regarding protection of the environment:

- "Maintain a Sanitary Utility which takes the utmost care in protecting the local environment, meeting all regulatory requirements"
- Reference is to the MECP guidance
- Kitchener retains a copy of the MECP form Grand River Watershed Sewage Discharge Notification Form for Spills and Bypasses

Sanitary network modelling is identified as an important metric for assessing the LOS via project model results compared to the design criteria. The following section further discusses sanitary system LOS and performance metrics.

3.1 Sanitary Sewers

A LOS analysis provides perspective into the resiliency of the collection system and assists in identifying if modifications to the existing infrastructure are required. A LOS analysis begins with understanding the performance of the collection system under dry weather flow conditions. The extent of the existing system's ability to accommodate increasingly infrequent wet weather flow events is then explored.

3.1.1 Difference Between Design and Existing System Performance

Municipalities who maintain and operate a hydraulic model face a challenge of assessing development applications completed through standard Design Sheets using the flow generation criteria outline in this document, which are fundamentally different than the methods of flow generation applied in the hydraulic model. The hydraulic model is based on macro-level population distributions with flow generation rates calibrated to trunk-level flow monitoring data. The input parameters in the hydraulic model are different than that used in design of new sewers, which makes it difficult to integrate the two data sources and can be a cause for confusion when assessing development applications with the hydraulic modelling tool. One major difference is that design sheets are simplified static representations of the dynamic flow routing that occurs in a sewer system. The use of the Harmon Peaking factor is a means of accounting for flow attenuation and dampening of the peak as it travels through the pipe (i.e., peak flows are not directly additive as you move downstream). As the population increases, the peaking factor is reduced to represent this in-system flow attenuation.

Dynamic hydraulic models simulate the full physical process of flow travel through pipes over time, and thus do not apply the Harmon formula. Instead, an actual diurnal pattern reflecting the daily change in flow rate is simulated over time, with incomparable peaking factors. Similarly, extraneous flow allowances from design sheets are not directly input either; instead, a dry weather groundwater infiltration rate and direct wet weather flow response to rainfall input is simulated to accommodate this input, again both derived from flow monitoring data.

The result is that peak flow rates as derived by the designers responsible for new developments and new sewers do not directly correlate to input used in the hydraulic model, and often result in more conservative values that are beneficial for new sewer sizing, but less appropriate for downstream system impact assessment. With the update to the hydraulic model as part of the ISAN-MP, the process for assessing development applications should continue to be modified to better integrate the two calculation methodologies, with the system model being used to evaluate the system-wide impacts of proposed development applications.

3.1.2 LOS Capacity-Based Metrics

For assessing sanitary sewer system capacity performance and triggers for upgrades, there are three main metrics typically used in the industry:

- Depth to Diameter or Height (d/D) ratio
- Peak Flow to Pipe Full Capacity (q/Q) ratio
- Hydraulic Grade Line (HGL) Freeboard

The first two ratios can be assessed at the individual asset (pipe) level, based on information readily available from the asset geodatabase (diameter or height), and with knowledge of the pipe slope and roughness, the Pipe Full Capacity (Q) can be calculated using Manning's formula. The updated hydraulic model is the preferred tool for retrieving and displaying this information, and with the migration to the InfoWorks ICM platform, pipe full Q is automatically calculated for easy reference against modelled results for peak flow (q) per pipe.

InfoWorks also provides another reference metric per pipe, which is called the Surcharge State (SS). The SS is a ratio of the slope of the HGL to the slope of the pipe itself, where:

- SS < 1: no surcharge, and the value is the d/D ratio
- SS = 1: surcharged, but the slope of the HGL is less than the pipe indicating the pipe has sufficient capacity and the surcharge is a result of downstream backwater

- SS = 2: surcharged, with the slope of the HGL greater than the pipe indicating insufficient capacity in the pipe

From a risk to flooding perspective, the depth of the HGL relative to the surface is commonly referred to as the HGL Freeboard. Within the hydraulic model, the maximum water surface elevation per node can be subtracted from the ground elevation of the node to compute the HGL Freeboard, where:

- HGL Freeboard > Threshold: water level is below the threshold and there is no risk of flooding
- HGL Freeboard < Threshold: water level is within the threshold and is a risk to basement flooding
- HGL Freeboard < 0: water level has breached the surface and is spilling to the environment

The HGL Freeboard Threshold varies from municipality to municipality, but is typically associated with an assumed depth to basement or underside of footing in the 1.8 m to 2.1 m range. Use of the HGL Freeboard and SS can provide valuable insights into system-wide performance when thematically mapped. Coupling these metrics with design storm simulations in the calibrated hydraulic model then allows for quantification of LOS based on design storm return frequency (e.g., 25-yr storm) using the City's Intensity-Duration-Frequency data.

Another metric for the sanitary sewer system is peak velocity in m/s, used as an indicator of adequacy for conveying solids and the potential for deposition which can lead to blockages and odour concerns. Conversely, extremely high velocities can be a threat to increased headlosses or long-term pipe shifting.

Through the ISAN-MP, the LOS Capacity Metrics were defined and applied as described in the following sections.

3.1.3 Dry Weather Flow Performance

The performance of the collection system under dry weather flow (DWF) condition should consider the range of flows expected throughout an average day. This can be accomplished considering a diurnal pattern which can be based on appropriate sewer flow monitoring data from a dry period.

Under DWF conditions, a common rule of thumb for hydraulic performance is that the pipe should flow no greater than 80% d/D, to allow for air movement in the open channel. Peak dry weather flow velocity should be adequate to provide the sufficient scour velocity of ≥ 0.6 m/s, to maintain system operation.

3.1.4 Wet Weather Flow Performance

The collection systems' performance under wet weather flow (WWF) conditions provides insight into the relative LOS related to basement and surface flooding risk. WWF analysis can be completed using various synthetic design storm distributions over a range of return periods (i.e. frequency of events), to establish the design event to base system upgrades. In lieu of design storms, some jurisdictions apply a historic event that has caused known issues in the past and use this as their design event for WWF LOS analysis. As an example, the City of Toronto uses the May 12, 2000 design storm as measured at a specific rainfall gauge in the City to assess its sanitary system performance and designs.

There is no Provincial design guidance for LOS. The City of Kitchener has informally adopted the 25-yr, 12-hr AES Distribution design storm for assessment of its sanitary collection system using the hydraulic model. Given the size of the Kitchener sanitary collection system, it is recommended that the AES storm distribution continue to be used as it is more reasonable than the application of the overly conservative, uniformly applied peaky design storm hyetograph of the Chicago Distribution, which is more appropriate for storm drainage systems. Note, the stormwater Master Plan indicates a 5-yr LOS for the minor storm system, and considers shorter duration (4 to 6-hr) Chicago Distribution hyetographs, which is appropriate for the scale of storm sewersheds in the urban environment. For the sanitary system, the larger trunk network and indirect nature of rainwater migration into the sewers justifies the use of the 12-hr duration, which is better suited to evaluation of both peak and volume impact of wet weather on system performance.

For the sanitary collection system LOS analysis, the work completed in Task 3 and Task 4 informed the recommendation for upsizing triggers regarding hydraulic performance. The Hydraulic Grade Line (HGL) elevations at model nodes are used as the main indicator of issues within the collection system. Elevated HGLs occur when a capacity constraint drives the upstream water levels to rise. Risk of basement flooding in the 25-yr AES, 12-hr design event is considered if the HGLs are within 1.8 m from the surface elevation, which coincides with the assumed basement elevation for homes with direct or indirect basement connections to the sewer, given the relatively low history of flooding due to sanitary back-up. Adopting this HGL freeboard from the maintenance hole surface elevation is consistent with other Ontario municipalities as a surrogate for private property flood risk.

Sewer performance is reviewed in conjunction with the elevated HGLs to determine the cause of the HGL issues observed and determine possible solutions. Sewer performance alone is generally not used to define the need to provide upgrades; however, surcharging observed in smaller events like the 5-yr AES, 12-hr storm may warrant upgrades. As noted, within the hydraulic model the Surcharge State (SS) is an indicator of performance. When the SS is less than 1, the pipe is considered free-flowing. When the SS is 1 or 2, the pipe is considered under backwater (slope of the HGL is less than the slope of the pipe), or bottlenecked/undersized (slope of the HGL is greater than that of the pipe), respectively.

For shallow sewers that are within 1.8 m from the surface, the HGL freeboard cannot be met; however, it is proposed that should the water level remain within the pipe and the pipe is under free-flowing conditions, that it not trigger the need for upgrades.

3.2 Pump Stations

LOS for pump stations is expressed as a Design Period, which is not directly related to a rainstorm return frequency. The minimum wet weather event is alluded to in the MECP guideline definitions of firm capacity, under Section 7.2.3 Pumps, where for a two-pump station, each pump should be of the same size, provide a Firm Capacity with one unit out of service, and be at least capable of handling the peak hourly flow of the 10-year Design Period. The KPF in Section 2.1 Station Capacity states “wastewater pumping facilities should be able to pump the expected 10-yr peak wastewater flows with the largest capacity pump out of operation.” From the Condition Assessment reporting completed by Kitchener, the highest 1-hr flow in a 10-year timeframe or within a given dataset, is referenced as the peak wet weather flow. Furthermore, Section 2.1.1 of the KPF elaborates on the Design Period for the station, with a minimum design period for ultimate conditions of 50 years and initial installation provided for a minimum 10-year design period.

The MECP does not speak specifically to wet weather response as a LOS item, or what constitutes an emergency overflow, while Section 2.1 of the KPF indicates that the peak hourly flow is the peak wet weather hourly flow. Section 2.2.3 of KPF states the emergency overflow response time is 1-hr, but does not indicate how this relates back to a design storm threshold. Once the station is in operation, actual peak wet weather flow can be derived from averaged SCADA measurements (preferably of influent flow), which can be used to derive a baseline for comparison over time. This was completed in the Region of Waterloo's Wastewater Treatment Master Plan Update (2018), Technical Memorandum No. 1B: Sewage Pumping Station Population and Flow Projections, including the Bridgeport and Spring Valley stations in Kitchener. **Table 3-1** presents the measured and calculated metrics for the Region-owned stations in Kitchener.

Table 3-1: Historic Average Statistics (RMOW, 2018)

Pump Station	Firm Capacity (L/s)	Ex. Average Day Flow (L/s)	Ex. Peak Wet Weather Flow (L/s)	Wet Weather Event
Bridgeport	136	32	85	March 31, 2015
Spring Valley	245	46	207	July 14, 2015
Source: Table 1, Appendix B, Wastewater Treatment Master Plan Update, TM#1B: Sewage Pumping Station Population and Flow Projections (CIMA, 2018)				

Therefore, the LOS for pump stations is tied to Firm Capacity over the Design Period relative to the peak hourly design flow. It is recommended that influent flow to pump stations be incorporated into the SCADA system upgrades to provide both inflow and pumped discharge to enable long-term trending analytics to assess changing RDII as well as pumping equipment performance. When analyzing pump station performance LOS, energy efficiency should be considered.

For the purposes of assessing LOS in this ISAN-MP, the 10-yr AES, 12-hr storm event is recommended, where all sewage pumping facilities should be designed to pump the 10-yr peak flow with the largest pump offline (firm capacity). Pumping stations receiving 10-yr peak flows greater than the station's firm capacity are considered to have capacity constraints. The 10-yr modelled peak flow is also compared to the firm capacity from the Environmental Compliance Approval (ECA) to determine if the current ECA is adequate for existing and future condition flows or requires amendment. Additionally, pumping station performance is evaluated with respect to overflows, in that overflows should not occur in events smaller than the 25-yr AES storm. Refer to TM#3 for more information.

3.3 Sensitivity Testing

To test the resiliency of system performance under the uncertainty of climate change (CC) impacts, it is recommended that additional model simulations be performed to inform the sensitivity of the existing and future system LOS, and potential consideration for oversizing planned capital upgrades. Application of the *IDF_CC Web-based Tool for Updating Intensity-Duration-Frequency Curves to Changing Climate – ver. 6.5*, Western University Facility for Intelligent Decision Support and Institute for Catastrophic Loss Reduction (open access https://www.idf-cc-uwo.ca) was considered as a means of defining factors to increase the 25-yr AES, 12-hr design storm rainfall intensities. Given the uncertainty in application of parameters and in the interest in defining an easily repeatable process for testing sensitivity, it was agreed with the City to apply a 20% increase to the design storm time series, herein called the 25-yr + CC event.

It is recommended that this 25-yr + CC event be applied to LOS and proposed capital project sizing to inform the sensitivity of the capacity constraint in terms of sizing and prioritization. This test should then be factored into the capital planning decision-making, and consideration for expanding the recommended solution and/or advancing the prioritization.

Additionally, the City's condition-based system assessment as part of the Asset Management program should be used in the identification and prioritization of LOS and capital upgrade triggers, considering the available metrics including condition-based scores from CCTV and the Total Wastewater Priority Assessment Score (TWPAS) accounting for criticality and risk. The City continues to collect and assess this data.

4.0 Recommendations

The following recommendations are provided for consideration of future updates to the design guidelines and interpretation of LOS:

- Kitchener Design Guidelines
  - Guidance be provided on the use and interpretation of flow monitoring data and importance of infiltration and inflow mitigation.
  - Standardization of drainage area definition for use in designs, to reduce uncertainty in application of unit rates.
  - Incorporate influent flow to pump stations into the SCADA system upgrades to provide both inflow and pumped discharge to enable long-term trending analytics to assess changing RDII as well as pumping equipment performance.
  - There are challenges associated with flow rates as derived by the designers responsible for new developments and new sewers not directly correlating to input used in the hydraulic model, which is used for overall system assessment. With the update to the hydraulic model as part of the ISAN-MP, the process for assessing development applications is proposed to be modified to better integrate the two calculation methodologies. Therefore, it is recommended to add a section in the KDM similar to Stormwater Management Section G.7 Analytical Methods to Section E, to acknowledge and outline how spreadsheet designs and existing system modelling analysis can interact, including overview of the spreadsheet and InfoWorks ICM modelling tools.
  - Add clarity that sewer velocities should also be checked against Actual Flow velocity in addition to theoretical Pipe Full to flag potential operational issues when pipes do not frequently flow full.
  - Add design guidance for sizing of new sewers to flow less than 80% d/D for peak design flow, to allow for air movement in the open channel.
  - Add a section related to Construction Dewatering requirements, and assessment of impact on downstream collection system.
  - Extend the benching standard to the top of the pipe, to improve hydraulics through MHs.
  - Consider adding section in the KDM specific to siting of MHs with consideration to potential existing of future surface water ingress, and outline potential mitigation measures such as watertight lids and/or raising of lid above hazard level.
- Level of Service and Sensitivity
  - Under DWF conditions, the modelled pipe should flow no greater than 80% d/D, to allow for air movement in the open channel. Peak dry weather flow velocity should be adequate to provide sufficient scour velocity (>= 0.8 m/s), to maintain system operation.
  - Under wet weather conditions, it is recommended that the 25-yr, 12-hr AES Distribution design storm continue to be used for in-system collection system performance using the hydraulic model. The 5-yr AES storm can be used as another indicator for upgrade sensitivity whereby there should be no surcharge in this event.

- Given the relatively low history of flooding due to sanitary back-up, it is recommended that a minimum HGL freeboard of 1.8m from the maintenance hole surface elevation be applied to assess LOS under the 25-yr storm, which is consistent with other Ontario municipalities as a surrogate for private property flood risk.
- For sanitary pump stations, the 10-yr AES, 12-hr storm event is recommended for assessing LOS performance within the hydraulic model, compared against the firm capacity (i.e., largest pump offline). Additionally, pumping station overflow performance is recommended to be assessed with the 25-yr AES storm, where there shall be no overflow.
- It is recommended that this 25-yr + Climate Change modified event (20% increase to 25-yr hyetograph intensities) be applied to LOS and proposed capital projects to inform the sensitivity of the capacity constraint in terms of sizing and prioritization. This test should then be factored into the capital planning decision-making, and consideration for expanding the recommended solution and/or advancing the prioritization.
- City's condition-based system assessment as part of the Asset Management program should be used in the identification and prioritization of LOS and capital upgrade triggers, considering the available metrics including condition-based scores from CCTV and the Total Wastewater Priority Assessment Score (TWPAS) accounting for criticality and risk.

Appendix A Supplementary Materials

Table 4: RESIDENTIAL ZONING CRITERIA

Zoning Category	People/hectare
R1	Not Serviceable
R2	36
R3	72
R4	143
R5	143
R6	196
R7	312
R8	387
R9	775

Source: https://www.kitchener.ca/en/resourcesGeneral/Documents/DSD_ENG_Development_Manual_2021.pdf

Table 1 - Common Sewage Flowrates for Commercial and Institutional Uses

Description	Unit Sewage Flow (L/d)	Flow Unit Per
Shopping Centre (floor area in m^2)	2.5 – 5.0	Total floor area in m^2
Hospitals	900 – 1,800	Bed
Schools	70 - 140	Student
Travel Trailer Parks	340	Space (without water hook-ups)
	800	Space (with individual. water hook-ups)
Campgrounds	225 - 570	Campsite
Mobile Home Park	1,000	Parking space
Motels	150 - 200	Bed space
Hotels	225	Bed space

Source: https://www.kitchener.ca/en/resourcesGeneral/Documents/INS_SSU_Design_Criteria.pdf