Sanitary System Plan for the Town of Adamsville

Connie Zhang	Maria Vetrici	Dana Bou Saab	Naveen Black
1009110999	1007941658	1009036455	1008899462

March 23, 2025
Team #4

Executive Summary

This report describes the proposed sewer system for a new development within the Town of Adamsville, a subdivision connected to the broader local sewer system. The development occupies about 16.7 hectares of residential, institutional, and mixed-use zoning and houses 1,800 residents. Externally, the sewer system serves a population of around 9,100 over 55.7 hectares.

The sewer system was designed based on factored residential and ICI demands, infiltration, and external demands. Unfactored average residential and ICI flows were estimated using the Adamsville Design Criteria with pipe flows of 0 to 30 L/s. Infiltration is constant at an average of 0.23 L/s per hectare of drainage area. Harmon peaking factors were computed for each pipe based on the pipe's aggregated residential population and applied to average flows (excluding infiltration). Pipes were designed for maximum flows up to 182 L/s (including external demand).

The network's hydraulic capacity was modelled using Manning's formula, based on the assumed flows, the chosen pipe lengths, slopes, diameters, and the roughness coefficient of PVC pipes (0.013). The design of slopes and diameters was iterative to satisfy minimum depth requirements while abiding by required drops at maintenance holes to offset local losses. Where pipe velocities exceeded 1.5 m/s, minimum drops were computed manually. In the final design, nominal pipe diameters range from 200 to 450 mm; all pipes meet the 200 mm limit and are at least as large as the largest connected upstream pipe.

The sewers were mapped alongside planned water pipes, placed within and parallel to the development's proposed roadways while maintaining clearance. Municipal service crossings are summarized where clearances could not be maintained. Maintenance holes were placed to facilitate maintenance at turns, junctions, and at maximum intervals along pipe lengths, and were designed to include drop structures where the drop between upstream and downstream inverts exceeded 0.6 m. Costs were minimized by optimizing slopes to ensure sewers followed the terrain while staying close to the minimum required invert depth (3.0 m) and reducing the need for unnecessary drop structures. This was done provided that sewers aligned with inlet and outlet external connections.

For odor control, the proposed sewer system has subcritical flow in all pipes where this flow regime can be evaluated, and limitations to this analysis are discussed. Moreover, the sewers meet the velocity criteria, ranging between the limits of 0.6 m/s and 3.0 m/s. Pipes predicted to have velocities below 0.6 m/s were designed with slopes of 1.0% and indicated as needing frequent cleaning. All flow depths are below 75% of the pipe diameter for air flow.

The design process made a variety of assumptions and assumed necessary easements would be granted (for pipes running through the mixed-use zone and for a drop structure outside the defined boundary). The design also neglected whether flows were subcritical in about half the network and neglected the possibility of surcharge. Subsequent implementation stages would require more thorough modelling of flows, particularly checking for supercritical flows and ensuring head losses are consistent with estimates. If the client ensures that the distribution network is built to this report's specifications, the network will safely satisfy the sanitary needs of all Adamsville residents.

Table of Contents

1. Introduction

A new development is planned for Adamsville and will be located adjacent to the City of Brampton in the province of Ontario, Canada. It occupies around 16.7 hectares and includes single-family homes, a mixed use space, an elementary school, and a park [1]. It is estimated that the development will have about 1,800 residents producing a sanitary demand, but as it sits in a broader sewer network, the development's sewer network will also accommodate significant upstream flows from external sewer lines. The development's sewer lines will be designed to convey flows using gravity only, ultimately transferring them to the external outlet at the southeastern point of the development. The physical scope of this report thus includes the boundaries of the development and the subterranean regions below it where sewer line construction is permitted, as well as select easements.

This report will document the planned sewer system and the key assumptions employed for this design. It will also present the system's predicted performance when compared against design requirements: it will acknowledge limitations of the design, but will demonstrate that all criteria are ultimately met.

2. Criteria and Assumptions

As will be described in the model description in Section 3, each pipe within the network was designed for the maximum flow it is predicted to convey. This flow represents sewage coming into, and any incremental flow produced within, the drainage area corresponding to a specific pipe (Appendix B). The pipe that crosses a given drainage area receives all sewage flows from its drainage area through service connections or infiltration, which constitute the pipe's incremental flow. This section will describe the assumptions and criteria governing demand decisions to predict the incremental flows of each pipe. In this report, "pipe" and "pipe segment" are used interchangeably to refer to a length of pipe with a constant diameter and slope, between two maintenance holes.

2.1. Residential Demand

The incremental residential demand of each pipe segment was estimated based on the residential population of the pipe's drainage area. Residential demand was assumed to be 450 Lpcd (litres per capita per day) [2]. For a given drainage area within the residential zone corresponding to the pipe being designed, the flow calculations are presented in the table below (Table 1).

Table 1. Calculations for unfactored residential demand flows.

	Single Family	**Townhouse**	**Apartments**
Density (ppu) [2]	4	3.5	3
Example	Pipe connecting western mixed-use block to Bernoulli Boulevard		
Number of units	0	45	50
Residential population	$0 \times 4\,ppu + 45 \times 3.5\,ppu + 50 \times 3\,ppu = 308\,capita$		
Average residential flow	$308\,capita \times \frac{450\,L}{capita{-}day} \times \frac{1\,day}{24\,hours \times 3600\,s} = 1.60\,L/s$		

This approach was used for all drainage areas with at least one dwelling, including residential and mixed-use zones.

2.2. Other Demand

In addition to residential demand, industrial, commercial, and institutional (ICI) demand was estimated based on characteristics of the planned mixed-use zone and the school. Alongside ICI demand, all pipes were designed for an infiltration allowance that will be described.

First, commercial and institutional areas were converted into equivalent populations and average demand flows. This process is described in Table 2 below. Though equivalent population for ICI zones is not used in the average flow calculation, it is still required since it is included when calculating Harmon peaking factors (see Section 3).

Table 2. Calculations of unfactored ICI demand flow and population, and conversion factors.

	Commercial zones	**Institutional zones**
Equivalent population [2]	75 ppl/ha	100 ppl/ha
Average demand flow [2]	0.29 L/s/ha	0.5 L/s/ha
Example	Pipe from western mixed-use block to Bernoulli Boulevard	Northern section of Moody Drive pipe
Drainage area (ha)	$400\ \mathrm{m}^2 \times \frac{1\ ha}{10^4\ m^2} = 0.04$ ha	$3349\ m^2 \times \frac{1\ ha}{10^4\ m^2} = 0.33$ ha
Equivalent population	$0.04\ ha \times \frac{75\ cap}{ha} = 3\ cap.$	$0.33\ ha \times \frac{100\ cap}{ha} = 33\ cap.$
Average flow (L/s)	$0.04\ ha \times \frac{0.29\ L/s}{ha} = 0.01\ L/s$	$0.33\ ha \times \frac{0.5\ L/s}{ha} = 0.17\ L/s$

This process was used for all pipes crossing drainage areas with institutional or commercial demand.

Another relevant demand is the effect of infiltration, shown in Table 3. It was assumed that an infiltration allowance of 0.23 L/s/ha applies to all drainage areas in the development [2]. The infiltration into a given pipe was calculated based on the total area upstream of the pipe and the drainage area the pipe crosses (area calculation described in Section 3).

Table 3. Calculations for infiltration flows in each pipe.

	Infiltration demand
Example	Pipe segment along Venturi Boulevard
Aggregated area (ha)	58.2 ha
$Q_{infiltration}$ (L/s)	$58.2\ ha \times \frac{0.23\ L/s}{ha} = 13.39\ L/s$

Infiltration was calculated separately for each pipe segment based on the pipe's aggregated area (see Section 3). No other demands (such as inflow from rain or the possibility of surcharge) were considered.

2.3. External Demand

External demands were determined based on the indicated demands on the provided sanitary layout [1]. For example, the Archimedes pipe segment originates at a connection to an external sewer line with an external area of 35.2 ha and a population of 5760 [1]. The population was assumed to be residential and to create demand flows at the same rate as the proposed development (450 litres per capita per day). This calculation exactly mirrors Table 1 in Section 2.1. Thus, external areas were simply added to the drainage area of the pipe segment connected to the external maintenance hole (see Section 3). Similarly, populations were combined into the connecting pipe's population (and any equivalent residential populations from ICI zones, if applicable) without any conversion factors. This is a reasonable assumption, assuming the external demand is already expressed in residential population equivalents, with a comparable sewage generation rate.

Another important assumption is that the infiltration allowance applied to all external areas at the same rate as the development, as 0.23 L/s/ha. If the external population is also residential, this suggests there is similar land use outside the proposed development, which makes the identical infiltration allowance consistent and reasonable.

2.4. Outlet Properties & Assumptions

The development's sewage flows were assumed to all drain to the south-eastern corner, to an existing exiting sewer at an elevation of 212.50 m [1]. It is assumed that this sewer is not at risk of surcharge and that it is capable of carrying the entire upstream flow while meeting all requirements [1].

3. Model Description & Analysis Methods

The flows described in Section 2 depend on the characteristics of a pipe's drainage area, and represent the flow predicted to enter the pipe crossing the given area. These drainage areas are shown in Appendix B and were delineated with these considerations:

1. to represent the most likely path taken by sewage and infiltration,
2. to avoid dividing mixed-use, school, or park zones into multiple drainage areas,
3. to sum to the total area of the total development (16.7 ha).

The size of each drainage area was calculated using the AutoCAD layout.

The sewers were designed to be gravity-driven, so the network was designed without loops and all pipes were assumed to have unidirectional flow. Since sewers were designed to be unidirectional, all sewer pipe segments are required to accommodate upstream flows, combined with the additional demands produced by a pipe's drainage area.

Thus, each pipe was designed for the demand of the drainage area it would cross (in Section 2) *and* all upstream demand. Flow, population, and area were aggregated for each pipe and indicated under the "Aggregated U/S" section in Appendix A to represent upstream demand. Calculations are described in Table 4.

Table 4. Calculation of the aggregated area (or population, or flow) of a given pipe.

Equation	$A_{Ag,N} = A_{external} + A_{upstream} + A_N$ for the N^{th} pipe segment			
Notes	1. Can use same process for population $P_{Ag,N}$ and flow $Q_{Ag,N}$ 2. Pipe segment N has an incremental drainage area A_N (Appendix B) 3. Pipe segment N has a total upstream drainage area of $A_{upstream}$ 4. Pipe segment N connects to an external pipe with an area $A_{external}$ (Section 2.3). *In the development, only two inlets have an explicit external area $A_{external}$ so all other pipes account for external areas with $A_{upstream}$.*			
Example	$A_{external}$ (ha)	$A_{upstream}$ (ha)	A_N (ha)	$A_{Ag,N}$ (ha)
N = western segment along the Archimedes Way pipe	35.20	0	0.44	35.64 ha
	This pipe segment has a drainage area A_N of 4,351 m^2 (0.44 hectares) and is connected to an external area of 35.20 hectares (see Sanitary Plan [1]).			
N = eastern segment of the Archimedes Way pipe	0	35.64	0. 40	36.04 ha
	This pipe's aggregated area includes its 0.40-hectare drainage area, in addition to the aggregated area of the pipe flowing into it (which was calculated above). This pipe does not directly receive external demand.			

The process in Table 4 was also used to determine the aggregated population $P_{Ag,N}$ for each pipe segment, using the residential population in the N^{th} pipe's drainage area (P_N), any external population ($P_{external}$), and the residential population of all upstream pipe segments ($P_{upstream}$). Note that some pipes cross drainage areas without a population: for example, the pipe along Venturi Boulevard has zero incremental population since its drainage area does not include any dwellings.

Average residential and ICI flows in each pipe were combined for each drainage area as Q_N and residential sewage generation rates were used to calculate $Q_{external}$ for external populations, as described in Section 2. Thus, flows from the N^{th} pipe's drainage area and all upstream areas were combined as $Q_{Ag,N}$ as shown in Table 4.

The aggregated equivalent residential population ($P_{Ag,N}$) of each pipe was used to predict the Harmon peaking factor for the average ICI and residential flow $Q_{Ag,N}$ in each pipe (Table 5) [2].

Table 5. Harmon's peaking factor calculation for maximum flow in each pipe.

Equation	$PF_N = 1 + \frac{14}{4+\sqrt{P_{Ag,N}}}$
Notes	1. $P_{Ag,N}$ is equivalent population in thousands 2. PF_N is bounded between 2.0 and 4.0
Example	Pipe along Venturi Boulevard
Aggregate eq. residential population (cap.)	$P_{Ag,N} = 9,990$ (equivalent residential population)
PF_N	$1 + \frac{14}{4+\sqrt{9.990}} = 2.96$

Infiltration was not scaled up for maximum flow conditions as it was assumed constant.

Finally, Table 6 shows that the maximum flow rate for each pipe was obtained by scaling the aggregated residential and ICI flow, and combining this with infiltration. This maximum flow represents the design flow for each pipe. Flows ranged from 0.29 to 182.35 L/s (Appendix A). As described, $Q_{Ag,N}$ represents the aggregated average flows for a pipe and all of its upstream segments, created by residential or ICI demands.

Table 6. Design flows for each pipe.

<table>
<tr><td>Equation</td><td colspan="3">$Q_{design,N} = PF_N \times Q_{Ag,N} + Q_{infiltration}$</td></tr>
<tr><td>Notes</td><td colspan="3">1. PF_N is a function of the N^{th} pipe's aggregate residential population, $P_{Ag,N}$
2. $Q_{infiltration}$ is a function of the pipe's aggregate area, $A_{Ag,N}$</td></tr>
<tr><td>Example</td><td>PF_N</td><td>$Q_{Ag,N}$</td><td>$Q_{infiltration}$</td></tr>
<tr><td>Pipe along Venturi Boulevard</td><td>2.96 (Table 5)</td><td>52.02 L/s</td><td>13.39 L/s (Table 3)</td></tr>
<tr><td>Q_{design} (L/s)</td><td colspan="3">$2.96 \times 52.02 + 13.39 = 167.12\ L/s$</td></tr>
</table>

The hydraulic capacity of each pipe was modelled next. First, it was assumed that pipes would run near the centreline of the roads, and pipe lengths were measured using the AutoCAD layout [1]. Pipe diameters and slopes were determined iteratively by checking flow requirements, relevant criteria, and invert depth, provided each pipe was at least as large as the largest upstream pipe connected to it [2].

Slopes were designed iteratively with the following goals:

1. minimal deviations from terrain elevations
2. minimal use of drop structures (used when invert drop is > 0.6 m) [2]
3. minimal excavation for pipes (invert depths kept near minimum depth)

Although cost-effectiveness was not an explicit goal of this proposed sewer system, it was assumed that drop structures should not be extensively used as they would incur a greater cost than regular maintenance holes. This conclusion is based on Ontario cost estimates, including the Region of Peel's wastewater system for Mississauga, which describe maintenance holes with and without drop structures [3]. See the Challenges section for further discussion of slope iteration.

All pipes were at most 450 mm in nominal diameter, so they were designed as PVC pipes, which were assumed to have a roughness coefficient of 0.013 [2]. A minimum nominal pipe size of 200 mm was also enforced [2]. Based on the design diameters and slopes, velocity requirements were checked by calculating the full-flow velocity and converting this to partially-filled velocity using the hydraulic elements chart for circular sewers [2].

Diameter and slope design had the following velocity, air flow, and odor priorities from [2], all of which were inputted into the model:

1. velocity ≥ 0.6 m/s, or else slope ≥ 1.0% and noted on design sheet (Appendix A)
2. velocity ≤ 3.0 m/s under maximum flow
3. flow depths are subcritical (only checked for depths of at least 30% of the full depth, using the equation provided in [2])
4. flow depths are at most 75% of the full depth

In addition to previous priorities, invert depths were chosen using the following criteria, which were also inputted into the model:

1. maximum invert depth requirements
2. minimum drops for local losses in maintenance holes
3. downstream obverts must not be higher than upstream obverts at maintenance holes
4. pipe elevations are constrained between the two external inlet pipe elevations and the external outlet pipe elevation

Minimum invert drops at maintenance holes, to accommodate for local losses due to turns, were based on the Design Criteria and angles measured in AutoCAD: 0.03 m (0-15°), 0.06 m (15-45°), 0.09 m (45-90°). Angles were measured with the assumption sewers will run parallel to the roadway. The pipe exiting south from the junction at Hazen Way and Adams Avenue required a 97° turn (based on the AutoCAD file) to connect to the external outlet [1]. This turn was completed with two maintenance holes, turning by 90° at the three-way junction and then by an additional 7.5° to complete the turn (see further discussion in the Challenges section).

4. Design Description

This section describes the proposed sanitary system, showing the layout and how it fits into the existing plans and the proposed water distribution system for the Adamsville subdivision.

4.1. Layout

The system is composed of 27 proposed maintenance holes, in addition to the 5 existing ones at the boundaries and in the mixed-use spaces. Maintenance holes are labelled numerically in order of decreasing elevation (Appendix C). To minimize the need for easements and to avoid crossing property lines, most sanitary pipes run underneath and parallel to roadways (Appendix C). The two exceptions to this are the pipes connecting the mixed-use areas to the roadway, which must pass beneath the mixed-use areas and therefore will require an easement and be concrete-encased [2]. The layout was designed to avoid loops, and includes discontinuities in pipes along some streets to ensure there is unidirectional flow in all pipes. As a result, the layout is generally split into a northern and a southern branch, divided along the southern edge of Venturi Boulevard and merging at the southeast corner near the exit.

Pipes run along the northern and eastern sides of the road centerlines, halfway between the centreline and the adjacent curb, to align with the external maintenance holes detailed in the General Plan. The pipe along Saint Venant Boulevard is an exception to this convention; it was shifted slightly closer to the centerline to ensure it would run at least 1.5 m from the curb at all points, as required [2].

The location of each maintenance hole and pipe can be seen in the Sanitary Drainage Area Plan in Appendix B and the General Plan of Services in Appendix C. Maintenance holes are located as required at turns, multi-pipe junctions, and to limit pipe lengths to 110 m, which is the maximum length for pipes of up to 450 mm diameter [2]. Efforts were made to minimize the number of maintenance holes required, while still abiding by the 110 m distance requirement. The type, size, and depth of each maintenance hole are tabulated in Appendix F.

The development's terrain slope is generally decreasing from northwest to southeast, so it was assumed that flooding could occur near the intersection of Weisbach Street and Saint Venant Boulevard where the slope terminates at the houses. As required, a watertight lid was included at the maintenance hole at that corner (noted in Appendices A, B, C) [2].

Pipe slopes range from 0.6% to 2.6%, designed to minimize deviations from terrain slopes. Where elevation drops between upstream and downstream inverts in a maintenance hole exceed 0.6 m (in addition to any required head loss drop), drop structures were added. In total, 4 drop structures were used to accommodate drops ranging from 0.85 to 2.13 m. Wye drop structures were selected, to minimize local losses through a smoother transition [4]. Additionally, it should be noted that one of these necessary drop structures is at an existing maintenance hole located on the development boundary (MH.1A). The sewer system was designed assuming the required easement would be granted. Drop structures are shown on the General Plan (Appendix C) and in the tabulation of maintenance holes (Appendix F).

Clearance between sanitary and water main pipes was also considered when placing the sanitary pipes. The minimum cover of 1.7 m from terrain to the crown of the water mains was provided in the proposed water main design, as seen in the plan and profile view of Horton Way (Appendix D). For the sanitary design, 2.5 m of horizontal clearance was kept between water and sanitary pipes where possible [2]. Where this was not possible, such as at intersections, at least 0.5 m of vertical clearance was included between the invert of the water pipe and the crown of the sewer. This clearance was calculated and verified at all crossings using sewer depths, water pipe diameters, and required water pipe crown depths [11]. A tabulated list of all municipal service crossings is available in Appendix G.

5. Design Performance

This section will describe how the proposed sanitary design fulfills all requisite criteria mandated in the Adamsville Guidelines [2]. This includes hydraulic capacity, pipe geometries, and hydraulic behaviour requirements. Certain pipes are unable to meet the generally-applicable criteria, and so are highlighted below for special attention as permitted by the guidelines.

5.1. Adherence to Criteria

Through modelling of flow through the sanitary system, the proposed design demonstrated that it meets the Adamsville criteria. The permissible and modelled values for select criteria are summarized in Table 7, and explained in detail below. While this section only shows the most extreme case for each parameter, a summary of the entire modelled system is provided in Appendix A, with modelled values of each criterion below for every pipe. All pipes have a minimum diameter of 200 mm, and no pipe has a smaller diameter than its upstream connections.

Table 7. Summary of criteria, demonstrating compliance of the design [2].

Criterion	Permissible Value	Simulated Value
Minimum diameter	≥ 200 mm	200 mm
Maximum velocity	≤ 3.00 m/s	1.60 m/s
Minimum velocity	≥ 0.60 m/s	0.26 m/s (see Table 8)
Maximum d/D	≤ 75%	73%
Critical difference $\frac{d}{D} - \frac{y_{crit}}{D}$ (for d/D ≥ 30%)	≥ 0.0%	0.2%
Minimum invert depth below ground	≥ 3.0 m	3.0 m

To reduce odor, the flow depth in each pipe was compared to the critical flow depth based on the pipe's diameter and flow under maximum flow conditions. Where the flow depth was greater than 30% of the pipe diameter, the pipe slope was designed so that the flow would be subcritical (flow depth greater than critical depth). Some pipes were simulated to have supercritical flow, but this was strictly in cases where the critical depth was less than 30% of the pipe diameter, so the associated formula was inapplicable. This is further discussed in Section 6, Challenges, as supercritical flow can present odor issues due to the possible formation of hydraulic jumps. Additionally, the maximum flow depth in all pipes was limited to 75% of the pipe diameter, to allow air flow above the sewage (Table 7).

All pipe velocities are below 3.0 m/s and most are above 0.6 m/s under maximum flow (Table 7). When this minimum velocity was not possible, the pipe slope was designed to be at least 1%. These exceptions are tabulated below in Table 8; since these pipes do not reach the minimum velocity needed for sufficient tractive stress, they will require more frequent cleaning. In total, 12 such pipes will require additional cleaning.

Table 8. List of pipes unable to meet minimum velocity, requiring more frequent cleaning.

Street of Pipe	Upstream MH	Downstream MH	Velocity (m/s)
Saint Venant Boulevard	17A	19A	0.32
Saint Venant Boulevard	20A	33A	0.39
Horton Way	18A	21A	0.50
Horton Way	24A	28A	0.56
Adams Avenue	27A	28A	0.26
Darcy Way	2A	3A	0.40
Darcy Way	3A	10A	0.55
Weisbach Street	10A	15A	0.54
Moody Drive	8A	12A	0.57
Moody Drive	12A	15A	0.56
Bernoulli Boulevard	14A	16A	0.39
Bernoulli Boulevard	16A	22A	0.59
12 pipes total			

Throughout the development, pipe invert depths were kept at least 3 m below ground level, to ensure all residential areas could be serviced regardless of basement presence. Invert drops were included at all maintenance holes, as described in Section 3. Where velocities exceeded 1.5 m/s, the invert drop in the downstream maintenance hole was calculated manually to ensure these standardized invert drops would be sufficient even at high velocity. This calculation is shown below for the highest-velocity case as an example, and similar computations for each maintenance hole downstream of a high-velocity pipe are included in Appendix E.

Invert drop for MH.32A on Adams Avenue (upstream maintenance hole is MH.31A):

$h_L = k \cdot \frac{v_2^2}{2g}$; assume $k = 0.15$ since $\theta \approx 0°$ [5]

$$\Delta I = (y_2 - y_1) + (\frac{v_2^2}{2g} - \frac{v_1^2}{2g}) + h_L$$

$$\Delta I = (0.303 - 0.303) + (\frac{1.60^2}{2g} - \frac{1.60^2}{2g}) + 0.15 \cdot \frac{1.60^2}{2g} = 0.020\ m$$

Since the calculated value is less than the standard invert drop of 0.03 m for this angle, the standard drop was used instead to be conservative and consistent. In total, there were three maintenance holes where the calculated invert drop governed over the standard one: MH.13A, MH.30A, and MH.31A. See Appendix E for these calculations.

6. Challenges Overcome

Challenges in designing the sewer system arose due to non-standard pipe turns, uncertainty in slope decisions, and the subcritical flow requirements. Firstly, to be functional, the development's sewer system was required to connect to the maintenance hole at the outlet (the south-eastern corner of the development). However, the very last road segment in the development makes a ~97° turn at the intersection of Adams Avenue and Hazen Way. Consequently, two maintenance holes were used in series to incrementally turn the pipe segments to ensure the pipe connects to the outlet while staying parallel to the roadway (Appendix C). Another challenge arose because pipe turns are required to comply with the standards described in OPSD 701.021 [2]. This requirement was met at the intersection by using a standard three-way junction with 90° turns, but the second maintenance hole was designed for a non-standard bend of 7.5° (somewhat resembling the standard 45° bend). The angle of 7.5° was used as it is half of 15°, which is closer to standard bend angles and likely more easily obtained as a result.

The verification of subcritical flows in many pipes also posed a challenge, because the critical depth formula in the Design Criteria is only valid for pipes with d/D ratios greater than 30%—almost half the sewers in the network do not meet this minimum ratio. Consequently, only 17 pipes (about 56% of the network, by length) were decisively verified as subcritical flow. Since subcritical flow is essential to reduce odor in the pipes, future iterations of this sewer system should be thoroughly evaluated for subcritical flow. Nonetheless, in this network it was assumed that at low depth ratios, the volume of sewage will be smaller and produce less odor.

Lastly, slope design presented a significant challenge due to the variety of possible designs which all satisfy the requirements. This mostly occurred due to the flexible nature of slopes and the use of drop structures in the network. For example, assuming that unlimited drop structures could be constructed, the first network iteration included 18 drop structures to keep slopes shallow, below 1%. However, later iterations prioritized matching pipe slopes to terrain slopes, ultimately resulting in steeper slopes up to 2.6% and only requiring 4 drop structures. To facilitate the decision process, the team consulted with the client, who suggested that cost was a reasonable implicit criteria of the final design. Accordingly, the slopes were shifted closer to the terrain slope and pipes were kept near the minimum invert depth, since shallower sewer systems have lower construction and maintenance costs [6]. Similarly, a review of sewer system cost estimates in Mississauga [3] and Uxbridge [7] reported much higher costs for maintenance holes with drop structures, so the number of drop structures was minimized as well based on the client's feedback.

7. Conclusions

An effective and odorless sanitary system is essential for any proposed development, and is crucial to convey sewage while preventing the spread of disease and the contamination of clean water or the environment [8]. This proposed sanitary system for the Town of Adamsville was designed to meet peak demand safely and to ensure flows experience minimal turbulence.

Iterative design and thorough modelling ensured the proposed system can meet the required sewage flows of the development, as well as upstream external demands, while maintaining required air flow within the sewers and keeping velocities in a safe and sustainable range (i.e., to avoid sewage build-up) as required in the Adamsville Design Criteria. The network also includes sufficient maintenance holes to ensure long-term success of the system. Moreover, economically-favourable decisions were taken to minimize both short-term construction costs and long-term maintenance costs, by optimizing sewer depths while staying within requirements.

If further iterations to the design are pursued, it is recommended that odorlessness be prioritized by ensuring flows remain subcritical wherever possible. Limited modelling was available to verify critical flow depths and more sophisticated sewage modelling would ensure that hydraulic jumps are mostly or entirely avoided. Moreover, surcharge was assumed not to occur and its possibility was not considered. However, this may be a risk and further investigation into its repercussions should be performed before the system is installed.

Subsequent steps in the implementation of the sewer system require detailed construction plans paying close attention to crossings with the water network, and more detailed design of the necessary drop structures. The specified easements must also be approved in order to construct all the pipes and meet the full demand of the development. Most importantly, the sewer model makes various assumptions regarding friction coefficients, local losses, actual demands, and infiltration, so thorough testing is recommended to verify such assumptions and ensure compliance with the design guidelines.

8. References

[1] *Sanitary Drainage Area Plan of Adamsville Village*, University of Toronto, 2025.

[2] *Town of Adamsville Engineering Design Criteria and Standards Manual*, University of Toronto, 2025.

[3] *Wastewater Capacity Improvements in Central Mississauga: Cost Estimates*, Region of Peel, 2024. peelregion.ca/sites/default/files/2024-07/appendix-f-cost-estimate.pdf.

[4] *Cast-In-Place Maintenance Hole Drop Structure WYE*, OPSD 1003.020, Ontario, November 2016. www.roadauthority.com/Standards/?id=d7d3554b-02ae-4e1c-8cca-07cc83efeb43.

[5] *Design Criteria for Sewers and Watermains*, City of Toronto, Ontario, 2021. www.toronto.ca/wp-content/uploads/2021/01/8d16-ecs-specs-dcm-design-criteria-sewers-watermains-Jan2021.pdf.

[6] Zapata, Graciela. "Hydraulics of Plunging Drop Structures in Urban Drainage Systems," PhD dissertation, Water Resources Engineering, University of Alberta, Canada, 2011. era.library.ualberta.ca/items/72078c56-f989-45e3-9198-9760ad6fb738/view/267e8135-d75d-4664-98b1-452c9a1d7df9/Camino_Graciela_Fall2011.pdf.

[7] Detailed Design Cost Estimate for Reach Street Lands, Township of Uxbridge, Oct. 2021. www.uxbridge.ca/en/business-and-development/resources/Documents/2452595-Ontario-Inc.---Venetian/Fourth-Submission-Documents---October-19-2021/20211018-SKA-386-Cost-Estimate---Oct-14-2021.pdf.

[8] *Municipal wastewater treatment*, Government of Canada, Aug. 2023. www.canada.ca/en/environment-climate-change/services/environmental-indicators/municipal-wastewater-treatment.html.

[9] *Maintenance Hole Benching and Pipe Opening Alternatives*, OPSD 701.021, Ontario, November 2014. www.roadauthority.com/Standards/?id=951531bf-27c3-47f3-a667-8adc2d8ff492.

[10] *Precast Concrete Maintenance Hole, 1200 mm Diameter*, OPSD 701.010. Ontario. Nov. 2014. www.roadauthority.com/Standards/?id=bb486d81-a356-4c70-b19a-d406569d4bee.

[11] *F-6-1 Procedures to Govern Separation of Sewers and Watermains*, Ministry of the Environment, Conservation and Parks, Ontario, Oct. 2021, https://www.ontario.ca/page/f-6-1-procedures-govern-separation-sewers-and-watermains.

Appendix A. Sanitary Design Sheet

The Sanitary Design Sheet is included on the following page. It identifies the layout and physical characteristics of the pipe network, and displays various metrics of the system's hydraulic performance. Combined with Section 5.1, these values demonstrate that the system meets all Adamsville design criteria. Horizontal lines between pipes indicate that flow is not immediately continuous between them.

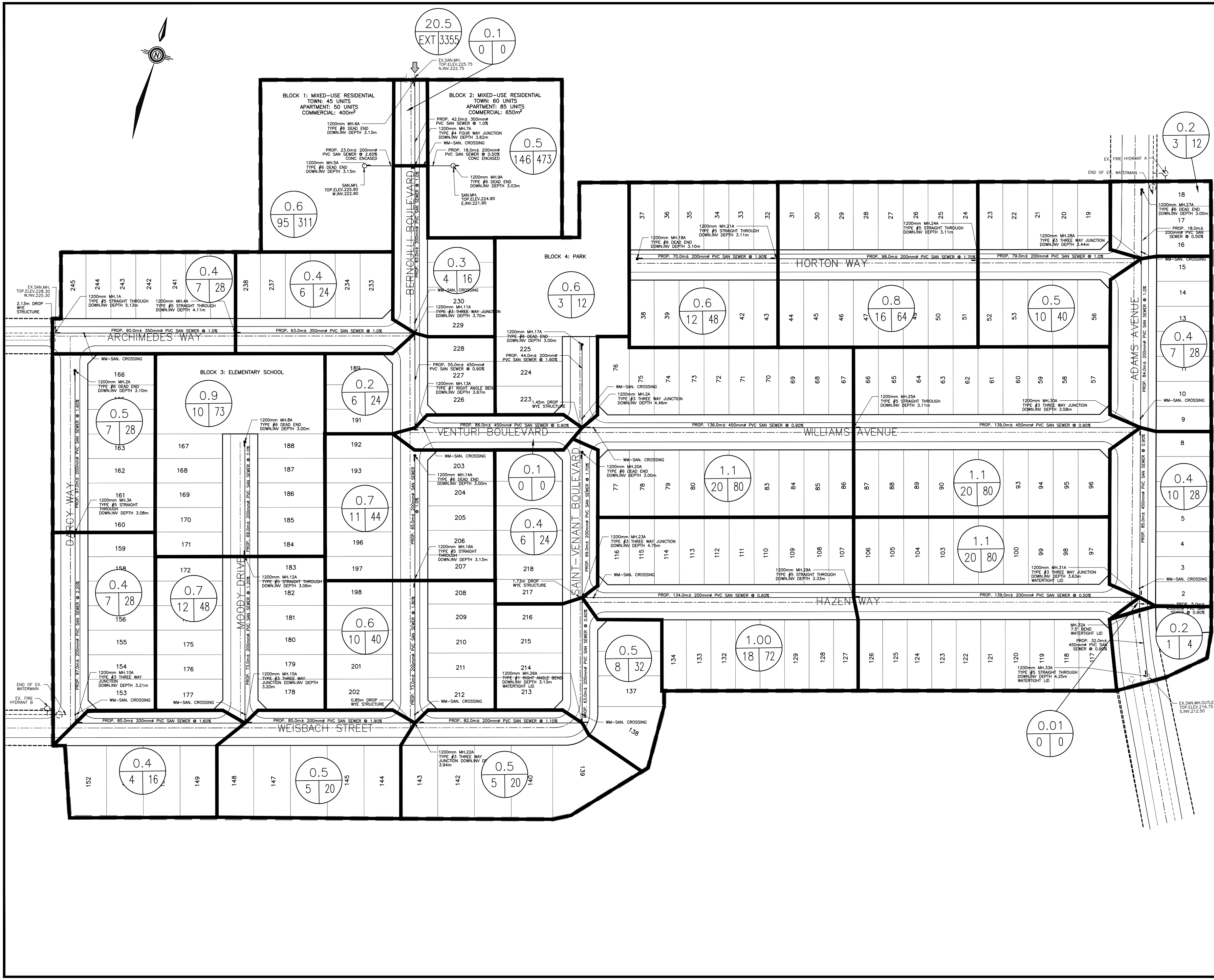
Subdivision/Project Name: Adamsville Proposed Sanitary System

Designed By: Team #4 | Checked By: Team #4 | File No: 1 | Date: 23-Mar-25

Pipe Location			Pipe Section			Aggregated U/S			Demand				Elevations (m)				Depths (m)			Pipe Data						Remarks
	Maintenance Hole (MH)		Area	Avg. Flow	Equiv. Pop	Area	Avg. Flow	Equiv. Pop	Peak Factor	Peak ICI + Res	Infil.	Design Flow	U/S MH		D/S MH		U/S MH	D/S MH	Max U/S Invert Drop	Dia	Slope	Full Flow	Flow Depth	Crit. Depth	Actual Vel.	
Street	U/S	D/S	ha	L/s	#	ha	L/s	#	K	L/s	L/s	L/s	Surface	Invert	Surface	Invert	Invert	Invert	Drop	mm		L/s			m/s	
Archimedes Way	1A	4A	35.6	30.1	5788	35.6	30.1	5788	3.19	96.0	8.20	104.2	228.30	223.17	226.25	222.27	5.1	4.0	2.13	350	1.0%	153	68%	68%	1.4	External demand entering; 2.13 m drop structure U/S in easement
Archimedes Way	4A	11A	0.4	0.1	24	36.0	30.3	5812	3.18	96.4	8.29	104.7	226.25	222.14	224.40	221.21	4.1	3.2	0.13	350	1.0%	153	69%	68%	1.5	
Bernoulli Boulevard	5A	7A	0.6	1.6	311	0.6	1.6	311	4.00	6.5	0.13	6.6	225.90	222.77	225.30	222.17	3.1	3.1	0.13	200	2.6%	55	26%	32%	0.9	Requires easement; concrete-encased
Bernoulli Boulevard	6A	7A	20.6	17.5	3355	20.6	17.5	3355	3.40	59.4	4.73	64.2	225.75	222.62	225.30	222.20	3.1	3.1	0.13	300	1.0%	101	65%	64%	1.3	External demand entering
Bernoulli Boulevard	9A	7A	0.5	2.5	473	0.5	2.5	473	3.99	9.8	0.12	9.9	224.90	221.87	225.30	221.78	3.0	3.5	0.03	200	0.5%	24	51%	40%	0.6	Pipe slope opposes terrain; requires frequent cleaning; requires easement; concrete-encased
Bernoulli Boulevard	7A	11A	0.3	0.1	16	22.0	21.6	4154	3.32	71.8	5.05	76.8	225.30	221.68	224.40	220.85	3.6	3.6	0.52	300	1.0%	101	73%	71%	1.3	
Bernoulli Boulevard	11A	13A	0.2	0.1	24	58.2	52.0	9990	2.96	153.7	13.39	167.1	224.40	220.70	223.55	220.20	3.7	3.3	0.51	450	0.9%	282	63%	62%	1.6	
Venturi Boulevard	13A	19A	0.1	0.0	0	58.3	52.0	9990	2.96	153.7	13.42	167.2	223.55	219.88	222.20	219.10	3.7	3.1	0.32	450	0.9%	282	63%	62%	1.6	
Saint Venant Boulevard	17A	19A	0.6	0.1	12	0.6	0.1	12	4.00	0.3	0.14	0.4	222.90	219.90	222.20	219.20	3.0	3.0		200	1.6%	43	7%	12%	0.3	Requires frequent cleaning
Williams Avenue	19A	25A	1.1	0.4	80	60.0	52.5	10082	2.95	154.9	13.81	168.8	222.20	217.74	219.60	216.52	4.5	3.1	1.45	450	0.9%	282	63%	63%	1.6	1.45 m drop structure U/S
Williams Avenue	25A	30A	1.1	0.4	80	61.1	52.9	10162	2.95	156.0	14.06	170.0	219.60	216.49	218.25	215.24	3.1	3.0	0.03	450	0.9%	282	64%	63%	1.6	
Horton Way	18A	21A	0.6	0.3	48	0.6	0.3	48	4.00	1.0	0.14	1.1	222.80	219.70	221.45	218.37	3.1	3.1		200	1.9%	47	12%	16%	0.5	Requires frequent cleaning
Horton Way	21A	24A	0.8	0.3	64	1.4	0.6	112	4.00	2.3	0.33	2.7	221.45	218.34	219.75	216.67	3.1	3.1	0.03	200	1.7%	44	18%	22%	0.6	
Horton Way	24A	28A	0.5	0.2	40	2.0	0.8	152	4.00	3.2	0.45	3.6	219.75	216.64	219.20	215.85	3.1	3.3	0.03	200	1.0%	34	24%	25%	0.6	Requires frequent cleaning
Adams Avenue	27A	28A	0.2	0.1	12	0.2	0.1	12	4.00	0.3	0.04	0.3	219.45	216.45	219.20	216.08	3.0	3.1		200	1.0%	34	7%	11%	0.3	Requires frequent cleaning
Adams Avenue	28A	30A	0.4	0.1	28	2.6	1.0	192	4.00	4.0	0.59	4.6	219.20	215.76	218.25	214.92	3.4	3.3	0.32	200	1.0%	34	27%	27%	0.6	
Adams Avenue	30A	31A	0.4	0.1	28	64.1	54.1	10382	2.94	158.9	14.75	173.6	218.25	214.67	217.50	213.91	3.6	3.6	0.57	450	0.9%	282	64%	64%	1.6	
Darcy Way	2A	3A	0.5	0.1	28	0.5	0.1	28	4.00	0.6	0.10	0.7	228.10	225.00	226.50	223.45	3.1	3.1		200	1.6%	43	9%	14%	0.4	Requires frequent cleaning
Darcy Way	3A	10A	0.4	0.1	28	0.8	0.3	56	4.00	1.2	0.19	1.4	226.50	223.42	224.40	221.28	3.1	3.1	0.03	200	2.2%	51	12%	17%	0.6	Requires frequent cleaning
Weisbach Street	10A	15A	0.4	0.1	16	1.2	0.4	72	4.00	1.5	0.28	1.8	224.40	221.19	223.00	219.83	3.2	3.2	0.09	200	1.6%	43	15%	18%	0.5	Requires frequent cleaning
Moody Drive	8A	12A	0.9	0.4	73	0.9	0.4	73	4.00	1.5	0.20	1.7	225.25	222.25	223.90	220.87	3.0	3.0		200	2.0%	48	14%	18%	0.6	Requires frequent cleaning
Moody Drive	12A	15A	0.7	0.3	48	1.5	0.6	121	4.00	2.5	0.35	2.8	223.90	220.84	223.00	219.96	3.1	3.0	0.03	200	1.2%	37	21%	22%	0.6	Requires frequent cleaning
Weisbach Street	15A	22A	0.5	0.1	20	3.2	1.1	213	4.00	4.4	0.74	5.2	223.00	219.80	221.40	218.19	3.2	3.2	0.16	200	1.9%	47	25%	29%	0.8	
Bernoulli Boulevard	14A	16A	0.7	0.2	44	0.7	0.2	44	4.00	0.9	0.16	1.1	223.30	220.30	222.75	219.65	3.0	3.1		200	1.0%	34	13%	16%	0.4	Requires frequent cleaning
Bernoulli Boulevard	16A	22A	0.6	0.2	40	1.2	0.4	84	4.00	1.8	0.29	2.0	222.75	219.62	221.40	218.31	3.1	3.1	0.03	200	1.8%	46	16%	19%	0.6	Requires frequent cleaning
Weisbach Street	22A	26A	0.5	0.1	20	5.0	1.6	317	4.00	6.6	1.15	7.7	221.40	217.46	219.60	216.56	3.9	3.0	0.85	200	1.1%	36	35%	35%	0.7	0.85 m drop structure U/S
Saint Venant Boulevard	26A	23A	0.5	0.2	32	5.5	1.8	349	4.00	7.3	1.26	8.5	219.60	216.47	220.75	216.09	3.1	4.7	0.09	200	0.6%	26	44%	37%	0.6	Watertight lid at U/S MH; Pipe slope opposes terrain
Saint Venant Boulevard	20A	23A	0.4	0.1	24	0.4	0.1	24	4.00	0.5	0.09	0.6	221.90	218.90	220.75	217.73	3.0	3.0		200	1.7%	44	8%	13%	0.4	Requires frequent cleaning
Hazen Way	23A	29A	1.0	0.4	72	6.9	2.3	445	4.00	9.3	1.58	10.8	220.75	216.00	218.50	215.20	4.8	3.3	1.73	200	0.6%	26	50%	42%	0.7	1.73 m drop structure U/S
Hazen Way	29A	31A	1.1	0.4	80	8.0	2.7	525	3.96	10.8	1.83	12.7	218.50	215.17	217.50	214.47	3.3	3.0	0.03	200	0.5%	24	58%	46%	0.7	
Adams Avenue	31A	32A	0.0	0.0	0	72.1	56.8	10908	2.92	165.7	16.59	182.3	217.50	213.87	217.30	213.83	3.6	3.5	0.60	450	0.9%	282	66%	66%	1.6	
Adams Avenue	32A	33A	0.2	0.0	4	72.3	56.8	10912	2.92	165.7	16.62	182.3	217.30	213.80	216.75	212.53	3.5	4.2	0.03	450	0.9%	282	66%	66%	1.6	Exiting development

Appendix B. Sanitary Drainage Area Plan

The Sanitary Drainage Area Plan is included at its full plotted size, folded on the following page.



METRIC
ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE SHOWN

KEY PLAN N.T.S.

LEGEND

- PROP OVERLAND FLOW DIRECTION
- MH.1 STORM MANHOLE
- MH.1A PROP SANITARY MANHOLE
- PROP SANITARY DROP STRUCTURE
- WATERMAIN SANITARY CROSSING
- 1.00 DRAINAGE AREA (ha) / 10 POPULATION / 40 NUMBER OF UNITS
- LIMIT OF SANITARY DRAINAGE AREA
- LIMIT OF PROPOSED DEVELOPMENT
- PROPOSED SANITARY SEWER
- EX.FH EX. VALVED HYDRANT
- PROP VALVED HYDRANT
- 90 DEGREE BEND
- TEE CONNECTION
- REDUCER
- WATER SERVICE CONNECTION

NO.	REVISION	BY	DATE
3			
2	STORM DESIGN SUBMISSION	X.X.	DD MMM 2025
1	SANITARY DESIGN SUBMISSION	T.4	23 MAR 2025
0	WATER DESIGN SUBMISSION	T.4	10 FEB 2025

REVISIONS

CLIENT:
fabian papa & partners
A Division of FP&P HydraTek Inc.
3901 Highway 7, Suite 500
Vaughan, Ontario, L4L 8L5
t: 905-264-2420
www.fabianpapa.com

MUNICIPALITY:
ADAMSVILLE
ENGINEERING AND CONSTRUCTION SERVICES

PROJECT NAME:
ADAMSVILLE VILLAGE
DRAFT PLAN SUBDIVISION

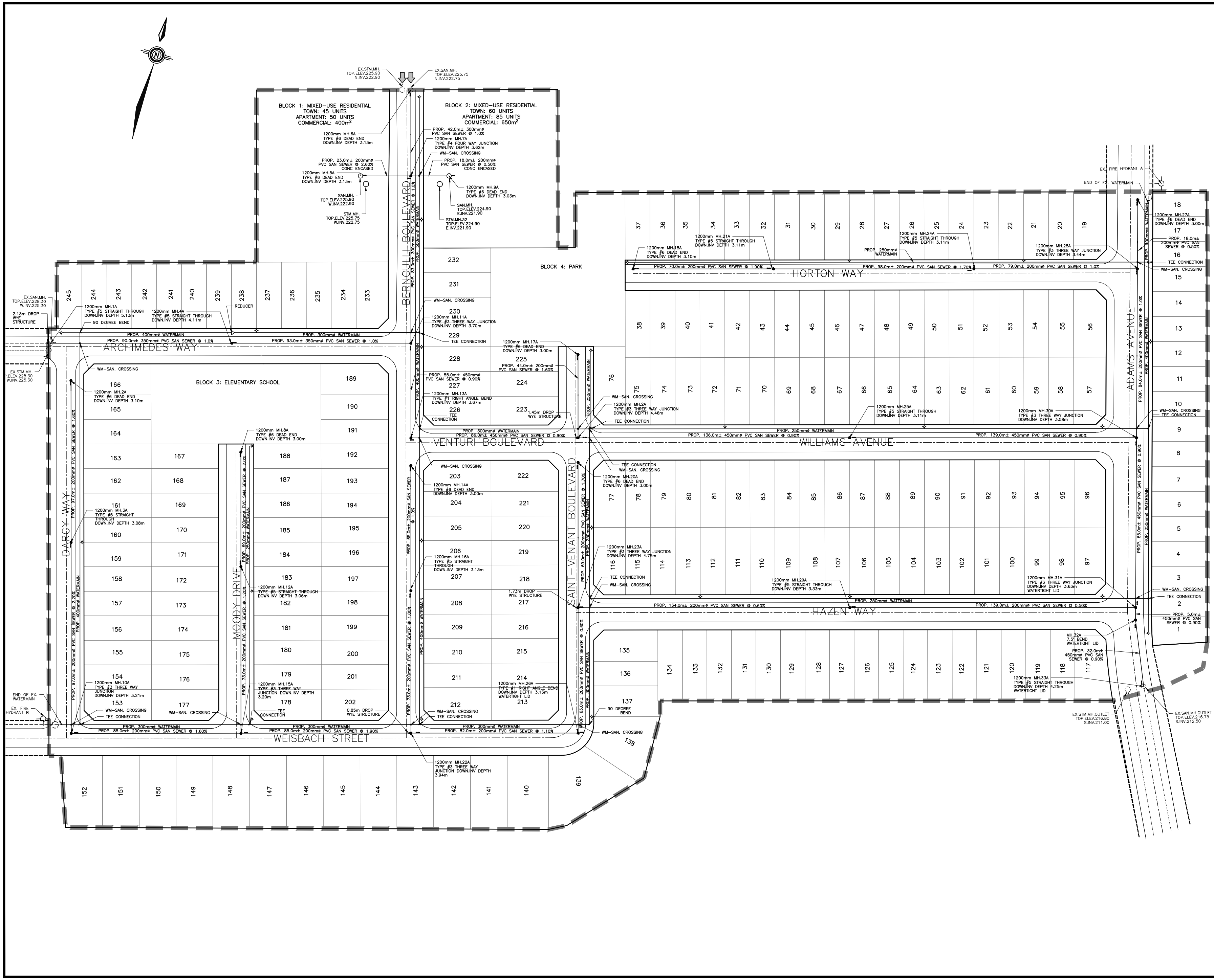
DRAWING TITLE:
SANITARY DRAINAGE AREA PLAN

DWN. BY:	T.4
DESIGNED BY:	T.4.
CHECKED BY:	T.4
SCALE:	1:500
DATE:	23 MAR 2025
SHEET NO:	2 OF 4

PROJECT NO.	DWG NO.	REV. NO.
25001	SAN-1	1

Appendix C. General Plan of Services

The General Plan of Services is included at its full plotted size, folded on the following page.



METRIC
ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE SHOWN

KEY PLAN N.T.S.

LEGEND

- PROP OVERLAND FLOW DIRECTION
- MH.1 STORM MANHOLE
- MH.1A PROP SANITARY MANHOLE
- PROP SANITARY DROP STRUCTURE
- WATERMAIN SANITARY CROSSING
- 1.00 DRAINAGE AREA (ha)
- 10 POPULATION
- 40 NUMBER OF UNITS
- LIMIT OF SANITARY DRAINAGE AREA
- LIMIT OF PROPOSED DEVELOPMENT
- PROPOSED SANITARY SEWER
- EX.FH EX. VALVED HYDRANT
- PROP VALVED HYDRANT
- 90 DEGREE BEND
- TEE CONNECTION
- REDUCER
- WATER SERVICE CONNECTION

NO.	REVISION	BY	DATE
3			
2	STORM DESIGN SUBMISSION	X.X.	DD MMM 2025
1	SANITARY DESIGN SUBMISSION	T.4	23 MAR 2025
0	WATER DESIGN SUBMISSION	T.4	10 FEB 2025

REVISIONS

CLIENT:
fabian papa & partners
A Division of FP&P HydraTek Inc.
3901 Highway 7, Suite 500
Vaughan, Ontario, L4L 8L5
t: 905–264–2420
www.fabianpapa.com

MUNICIPALITY:
ADAMSVILLE
ENGINEERING AND CONSTRUCTION SERVICES

PROJECT NAME:
ADAMSVILLE VILLAGE
DRAFT PLAN SUBDIVISION

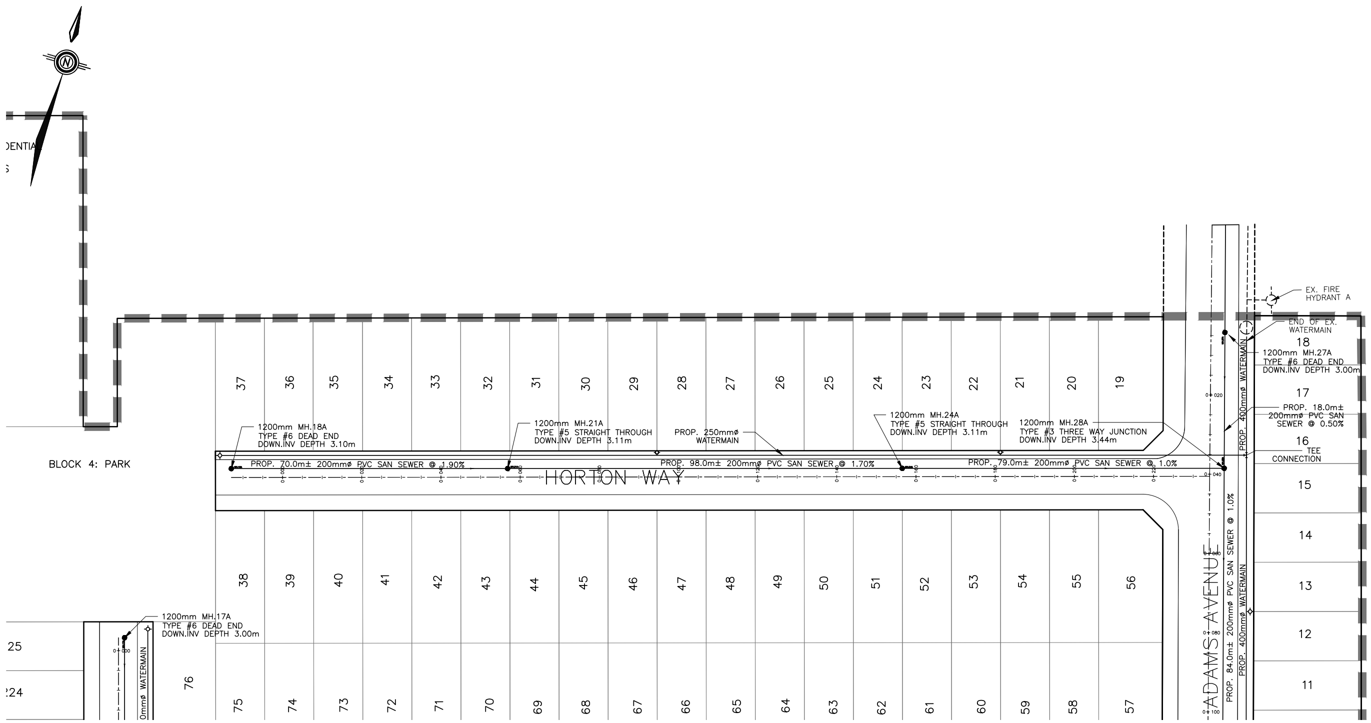
DRAWING TITLE:
GENERAL PLAN

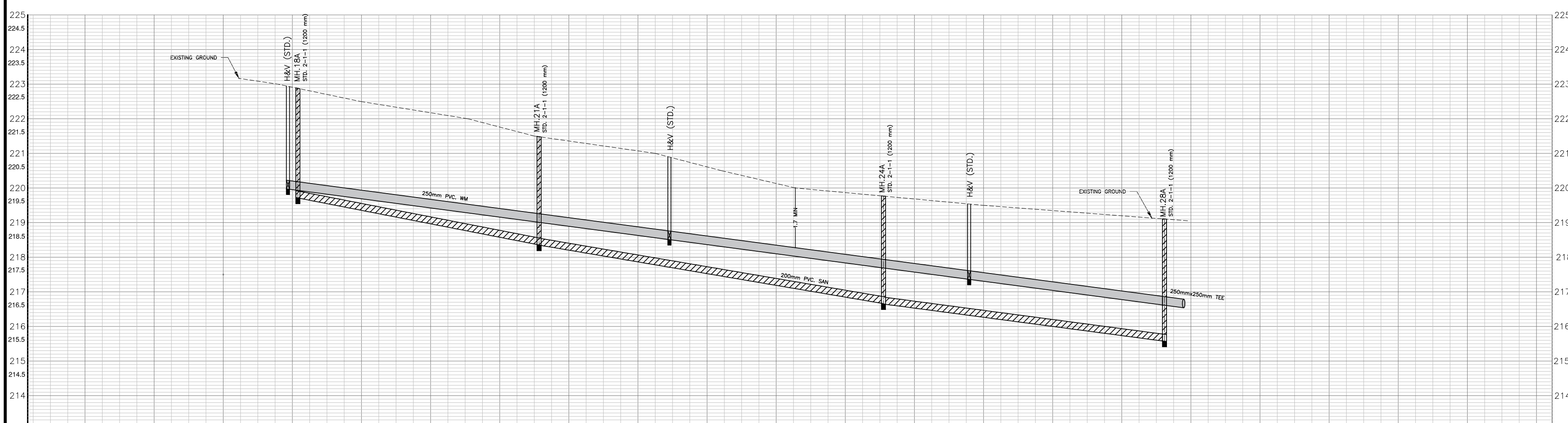
DWN. BY:	T. 4
DESIGNED BY:	T. 4
CHECKED BY:	T. 4
SCALE:	1:500
DATE:	23 MAR 2025
SHEET NO:	1 OF 4

PROJECT NO.	DWG NO.	REV. NO.
25001	GP–1	1

Appendix D. Plan and Profile Drawing

The General Plan of Services is included at its full plotted size, folded on the following page.





STORM INVERT	
SANITARY INVERT	E219.7 · PROP 250mm DIA 70m PVC SAN. @1.9% · W218.37 E218.34 · PROP 250mm DIA 98m PVC SAN. @1.7% · W216.67 E216.64 · PROP 250mm DIA 79m PVC SAN. @1.0% · W215.85

C/L CHAINAGE	0+020	0+040	0+060	0+080	0+100	0+120	0+140	0+160	0+180	0+200	0+220	0+240	0+260
PROPOSED GRADES	223.000	222.600	222.250	221.900	221.450	221.150	220.750	220.250	219.920	219.750	219.550	219.390	219.250

METRIC
ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE SHOWN

KEY PLAN N.T.S.

LEGEND

- × 123.45 PROPOSED ELEVATION
- MH.1A SANITARY MANHOLE
- EX.FH EX. VALVED HYDRANT
- EX. PROPOSED HYDRANT
- PROPOSED 2 WAY CONNECTION
- PROPOSED TEE CONNECTION
- WATER SERVICE CONNECTION
- PROPOSED SANITARY SEWER
- 1.00 DRAINAGE AREA (ha); 10 POPULATION; 40 NUMBER OF UNITS
- LIMIT OF SANITARY DRAINAGE AREA
- LIMIT OF PROPOSED DEVELOPMENT

NO.	REVISION	BY	DATE
3			
2	STORM DESIGN SUBMISSION	X.X.	DD MMM 2025
1	SANITARY DESIGN SUBMISSION	T.4	23 MAR 2025
0	WATER DESIGN SUBMISSION	T.4	10 FEB 2025

REVISIONS

CLIENT:
fabian papa & partners
A Division of FP&P HydraTek Inc.
3901 HIGHWAY 7, Suite 500
Vaughan, Ontario, L4L 8L5
t: 905-264-2420
www.fabianpapa.com

MUNICIPALITY:
ADAMSVILLE
ENGINEERING AND
CONSTRUCTION SERVICES

PROJECT NAME:
ADAMSVILLE VILLAGE
DRAFT PLAN SUBDIVISION

DRAWING TITLE:
PLAN & PROFILE – HORTON W
FROM STA 0+020 TO STA. 0+260

DWN. BY:	T.4
DESIGNED BY:	T.4
CHECKED BY:	T.4
SCALE:	HORZ. 1:500 VERT. 1:50
DATE:	23 MAR 2025
SHEET NO:	4 OF 4

PROJECT NO.	DWG NO.	REV. NO.
25001	PP–1	1

Appendix E. Manual Invert Drop Calculations

When velocity exceeds 1.5 m/s in a pipe, the invert drop in the maintenance hole downstream of it was calculated manually to ensure safe design. When the calculated drop is greater than the standard drop for the pipe, the calculated value was used for accuracy. However, when the calculated drop is less than the standard one, the standard value was used to be conservative and consistent. In total, 7 pipes have a maximum velocity above 1.5 m/s, and manual calculations for each are shown in Table 9 below. See Section 5.1 for a detailed example calculation. Even though it has a high upstream velocity, no manual calculation was done for maintenance hole 33A since it would require the flow characteristics in the downstream pipe, which is outside the scope of the development. The standard value of 0.03 m was assumed to apply in this case, based on the calculation done for maintenance hole 32A—which carries near-identical flow. In cases when multiple pipes flow into one maintenance hole, only the pipe with velocity above 1.5 m/s was considered in the calculation.

Table 9. Manual calculations of required invert drops.

Maintenance Hole	Manual Calculation	Invert Drop Used
13A	$\Delta I = (0.287 - 0.287) + (\frac{1.56^2}{2g} - \frac{1.56^2}{2g}) + 1.0 \cdot \frac{1.56^2}{2g}$ = 0.124 m	0.124 m
19A	$\Delta I = (0.289 - 0.287) + (\frac{1.56^2}{2g} - \frac{1.56^2}{2g}) + 0.15 \cdot \frac{1.56^2}{2g}$ = 0.021 m	0.03 m (standard)
25A	$\Delta I = (0.290 - 0.289) + (\frac{1.57^2}{2g} - \frac{1.56^2}{2g}) + 0.15 \cdot \frac{1.57^2}{2g}$ = 0.021 m	0.03 m (standard)
30A	$\Delta I = (0.294 - 0.290) + (\frac{1.58^2}{2g} - \frac{1.57^2}{2g}) + 1.0 \cdot \frac{1.58^2}{2g}$ = 0.132 m	0.132 m
31A	$\Delta I = (0.303 - 0.294) + (\frac{1.60^2}{2g} - \frac{1.58^2}{2g}) + 0.15 \cdot \frac{1.60^2}{2g}$ = 0.032 m	0.032 m
32A	$\Delta I = (0.303 - 0.303) + (\frac{1.60^2}{2g} - \frac{1.60^2}{2g}) + 0.15 \cdot \frac{1.60^2}{2g}$ = 0.020 m	0.03 m (standard)
33A	Not calculated (out of scope)	0.03 m (standard)

Appendix F. Maintenance Holes and Drop Structures

The type, size, and depth of each maintenance hole is tabulated in this section (Table 10). The downstream invert depth is used as a measure of maintenance hole depth. The identifying type numbers are taken from OPSD 701.021 [9]: Type 1 is a right angle bend, Type 2 is a tee connection, Type 3 is a three-way junction, Type 4 is a four-way junction, Type 5 is straight through, and Type 6 is a dead end. For maintenance holes with drop structures, the appropriate wye drop structure standard was also included below the maintenance hole standard.

Table 10. Tabulated list of maintenance holes, drop structures, and their properties.

Name	Type	Size	Standard [4][10]	Downstream Invert Depth
1A	5 - Straight Through	1200 mm	OPSD 701.010	5.13 m
	Drop Structure	2.13 m	OPSD 1003.020	-
2A	6 - Dead End	1200 mm	OPSD 701.010	3.10 m
3A	5 - Straight Through	1200 mm	OPSD 701.010	3.08 m
4A	5 - Straight Through	1200 mm	OPSD 701.010	4.11 m
5A	6 - Dead End	1200 mm	OPSD 701.010	3.13 m
6A	6 - Dead End	1200 mm	OPSD 701.010	3.13 m
7A	4 - Four Way Junction	1200 mm	OPSD 701.010	3.62 m
8A	6 - Dead End	1200 mm	OPSD 701.010	3.00 m
9A	6 - Dead End	1200 mm	OPSD 701.010	3.03 m
10A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.21 m
11A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.70 m
12A	5 - Straight Through	1200 mm	OPSD 701.010	3.06 m
13A	1- Right Angle Bend	1200 mm	OPSD 701.010	3.67 m
14A	6 - Dead End	1200 mm	OPSD 701.010	3.00 m
15A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.20 m
16A	5 - Straight Through	1200 mm	OPSD 701.010	3.13 m

17A	6 - Dead End	1200 mm	OPSD 701.010	3.00 m
18A	6 - Dead End	1200 mm	OPSD 701.010	3.10 m
19A	3 - Three Way Junction	1200 mm	OPSD 701.010	4.46 m
	Drop Structure	1.45 m	OPSD 1003.020	-
20A	6 - Dead End	1200 mm	OPSD 701.010	3.00 m
21A	5 - Straight Through	1200 mm	OPSD 701.010	3.11 m
22A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.94 m
22A	Drop Structure	0.85 m	OPSD 1003.020	-
23A	3 - Three Way Junction	1200 mm	OPSD 701.010	4.75 m
	Drop Structure	1.73 m	OPSD 1003.020	-
24A	5 - Straight Through	1200 mm	OPSD 701.010	3.11 m
25A	5 - Straight Through	1200 mm	OPSD 701.010	3.11 m
26A	1- Right Angle Bend	1200 mm	OPSD 701.010	3.13 m
27A	5 - Straight Through	1200 mm	OPSD 701.010	3.00 m
28A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.44 m
29A	5 - Straight Through	1200 mm	OPSD 701.010	3.33 m
30A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.58 m
31A	3 - Three Way Junction	1200 mm	OPSD 701.010	3.63 m
32A	7.5° Bend	1200 mm	OPSD 701.010	3.50 m
33A	5 - Straight Through	1200 mm	OPSD 701.010	4.25 m

Appendix G. Municipal Service Crossings

As described in Section 4.1, some sewers do not meet the minimum 2.5 m horizontal clearance between sanitary pipes and water pipes. One of these crossings occurs where the eastern mixed-use sanitary pipe crosses the water main, and the rest occur at street intersections where sanitary and water pipes cross out of necessity. These cases are tabulated below (Table 11). The sewer system was designed in alignment with the MOE guidelines such that water pipes run over the sewer pipes, with at least 0.5 m of vertical clearance [11]. This is further explained in Section 4.1. In total, water pipes pass over sanitary pipes on 14 occasions in the proposed network.

Table 11. List of locations where water distribution pipes cross over sanitary pipes.

Intersection
Bernoulli Boulevard (between mixed-use blocks)
Archimedes Way & Darcy Way
Archimedes Way & Bernoulli Boulevard
Bernoulli Boulevard & Venturi Boulevard
Bernoulli Boulevard & Weisbach Street
Weisbach Street & Moody Drive
Weisbach Street & Darcy Way
Venturi Boulevard & Saint Venant Boulevard (north side)
Venturi Boulevard & Saint Venant Boulevard (east side)
Saint Venant Boulevard & Hazen Way
Saint Venant Boulevard & Weisbach Street
Adams Avenue & Horton Way
Adams Avenue & Williams Avenue
Adams Avenue & Hazen Way

Appendix H. Updated Team Charter

<table>
<tr><th>Team Dynamic</th><th>Norms (the shared action/behaviour)</th></tr>
<tr><td>Building Relationships & Trust among members

(create psychological safety!)</td><td>As a team, we will create a psychologically safe work environment in our interactions by:
- Avoiding mention of private matters unrelated to the project, to prevent sensitive issues being discussed that may inhibit members from engaging in the discussion
- Being aware of and intolerant towards any humiliation of team members, both purposeful and accidental
    - This encapsulates comments about the project but also about any unrelated topics
- Considering any ideas and input from all team members, acknowledging that each member brings a unique perspective that can add value to the team’s work
    - This involves actively listening when members are speaking (eye contact, etc.), giving each member attention during team meetings, and discussing politely and respectfully with team members if any completed work needs to be changed
- Avoiding derogatory or discriminatory language in our discussions, including potentially-offensive slang terminology
    - This will ensure a safe environment in which all members can express themselves without fear of reprisal</td></tr>
<tr><td>Team Communication</td><td>Update:

The team will also communicate every time there is a significant development in the project—e.g., a question was answered on Piazza or a design decision was made. This should also be noted in the "Tasks/Internal Deadlines" Google Doc so there is a record for all team members to review.

- The team will communicate through:
    - Discord group chat to share large files
    - Instagram group chat for quick updates and messages
- Our communication style will be professional, respectful and timely
- We will communicate when:
    - We are struggling with understanding a concept
    - We are unable to complete a task on time
    - We want to clarify any work that has already been completed or get a status update on a task
- We will communicate with each other in a timely manner
    - 2-3 hour response time on regular days</td></tr>
</table>

	- 1 hour maximum response time 2 days before submission - To ensure respectful communication, we will: - Abide by all requirements laid out in the rest of the team charter, particularly including any those on psychological safety and handling disagreements - We will give other team members the benefit of the doubt when offering suggestions for changes to their work

Organizing & Conducting Meetings	**Update**:
	Not all team meetings will require all team members to be present where pre-existing plans preclude this possibility. In these cases, the "Team Communication" norms will be enforced such that there is minimal need to update team members—instead, team members will read updates from the task log document and get on track quickly.
	
	To organize our meetings, we will:
	- Communicate intentions to meet at least 2 days before the proposed meeting time
	- Ensure all members are able to attend meetings, and avoid scheduling meetings during times others indicate they are unavailable
	    - This means ensuring all members are able to provide their input or consent to a planned meeting time, before confirming it for the team
	- Ensure that the time and place of meetings do not negatively affect the physical, mental, or emotional health of any members
	    - This includes scheduling during working hours if possible, to accommodate a wide range of sleep schedules
	    - This also includes a conscious effort to avoid infringing on any member's religious practices
	
	During our meetings, we will:
	- Treat all members with respect, as outlined in the 'Building Relationships and Trust' section
	- Remain present and focused, working on the project and discussing topics related to the project, and leaving other conversations for later
	- Avoid becoming distracted by outside sources, such as non-team members or social media
	- Do our best to avoid extending meetings past the agreed-upon ending time, in recognition of all members' busy schedules

Handling Conflict & Disagreements	- We will resolve conflicts civilly and politely, in keeping with the respect-focused guidelines laid out in the rest of this charter

	- When two team members cannot come to an agreement, they will consult the other members of the team and agree to abide by whatever decision they come to
	    - All major changes to the project will only continue with team consensus, meaning each team member has provided their verbal or written agreement with the change
	    - If a disagreement continues, we will consult with a TA or Piazza, and this decision will be final
	- Whenever possible, resolutions to disputes should involve fair compromise between those involved, recognizing that all members have a right to express their ideas and have them heard by the team

Managing Work & Projects	To ensure team responsibility for the project: **Update**: - All tasks should be split as early in advance and possible to assigned to team members such that each team member knows what they should be working on and all team members know what all other team members are working on, and such that all work is accounted for - All team members should update the "Tasks/Internal Deadlines" Google Doc once they have completed a task with a timestamp added, to communicate their progress to other team members - Additionally, all office hours and client consultations should be updated into the "Tasks/Internal Deadlines" document so all team members are aware of developments in the project decisions *Justification: Based on our last team experience, we had unassigned work that was not tracked. It became difficult to stay on task since the uncompleted tasks were not clear to all team members.* - We agree that all team members are responsible for the successful completion of the entire project - All team members put in full effort to fulfill responsibilities that are assigned to them, including completing work on time, reviewing other members' work, and communicating with other members - We will ensure to the best of our ability that the work is divided evenly amongst team members and no team member is doing significantly more or significantly less than the other - All members commit to speaking openly if they feel that they cannot complete their work to the best of their abilities or if they need help; the remaining team members will react constructively, offering support in line with the points outlined in the "Trust among members" section

	- Where possible, the team members who have finished their section will reach out to other team members to offer help, non-judgmentally and constructively, to ensure the project is finished on time