Clean Water Collector (CWC) System Implementation Report

Block 12 Development Lands
City of Vaughan

Water Resources and Environmental Consulting

588 Edward Avenue Unit 28
Richmond Hill, Ontario
L4C 9Y6

SCHAEFFERS
CONSULTING
ENGINEERS
64 Jardin Drive
Concord, Ontario
L4K 3P3

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Credits

This project was possible because of the environmental leadership and vision of the Toronto and Region Conservation Authority staff. The City of Vaughan planning and engineering staff also provided excellent input and comments during the conceptual and detailed design as well as during the testing phases.

The design process evolved from an initial concept to a detailed design after a series of iterations involving the development and implementation of the research site plus frequent consultations with geotechnical, water resources and municipal engineers, hydrogeologists, material suppliers, contractors, Conservation Authority staff, City of Vaughan staff, and participating developers. Credit should go to each for the development of the final implemented design.

1 INTRODUCTION

1.1 Background

The Clean Water Collector (CWC) system is a new municipal stormwater servicing technology designed and implemented in the Block 12 development lands in the City of Vaughan to enhance safe groundwater recharge in lands undergoing urban development. The system is different from other groundwater recharge methods because it uses only relatively clean water from roof areas and provides means to modify its operation and a direct access for maintenance. Other systems attempt to infiltrate runoff generated from pervious and impervious surfaces after providing a measure of water quality treatment to remove suspended solids and other contaminants and provide little or no opportunities for controlling its operation or maintenance. The concerns with these other systems are their longevity and the potential for groundwater contamination. Appendix A summarizes documentation on recent experiences with similar infiltration systems.

The CWC system will have significant environmental benefits beyond groundwater infiltration. The stormwater management strategy for Block 12 provides an integrated treatment train approach to water management premised on controlling runoff first at the source and in the conveyance system followed by end-of-pipe controls. According to the MOE (2003, p. 4-1), this combination of controls is the only means of meeting the multiple criteria for water balance, water quality, erosion control and water quantity. The CWC system will help achieve key watershed objectives such as:

- Preserve groundwater recharge and baseflow characteristics;
- Prevent undesirable and costly geomorphic change in the watercourse;
- Prevent an increase in flood risk potential;
- Protect water quality; and ultimately
- Maintain an appropriate diversity of aquatic life.

1.2 Area Proposed for Implementation

The Block 12 development area is located east of the community of Maple, in the City of Vaughan, Ontario. As shown in Figure 1, the block is rectangular in shape and is north of Major Mackenzie Drive, east of Dufferin Street, south of Teston Road and west of Bathurst Street. Figure 2 shows the latest block plan. The block is partly within the Oak Ridges Moraine (ORM) identified as one of the primary groundwater recharge areas supplying aquifers, streams, wetlands, ponds and other surface water systems. Maintaining infiltration is an important development requirement identified early in the Block 12 planning process.

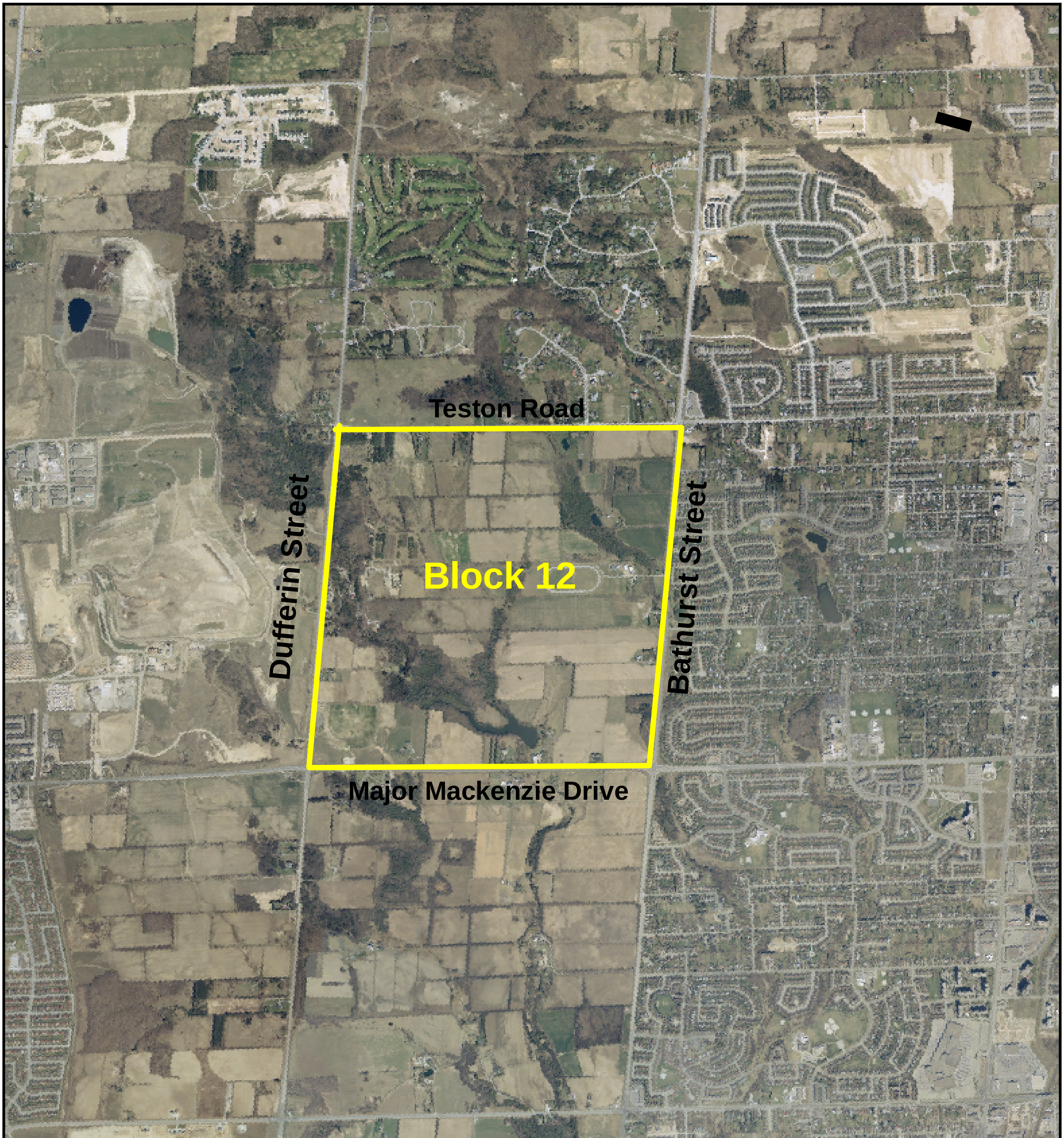

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Figure 1: Key Plan

Date: October 3, 2005

0 250 500 1,000 1,500 Meters

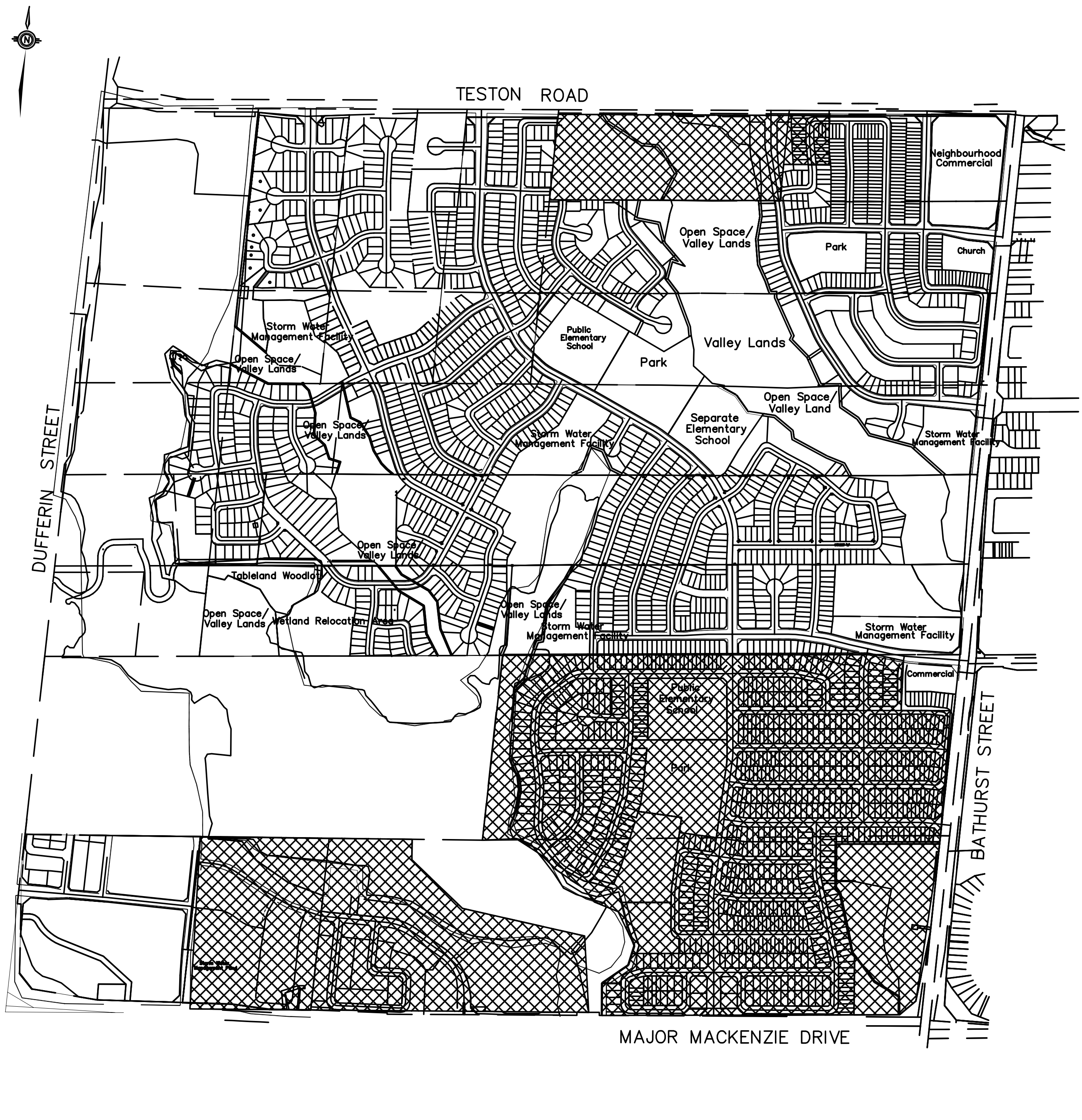

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Figure 2: Block 12 Development Plan

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1.3 Need for the CWC System

A Master Environmental Servicing Plan (MESP) and Environmental Impact Statement (EIS) (Schaeffers et al., 2001) presented the results of a watershed-based water balance analysis used to assess the impacts of proposed development on groundwater recharge. Water balance calculations of post-development conditions indicated that infiltration over the entire block might be reduced by approximately 21% due to the increase in impervious surfaces. Losses in infiltration within the watershed areas ranged from 18% to 31%, in the East Don River and McNair Creek respectively, depending on the proportion of undeveloped lands remaining undeveloped.

To ensure no net loss of infiltration, the MESP proposed a system that would collect the roof runoff from residential roof areas for conveyance to perforated pipes under the municipal right-of-way. Sufficient storage would be provided in the system to capture the runoff from a 22 mm event. For events exceeding 22 mm in depth, at least the first 22 mm would be stored and infiltrated and the excess would overflow into the standard storm sewer. The perforated pipe and overflow system would be contained within the right-of-way under the control of the municipality.

The MESP's long-term water balance analysis estimated a roof runoff capture rate of 87% within the Clean Water Collector system. The remaining 13% would overflow into the storm sewers.

1.4 Purpose of this Document

This document describes the design, testing, implementation, and the operation and maintenance of the Block 12 CWC system. The information contained herein should assist reviewers, potential proponents, and others to understand the concept and to evaluate the detailed design features and site conditions under which the system was implemented. The ultimate configuration of the Clean Water Collector system in Block 12 in the City of Vaughan is prescribed through detailed municipal servicing drawings and tender documents prepared by Schaeffers Consulting Engineers.

2 RESEARCH SITE

2.1 Introduction

The CWC system was tested prior to detailed design through the implementation and operation of a research site in the Block 12 development lands. The site was operated from March 2003 to June 2004. Appendix B presents the detailed documentation related to the CWC research site work. This section summarizes the findings of the research site investigations.

2.2 Location

Figure 3 shows the CWC research site location. The location was selected to represent average hydrogeologic conditions in the block. The conditions at the site were determined by excavating two 5-metre deep test pits on November 26, 2002. The pits were excavated in the presence of an experienced hydrogeologist[1]. The soil at the selected location was found to be homogeneous, dry, and loose enough to be worked by hand characteristic of typical sandy-silts. No moisture was observed at depth. The selected site was deemed to be representative of typical conditions in Block 12 based on previous experiences excavating similar pits at various locations in the block and conducting infiltration tests.

2.3 Site Design

The research site replicated the conditions that would be found in developed areas in Block 12. The configuration and dimensions maintained the functional characteristics of the average residential lot. Figure 4 compares the layouts of a one lot tributary area and the research site.

The main features of the design included:

- The dimensions of the tributary area are consistent with the typical average sized lot and roof dimensions proposed in Block 12 (Schaeffers et al., 2001). The site represents one lot and one half of the municipal right-of-way. Only on half the length of the CWC pipe and trench was implemented.
- The size of the trench was selected to provide, together with the perforated pipe, the volume required to capture the runoff from a 22 mm rainfall/snowmelt event over the roof area.

[1] Two test pits were excavated on November 26, 2002 under the supervision of Mr. Edward Graham, M.A.Sc.Eng., P.Eng. (Water Resources Engineer, Clarifica Inc.) and Mr. Norbert Woerns, B.Sc.Geol, M.Sc.Geol., P.Geo. (Hydrogeologist, Gartner Lee Ltd.).

- The perforated pipe consisted of a smooth 525 mm diameter PVC pipe. A 57 cm^2/m perforation area was determined to pass the 5 year peak flow with a longevity factor of 3 against clogging. Four 16 mm diameter holes were drilled around the perimeter of the pipe spaced at 125 mm along its length providing 64 cm^2/m. Perforations were drilled on-site.
- The sanitary sewer was not installed in the test site.
- The site was divided into three functional rectangular areas:
  1. Roof
  2. Grass.
  3. Road, curb, driveway, and sidewalk.

  The roof area was connected to the CWC system; while the second and third areas were connected to the standard storm sewer.
- Separate catch basins were used to capture runoff from the roof area going into the CWC and from the ground areas draining into the standard storm sewer.
- Three manholes were installed to monitor flows from:
  1. Roof (connected to CWC system)
  2. Overflow from CWC system.
  3. Other areas in the lot and Right-of-Way (i.e. connected to the standard storm sewer pipe).
- A climate station comprised of a heated tipping bucket rain gauge, temperature sensor, and a data logger was installed on-site.
- Clean stone was used for backfill in the trench. The stone porosity was measured to be 0.35.
- Filter fabric (270R) was used around the PVC perforated pipe. No filter fabric was used to isolate the clear stone and the native soil. If clear stone would be used as trench backfill material, filter fabric would be required at the top and sides of the trench.

The photo in Figure 5 illustrates the completed research site.

2.4 Monitoring Results

Monitoring locations are depicted in Figure 6. Numerous events were monitored during the period of operation and these are documented in Appendix B. Except for the initial abstractions over the roof area (approx. 3 to 5%), all the rainfall over the roof area was captured by the CWC system and infiltrated.

The two largest events occurred on June 8, 2003 and May 22, 2004. They produced 34 and 45 mm rainfall depth and they were captured and infiltrated by the system without the storage in the trench reaching its maximum (22 mm). The May 22, 2004 event lasted two days. Figure 7 illustrates the runoff captured and trench storage response during the June 8, 2003 event and Figure 8 shows the May 22, 2004 event.

In both cases, the water level in the trench (displayed at the bottom of the chart) responded quickly to inputs and also recovered relatively quickly - in about 5 to 6 hours. The fast system response time suggests effective performance of the pipe perforations, the storage utilization, and the infiltration into the surrounding soils significantly enhances the system performance during the same event or other consecutive storms.

The May 22, 2004 event was comprised of several consecutive rainfall burst over short durations within 3 hours of each other (9.5 mm and 9.25 mm). The trench storage recovery occurs rapidly, even during relatively wet antecedent conditions.

The water table elevations did not rise to be measurable or affect the infiltration rates and storage remained at about half of the storage capacity. This suggests that:

- The test site did not infiltrate sufficient volume to affect the water table position.
- The infiltration from all the surrounding pre-development areas was also not sufficient to affect the water table.
- There is efficient groundwater flow in the area - small changes in infiltration rates cause relatively rapid increases in groundwater flow.

2.5 Practical Lessons Learned from Research Site

The CWC research site results exceeded the performance expectations. Although a decrease in effectiveness may be expected with less favourable hydrogeologic conditions (higher water table or less permeable soils), the efficient capture and infiltration rates suggest that some optimization may be possible without sacrificing water balance objectives. The high performance also suggests that the system may be effective under less favourable hydrogeologic settings.

Infiltration into native soils occurring from the start of the event significantly improves the system performance. Specific recommendations resulting from the research site monitoring include:

- The size of the perforated pipe could be reduced from the original size of 525 mm.

- There may be more flexibility for the selection of trench backfill material as long as the flow rate from the pipe into the trench storage is not sacrificed.
- The area of perforations was adequate and should be maintained to maintain longevity.
- The system may operate in many hydrogeologic settings. The CWC system may be effective in less favourable hydrogeologic conditions when considering the infiltration during inter event periods. The results suggest that most of the infiltration occurs during a runoff event or soon thereafter.

The results of the monitoring will be very useful in determining the CWC benefits towards reducing overall runoff volumes and erosion potential from the site. Potential reductions in stormwater management facility volumes and sewer sizes may be justified particularly in very favourable hydrogeologic conditions. The costs of implementation may be partially recoverable through reduced land and construction requirements associated with the implementation of the standard storm sewer service and storm water management facilities.

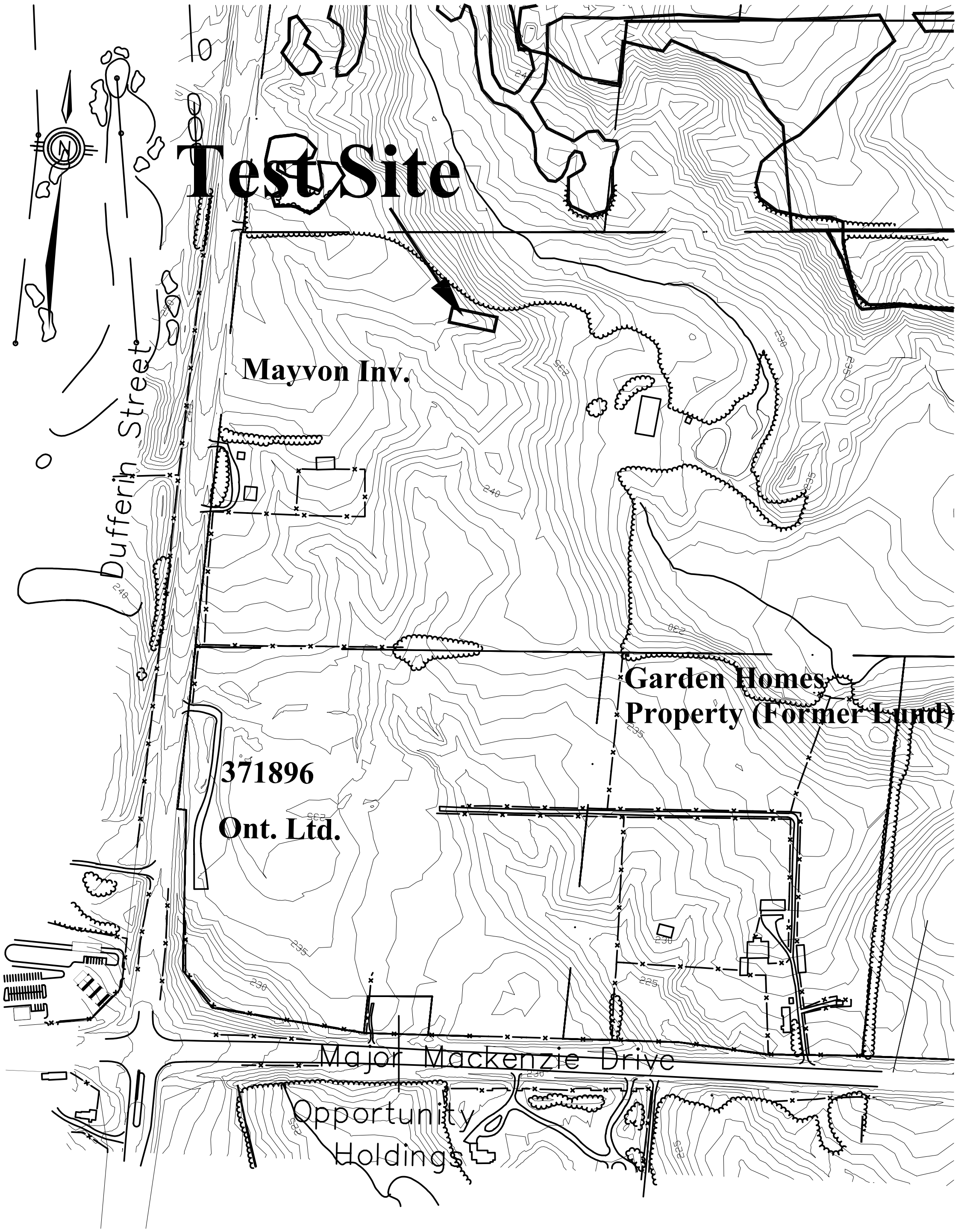

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Figure 3: CWC Research Site Location

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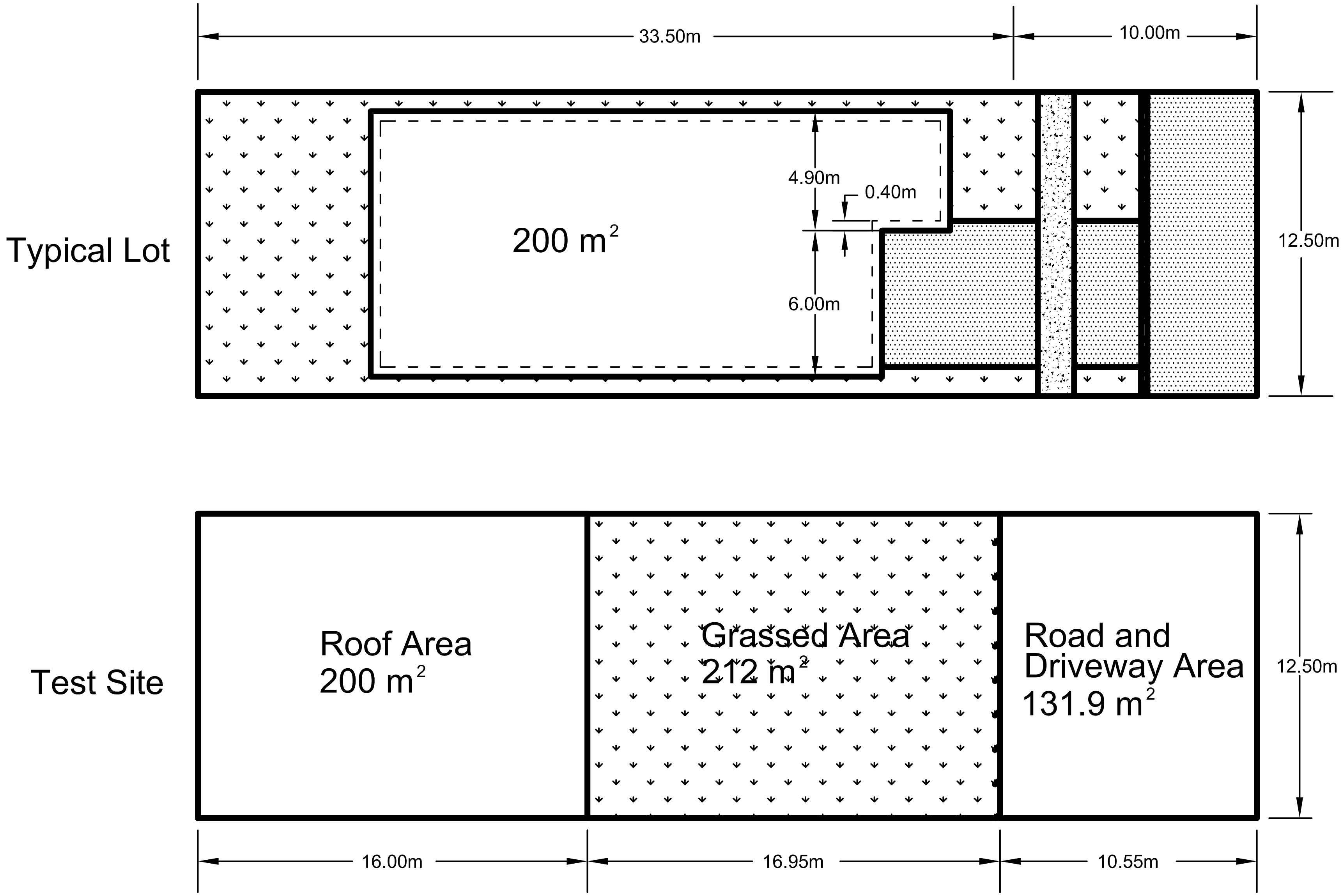

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Figure 4: Typical Lot and Test Site Comparison

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		Figure 5: Research Site Photo
		Date: October 3, 2005

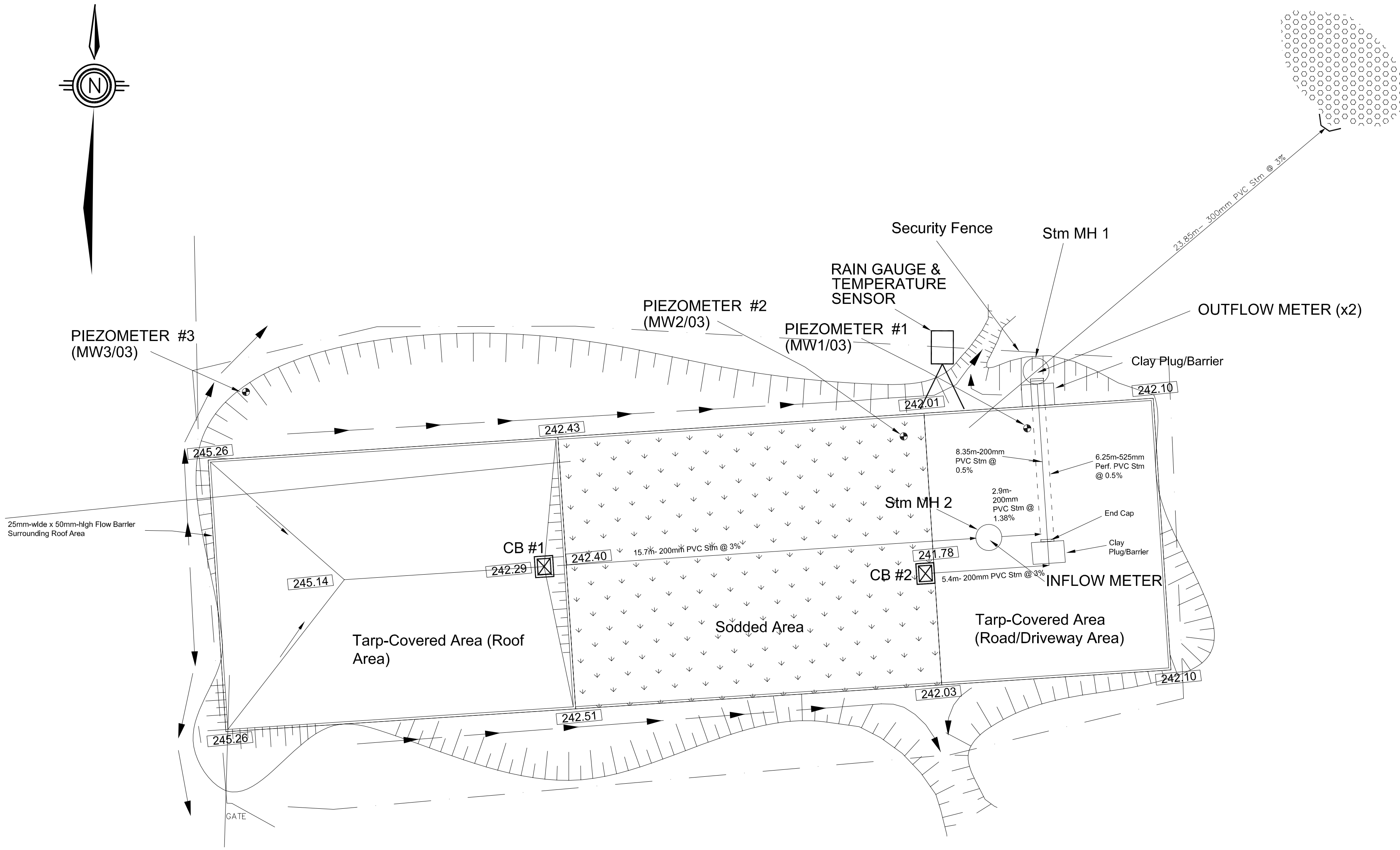

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Figure 6: Research Site Monitoring Locations

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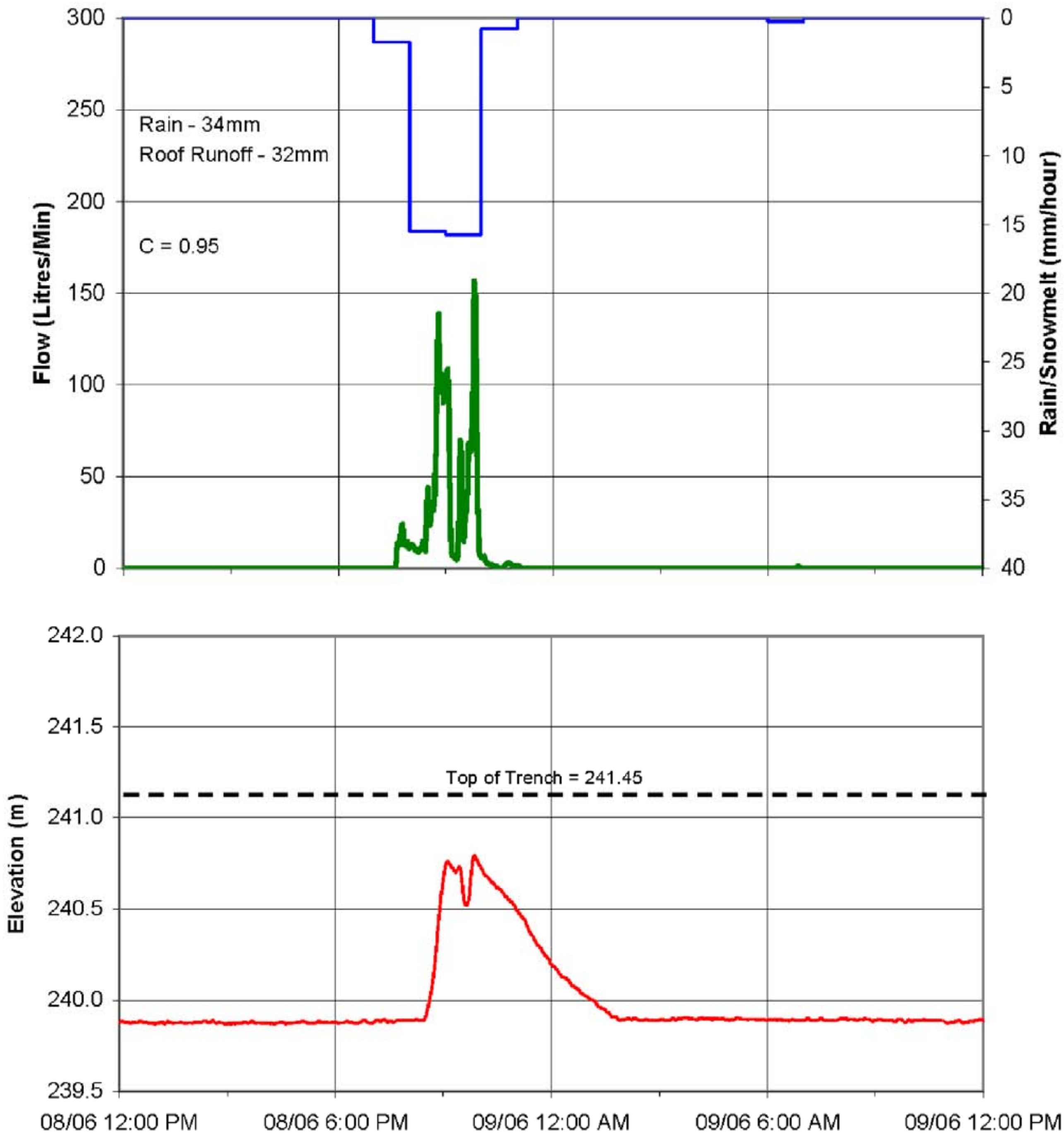

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Figure 7: June 8 2003 Storm Event Monitoring Results

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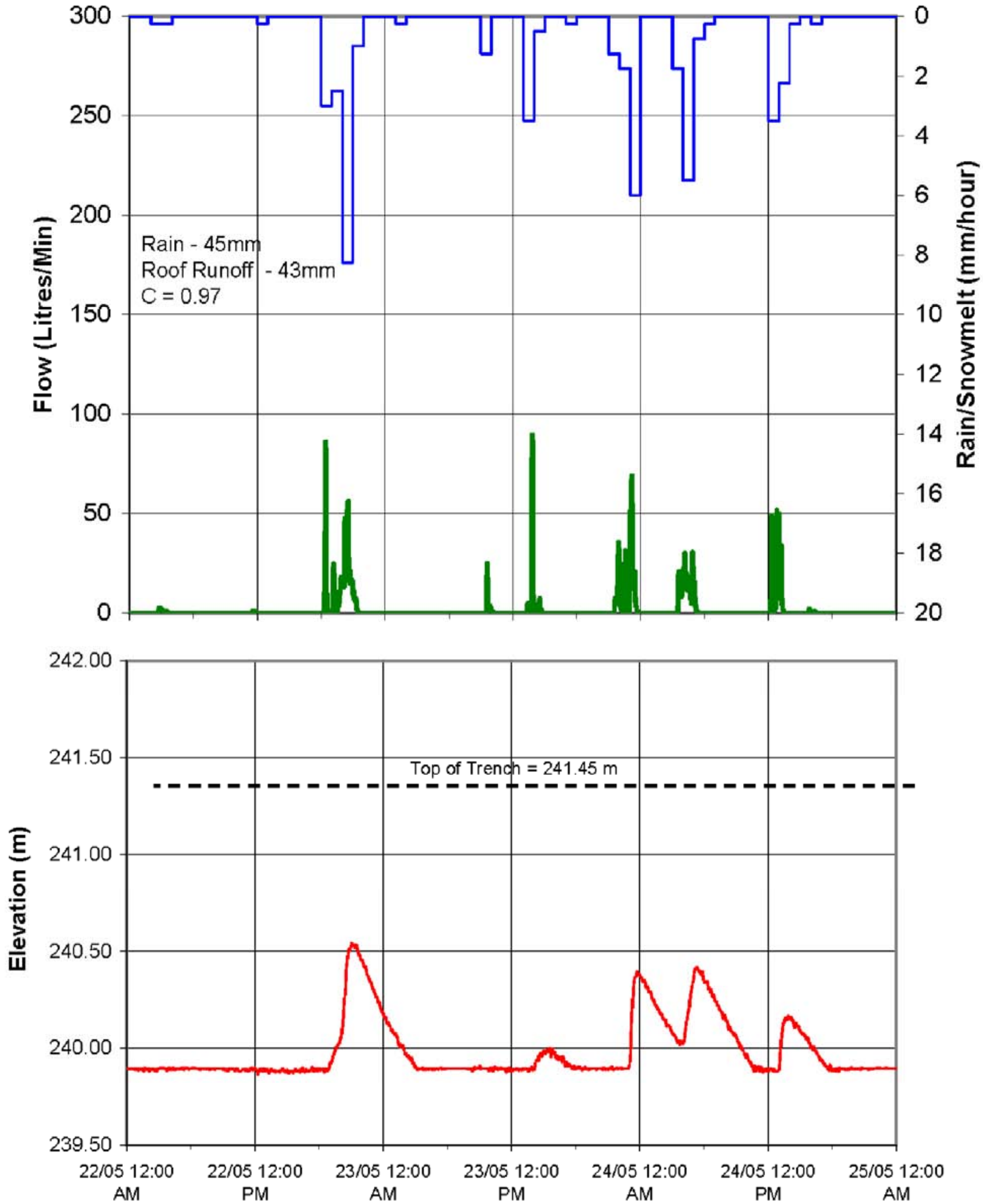

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Figure 8: May 22 2004 Storm Event Monitoring Results

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3 CWC SYSTEM DESIGN

This section describes the final design of the Clean Water Collector System, as implemented in the Block 12 development lands. The design process evolved from an initial concept to a detailed design after a series of iterations involving the development and implementation of the research site plus frequent consultations with geotechnical, water resources and municipal engineers, hydrogeologists, material suppliers, contractors, Conservation Authority staff, City of Vaughan staff, and participating developers.

The following sections describe the details of the design. Description of the feasibility criteria and feasible areas, and the operation and maintenance and proposed post-construction monitoring program are described in subsequent sections. The ultimate design configuration and system specifications are included in the approved detailed municipal servicing drawings and tender documents at the City of Vaughan and Schaeffers Consulting Engineers.

3.1 Operation

The CWC will collect the runoff from the house roofs in residential areas and will be used to replenish the ground water. Rainfall or snowmelt water from the roof will be conveyed to a perforated pipe and trench under the municipal right-of-way for distribution into the surrounding native soils. Figure 9 illustrates the cross-section of the CWC system prototype while Figure 10 illustrates a typical profile.

Eaves troughs and vertical roof leaders will collect the rain water from the roof and convey it towards the ground at pre-determined locations at the side of the house. Instead of splashing on the ground and continuing overland towards the street or to a catch basin, the roof water will flow through a large debris filter trap prior to entering the a underground pipe laid along the outside of the foundation wall and into a 150 mm diameter lateral connection. These lateral connections will be the third underground service connection (in addition to the sanitary and regular foundation drains) in front of the lot. The 150 mm diameter lateral will be connected to the CWC perforated pipe under the road. The perforated pipe, located above the standard storm sewer system and wrapped in geotextile fabric, will distribute the flow into the surrounding trench and native soil.

3.2 Pipe System

Figure 11 shows a photograph of the CWC pipe system. The CWC pipe is comprised of five main components:

1. The 375 mm diameter HDPE perforated pipe.
2. Solid connector to the downstream manhole.
3. Overflow system to downstream storm manhole.
4. Pipe plugs.
5. Lateral house connection leads.

3.2.1 Perforated Pipe

A 375 mm diameter High Density Polyethylene (HDPE) perforated pipe will collect and distribute water to the surrounding soil. The pipe will be smooth-walled inside and corrugated on the outside. Perforations are located within the channel section of the corrugations to avoid contact with the backfill material and maximize movement into the surrounding trench. The size and frequency of perforations have been selected to provide sufficient area and capacity to convey at least the 5 year peak storm captured over the roof areas. The perforations sizing calculation and holes pattern are presented in Figure 12.

To maximize the use of available storage in the trench, the perforated pipe will be installed using the shallowest longitudinal slope possible. Figure 10 shows the CWC pipe at shallower slopes than both the sanitary and storm sewer systems.

The perforated pipe will also operate as an additional treatment system by allowing settling and storage of particles entering the system. The area of the perforations has been specified assuming no perforations below the middle of the pipe or that these perforations are clogged. The outside of the perforated pipe will be wrapped with geotextile fabric (270R) to prevent contact with backfill material.

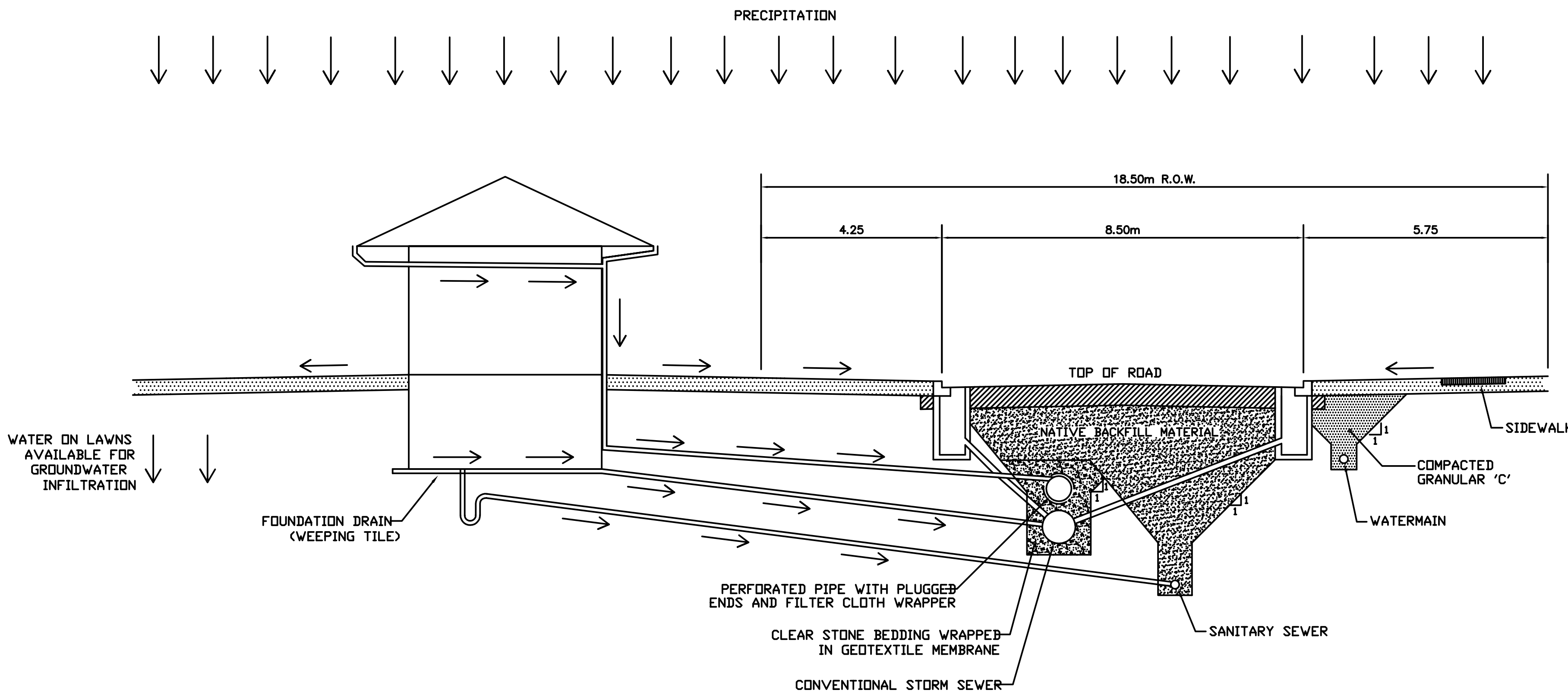

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Figure 9: Clean Water Collector Design Concept

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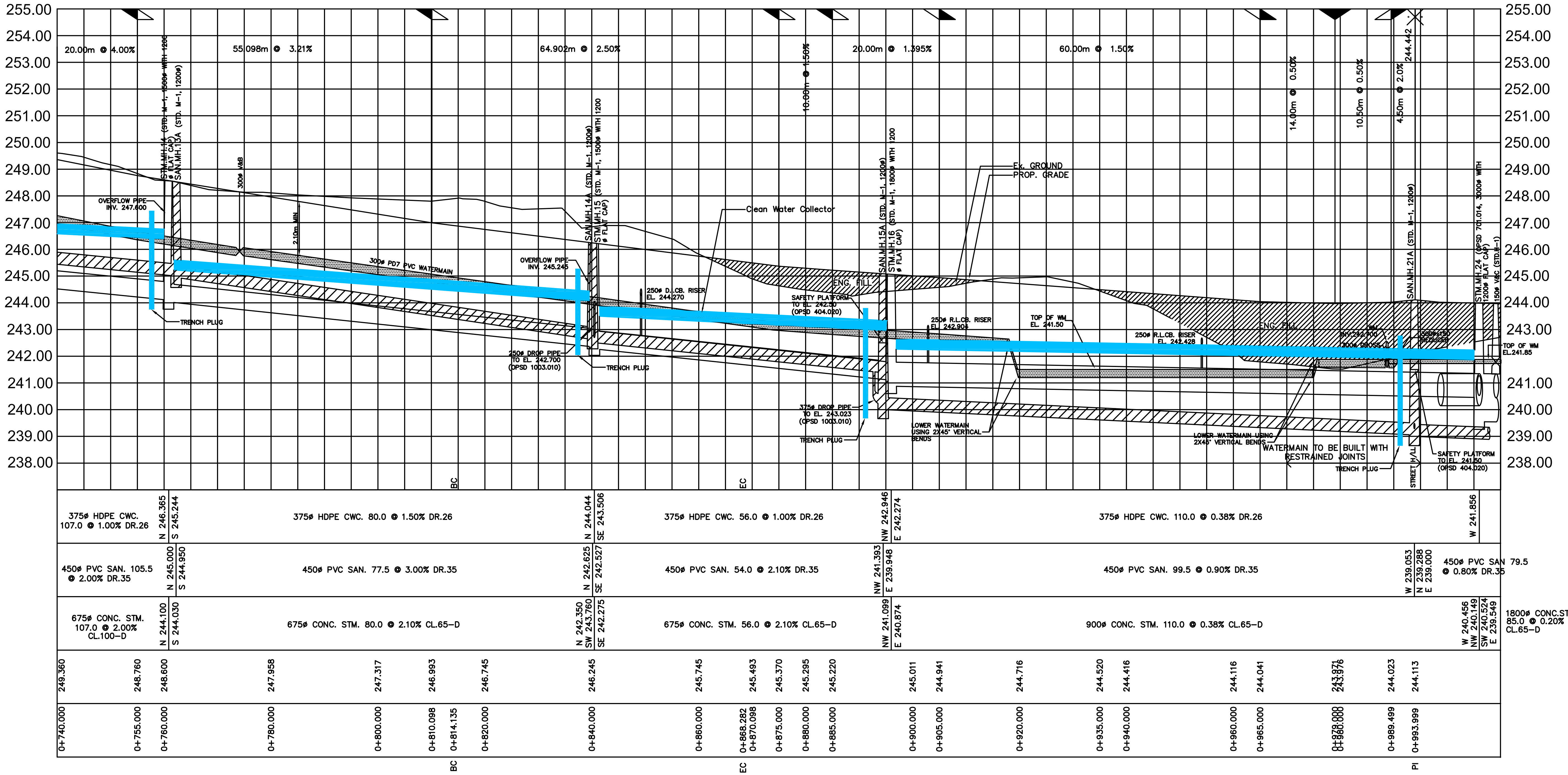

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Figure 10: Typical Profile of Road and Underground Services

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Figure 11: Perforated Pipe Design Photo

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Perforations Sizing Calculation

Assumptions:

Peak 5-year/5-min. Flow (Q): $0.008 m^3/s$
Head acting on orifice (h): 0.10 m
Longevity Factor (LF): 3
Gravity (g): $9.8 m/s^2$
Discharge Co-efficient (C): 0.6

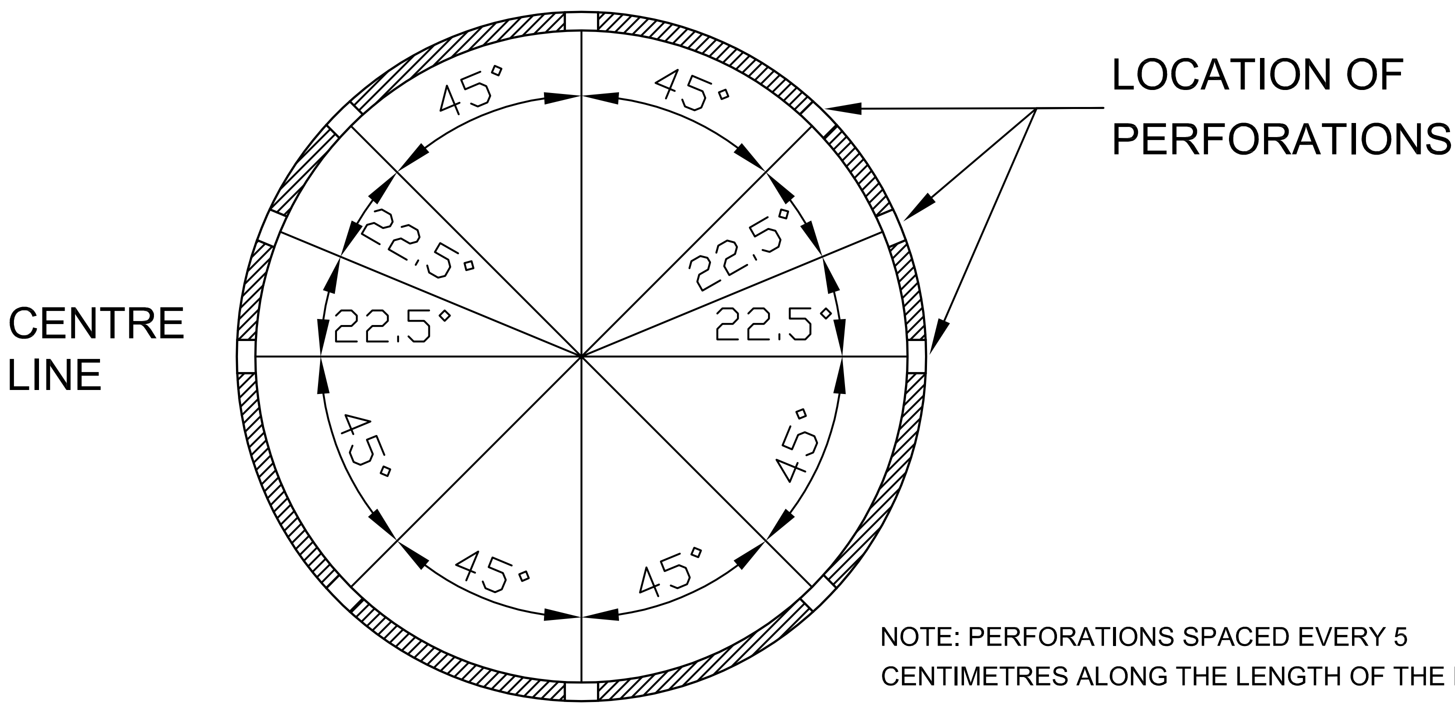
Calculations:

$$\frac{LF \times Q}{C\sqrt{2gh}}$$

$$\frac{3 \times (0.008 m^3/s)}{0.6\sqrt{2 \times 9.8 m/s^2 \times 0.1 m}}$$

Results:

Hole area/metre: $57 cm^2/m$



NOTE: PERFORATIONS SPACED EVERY 5 CENTIMETRES ALONG THE LENGTH OF THE PIPE.

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Figure 12: Perforated Pipe Hole Pattern

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3.2.2 Solid PVC Pipe Connectors

The perforated pipe will be connected to the same storm manholes as the standard storm sewer. The CWC pipe system will use solid PVC pipe segments at the manholes. Details of the manhole connections are illustrated in Figure 13. At the downstream side of the pipe segment (upstream of the downstream manhole connection), the solid pipe segments will extend from the manhole to the proposed trench plugs. This system will isolate each CWC segment at or near manhole locations to promote lateral and downward infiltration instead of longitudinal flow along the trench. The solid PVC pipe segment provides a connection to the downstream manhole to allow for inspections, flushing and for overflowing any excess water in the trench when filled to capacity.

3.2.3 Overflow System to Downstream Storm Manhole

The CWC pipe system includes an overflow/relief system. Figure 14 illustrates the overflow connection details while Figure 15 shows the actual overflow system construction. The overflow occurs at the downstream end of the CWC pipe system through a connection to the standard storm sewer manhole. The purpose of the overflow is to prevent hydrostatic pressure above the CWC trench and potential saturation of the road bed[2]. Furthermore, the layer of engineering fill below the road sub base also separates the road structure from the granular fill around the CWC pipe will also isolate potential effects from the CWC system. This is also discussed in the geotechnical statement in Appendix C.

The overflow system will also optimize the use of available storage in the trench limiting maximum water level to the elevation of the trench at the downstream manhole.

3.2.4 PVC Pipe Plugs

The CWC pipe system will be connected to the standard storm sewer manholes and fitted with removable plugs to allow for system disconnection and maintenance. Details of the plugs are illustrated in Figure 16 and in Figure 17. When in operation, the CWC pipe will be capped at the connecting manholes with the plugs. Removal of the plugs inside the manholes will allow for inspection and for flushing of debris that may enter and settled at the bottom of the pipe. Flushed sediments would be disposed through the standard storm sewer and eventually into a stormwater management facility downstream.

[2] The municipal standard also includes subdrains below the road base to dispose of excess moisture below the pavement.

3.2.5 Lateral Connections

Solid 150 mm diameter PVC pipes will connect the CWC perforated pipe system to the roof water collection system inside the lots. Figure 18 illustrates the lateral connections as constructed in early stages of Block 12 servicing.

Laterals will be constructed in two stages: stage 1 occurs during main road servicing construction when the CWC perforated pipe is installed. Laterals will be connected using T-connectors from the perforated pipe to the property line and capped. During stage 2, the builder will extend the laterals from the property line to the foundation walls and to the ground surface elevation (above proposed finished grade) at the side of the house immediately below the roof downspout locations.

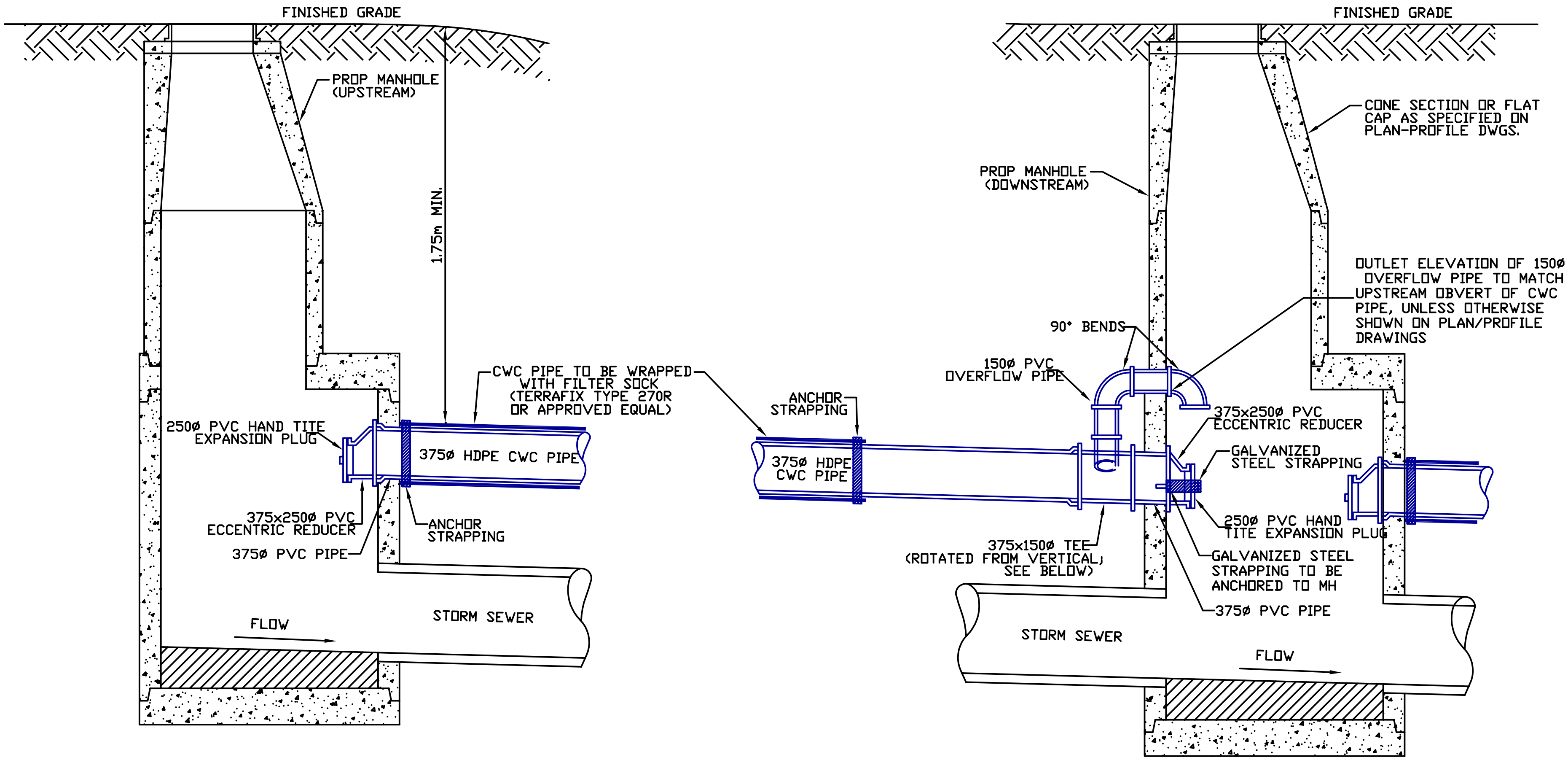

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Figure 13: PVC Pipe Connectors Drawings

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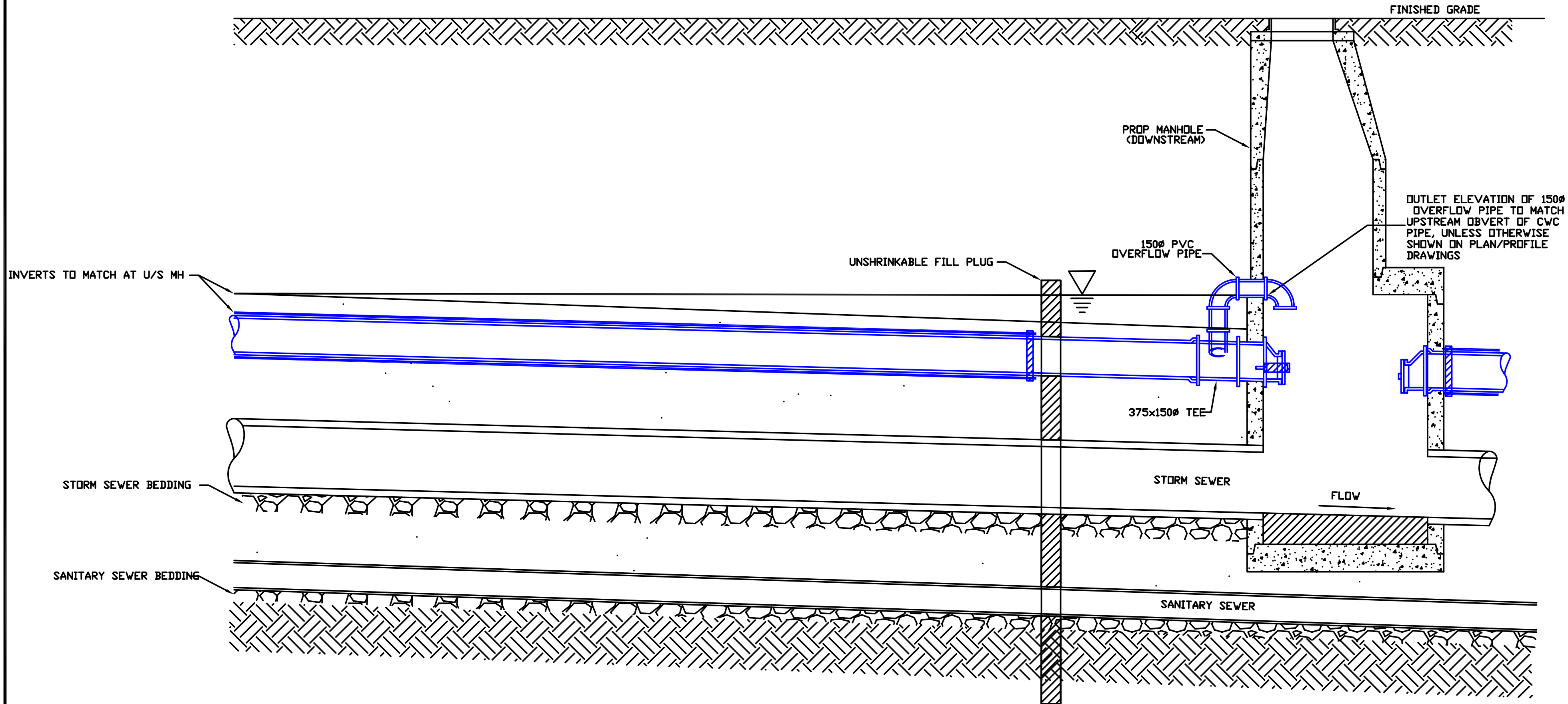

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Figure 14: CWC Overflow System Drawing

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Figure 15: Photo of CWC Overflow System

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Figure 16: Photo of CWC Pipe Connections Inside Manhole

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Figure 17: Photo of CWC Pipe Connections Outside Manhole

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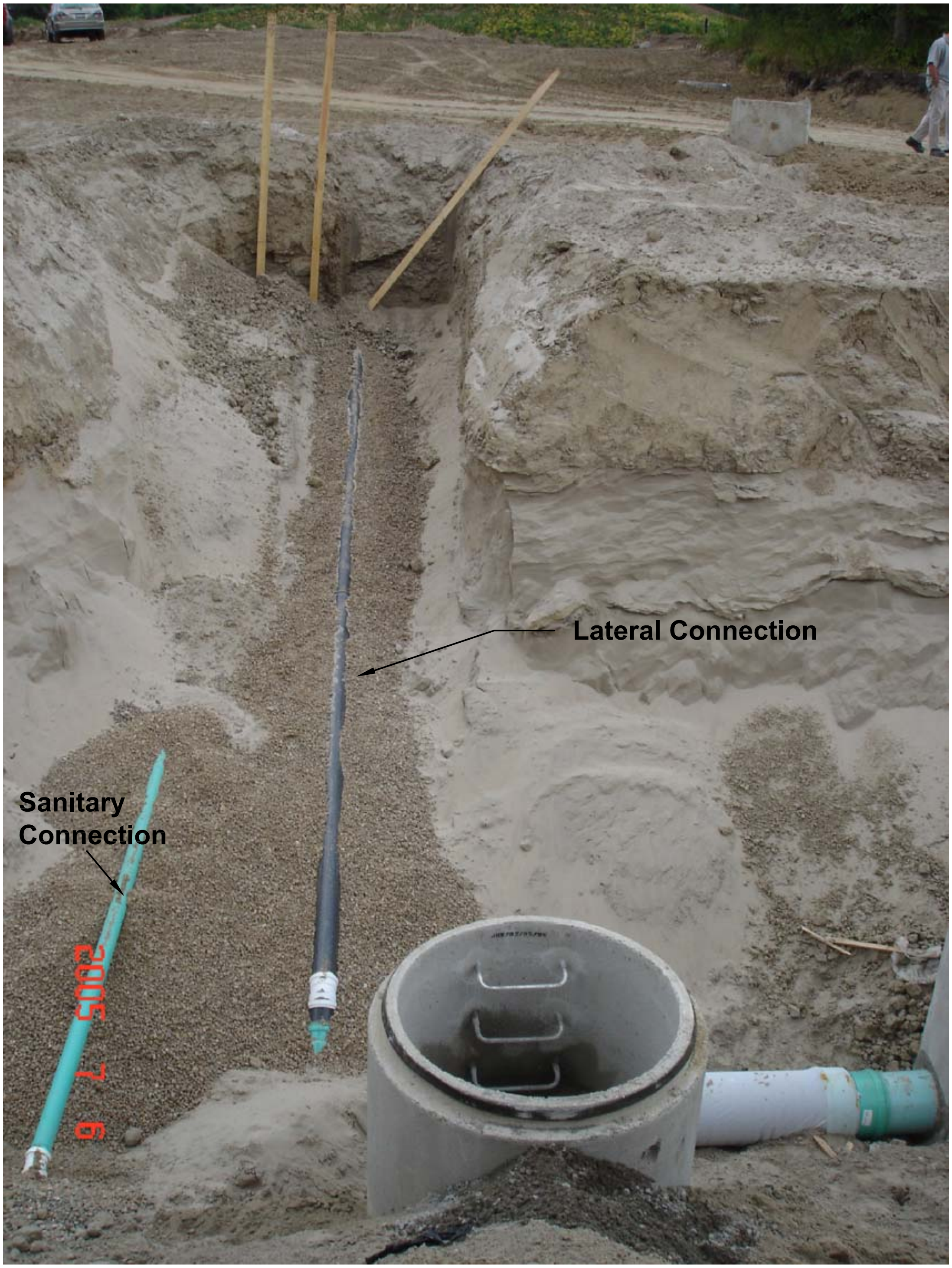

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Figure 18: Photo of CWC Pipe Lateral Connections

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3.3 CWC Trench and Trench Plugs

The CWC trench will be backfilled with Granular C (sand). The CWC trench will also contain the standard storm and sanitary sewers. The trench backfilling and road pavement construction will follow the City's standards including the provision of sub-drains under the curbs and road bed. Granular 'C' was selected after consultations with geotechnical engineers because:

1. It has sufficient porosity and hydraulic conductivity to store and rapidly convey the water exfiltrate from the perforated pipe.

2. It provides suitable support to the road base.

3. The particle size distribution is compatible with native soils (in many cases, native soils used as trench backfill material) and does not require an additional filter fabric around the trench.

The CWC trench design calls for a backfill material that, together with the filter fabric around the pipe, the pipe corrugations, and perforations placed at the bottom of the corrugation channel would offer sufficient space with the least opportunity for plugging near the point of entry around the perforated filtration pipe. It contains enough pore space to infiltrate the required amount of water. As per the geotechnical statement in Appendix C, the permeable nature of the Granular C and the bedding layers under the pipes and the relatively large interface area of the trench section with the surrounding soil boundaries are expected to allow rapid spreading out of water from the CWC pipes.

The design also specifies "Unshrinkable Fill Trench Plug" (concrete) to create flow barriers upstream of the downstream connecting manhole. As shown in Figure 19 and in Figure 20, two types of plug configurations are used for typical CWC system and for the end of the CWC system. Note that the plug at the end-of-the-system is lower because native backfill material would restrict the longitudinal flow along the trench. The plugs will limit groundwater flow along the longitudinal axis of the trench. The plug will promote lateral and downward infiltration into the surrounding soil. The plugs are especially necessary because of the high permeability bedding used under the standard storm and sanitary sewers.

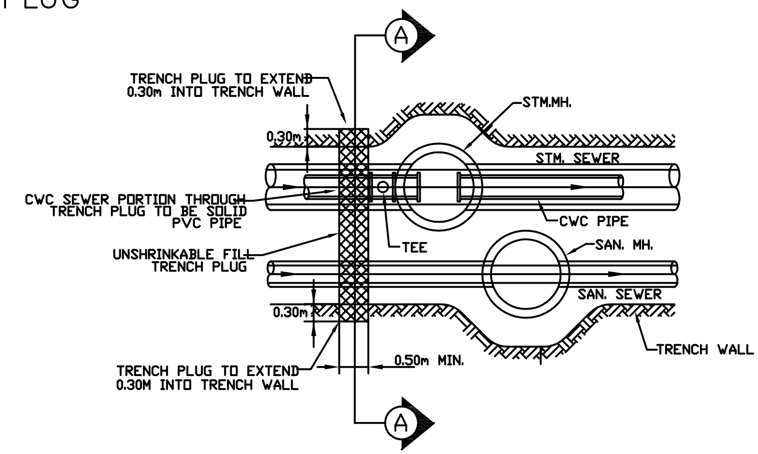
TRENCH PLUG – TYPICAL DETAIL

TYPE 'C'
TRENCH PLUG

NOTE:
LOCATION OF TRENCH PLUGS TO BE AS SHOWN ON DRAWINGS

PLAN VIEW

SCALE: NTS



SECTION A–A

SCALE: NTS

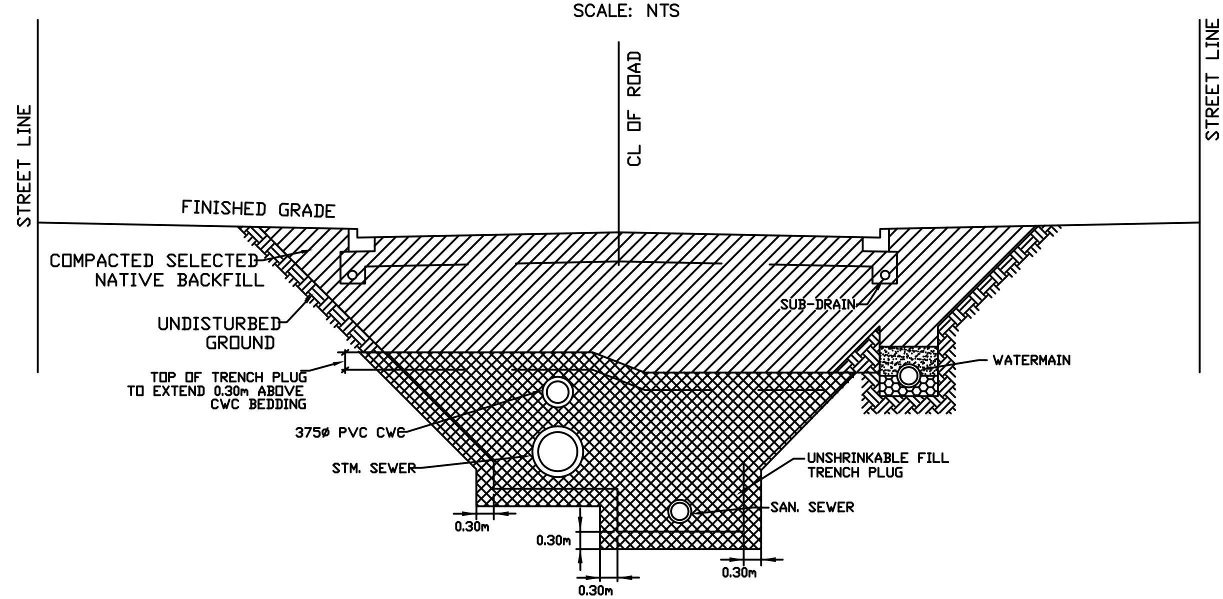


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Figure 19: Trench Plug
Case 1 -Typical

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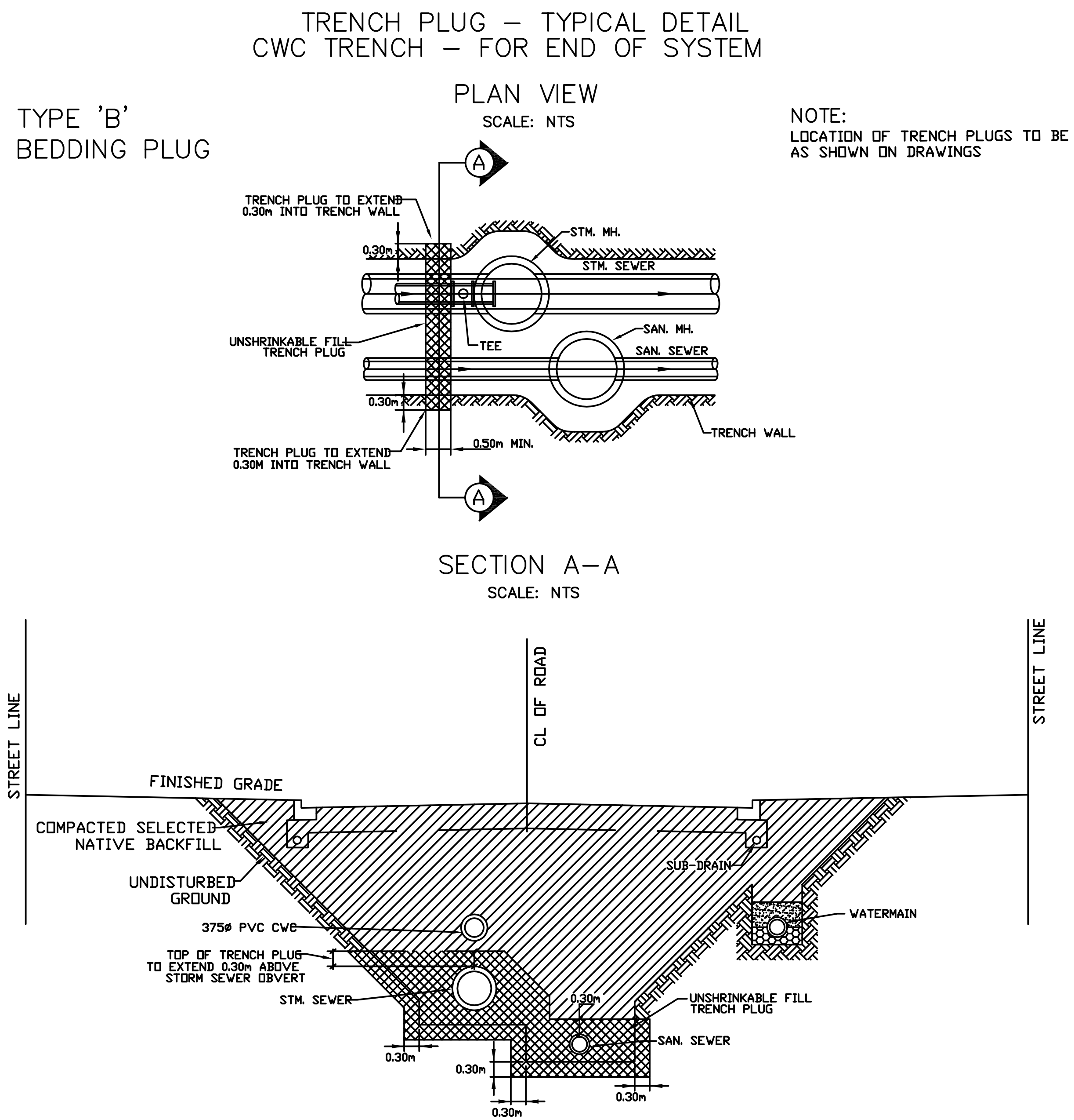

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Figure 20: Trench Plug Case 2 - End of System

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3.4 Special Design and Implementation Measures

Special issues raised, addressed, and approved during design process include the protection of the road base and/or sub base and the protection against the migration of trench materials into the perforated pipe or trench material into the surrounding native soil (refer to Appendix C: geotechnical statement).

In addition to collecting only relatively clean water from the roof of houses, the CWC design also provides special measures that will increase the infiltration reliability and longevity. These include roof leader filters with a surface overflow, and the ability to 'disconnect' the system.

3.4.1 Roof Leader Filter and Overflow to Ground

Special filters will be installed at each vertical pipe at the side of the houses. The surface filters will remove large debris (leafs, large roof shingle particles, etc.) roof prior to entering the vertical lateral intake pipes and the underground drainage system at the edge of the foundation wall. In case the filter clogs, water will overflow through a lateral draining to a splash pad.

Figure 21 shows a similar roof leader filter and overflow device.

3.4.2 System Disconnection Prior to Stabilization

Above-ground intakes at the side of the houses should remain capped until the entire system connection has been approved, the sub-division has been stabilized, and roof gutters have been flushed.

The CWC system pipes under the right-of-way will remain un-capped at the connecting manholes. Until capped, any water entering the perforated pipes will be discharged to the downstream storm sewer manhole and continue along the standard storm sewers. Caps will be installed after the house connections have been made, the site has been stabilized, and the system has been flushed.

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Figure 21: Example of Roof Leader Filter and Overflow to Gound system

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3.5 Storage Sizing

The initial CWC system concept requires sufficient storage to infiltrate the roof runoff from most rainfall and snowmelt events. The perforated pipe and trench void volume was assumed to store the equivalent runoff from a 22-mm event. For larger events, in excess of this volume (and in excess of the infiltration rate of the surrounding native soil) will overflow into the standard storm sewer system.

Details of the storage sizing are presented in the table below. As shown, due to the large cross-sectional area of the trench, the actual volume provided from the bottom of the sanitary sewer bedding to the top of the Clean Water Collector pipe far exceeds the runoff volume from a 22 mm storm event. A 6:1 factor has been estimated. This factor would account and provide a factor of safety in case the actual porosity is lower and should increase the longevity of the system.

Table 1: Trench Storage Volume Determination

Storage Volume Determination

Assumptions

Typical Roof Area=200m²
Fraction of Rainfall Captured Over the Roof=97%
Pipe Length (1/2 Lot Width) = 6.25m
Porosity of sand (η) =0.39 (fine sand)

Note: *The following parameters have been considered in the analysis:*

Range of porosity of sand = 25 to 50%
Range of porosity of gravel = 25 to 40%
Representative values of porosity:

Gravel, coarse = 28%
Gravel, medium = 32%
Gravel, fine = 32%
Sand, coarse = 39%
Sand, medium = 39%
Sand, fine = 43%

Similar values in various references: (Ref."Groundwater". Freeze R.A., J.A. Cherry p.37; "Groundwater and Wells", Driscoll, F.G. pp.67, 399)

Typical cross-sectional area of trench = A_{trench} =10.7 m²

Roof Runoff Volume from a 22-mm Event, *RO*:

$$V = A_{roof} \times 22mm \times 97\% = 200m^2 \times 0.022m \times 90\% = 4.3m^3$$

CWC Pipe and Trench Storage, *S*:

$$S_{pipe} = \frac{\pi \times \phi^2}{4} \times L = \frac{\pi \times (0.375m)^2}{4} \times 6.25m = 0.69m^3$$

$$S_{trench} = A_{trench} \times \eta \times L = 10.7m^2 \times 0.39 \times 6.25m = 26.1m^3$$

$$S_{total} = S_{pipe} + S_{trench} = 0.69m^3 + 26.1m^3 = 26.8m^3$$

Conclusion

S_{total}>> *RO*; storage provided is larger than storage required by 6:1 factor.

4 INSTALLATION LOCATIONS AND WATER BALANCE

4.1 Installation Locations

This section describes the feasibility criteria and scope for the installation of the CWC system within Block 12. This section also documents the water balance verification to ensure that the CWC will meet the groundwater recharge targets after development.

Favourable infiltration characteristics of the underlying native material are critical to the proper functioning of the CWC System. The high hydraulic conductivity of the soil and low groundwater beneath the CWC are key factors that have enhanced the performance of the test site.

A primary consideration for the design of the CWC is to ensure that the CWC system operates efficiently, economically and with a minimum of maintenance. The CWC will therefore be implemented in areas of the Block that have conditions most suitable for the effective infiltration of clean runoff from rooftops. Areas eliminated from the construction of the CWC are those areas that are underlain by fine-grained soils (i.e. predominantly silt and clay sized articles) that are greater than 5 m thick. Areas underlain by soils having suitable conductivity or have soils with suitable conductivity within 5 m of the surface are considered acceptable for the implementation of the CWC System. In addition, areas having high water tables that would inhibit the free draining of the CWC are also considered unsuitable for the construction of the CWC. The latest borehole information in the proposed development area in Block 12 was used to identify those areas considered to be ineffective for infiltrating roof runoff. In addition, areas interpreted as having high water tables, primarily the low lying areas in the bottom of major swales and valley systems were considered to be unsuitable for the effective operation of the CWC. The remaining areas considered to be suitable for the implementation of the CWC are shown in Figure 22.

Areas in Block 12 that meet the installation criteria have been identified and are illustrated in Figure 22. The hydrogeologic data used in the feasibility assessment is presented in Appendix D.

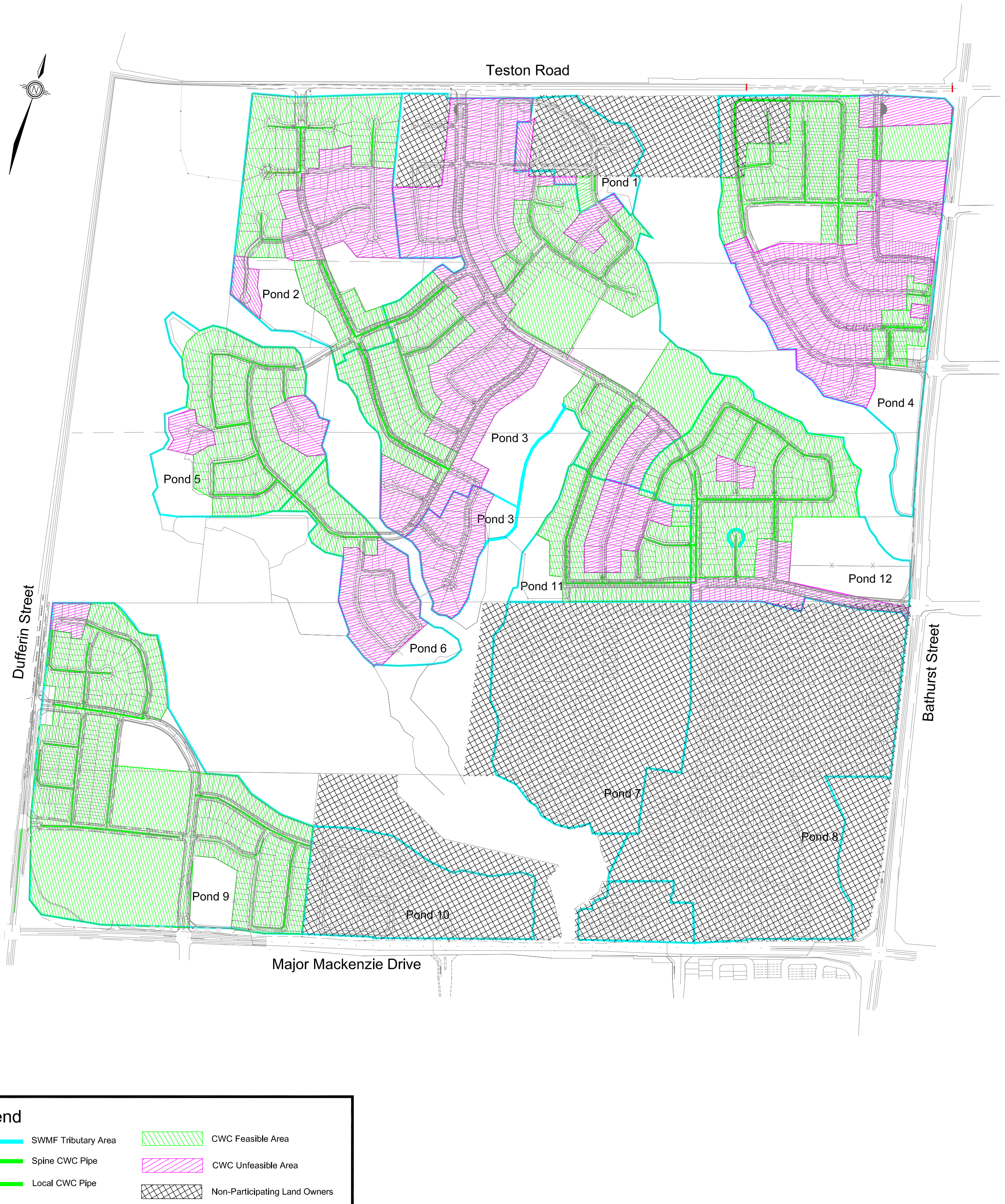

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Figure 22: Feasible Areas

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4.2 Water Balance Verification

Detailed soils investigations have been completed for the participating landowners in Block 12. Those landowners not participating at this stage are shown on Figure 22. The results of detailed subsurface investigations for those participating landowners were reviewed and the borehole logs were examined to assess the suitability of the soil conditions at each borehole for construction of the Clean Water Collector. Factors such as depth to water table and thickness of fine grained soils (i.e. sandy silt or silty clay till) at surface were used to determine whether the CWC could be constructed at each borehole location. The following detailed subsurface soil investigations were reviewed for this analysis:

1) Proposed Residential Subdivision, 1274 Major Mackenzie Drive, Prepared for Laterna Group by Chih S.Huang & Associates Inc. July 25, 2002.
2) Geotechnical Subsurface Investigation Proposed Residential Subdivision, 1274 Major Mackenzie Drive, City of Vaughan, prepared by Chih S. Huang & Associates, Inc. May 17, 2002
3) Geotechnical Investigation Proposed Residential Subdivision, Major Bob Farms Property, Part of Lot 24, Concession 2, City of Vaughan, prepared for Major Bob Farms Inc. by Golder Associates, February 2004.
4) A Soil Investigation for Proposed Residential Subdivision, Block 12, Part of Lot 22, Concession 2, prepared for Emery Investments, by Soil-Eng Limited, February 2004.
5) A soil Investigation for Proposed Residential Subdivision, Block 12, Part of Lots 22, 23, 24, and 25, Concession 2, City of Vaughan, prepared by Soil-Eng Limited for Andridge Homes Ltd. January 2004.
6) Geotechnical Investigation Proposed Residential Subdivision Lindstone Development Corporation, Part of Lot 23, Concesion2, City of Vaughan, prepared by Golder Associates Ltd. for Lindstone Development Corporation, May 2003.
7) Test Pit Investigation and Chemical Analysis of Soil Samples, North East Corner of Dufferin Street and Major Mackenzie Drive City of Vaughan, prepared for Fernbrook Homes by Soil-Eng Limited, July 2003.

Areas considered unsuitable for the construction of the CWC include those having greater than 5.0 m of fine grained silt till or clayey silt soil at surface and areas showing a water table above the invert of the CWC pipe. The MESP calculated that 77% of the Block 12 area would be suitable for the CWC. The detailed subsurface soil investigations indicated that 67% of the areas of the participating landowners would be suitable for the CWC. Using the revised area suitable for the CWC, the water balance for the area including the participating landowners in Block 12 was recalculated. The results indicated that the preferred scenario (100% of the roof runoff directed to CWC) would result in an increase in post development infiltration of about 32% for the participating landowners in Block 12 compared to 37% previously calculated in the MESP for the entire Block 12 area. The pre development infiltration will therefore be maintained and enhanced provided the clean water collector is implemented throughout the revised areas suitable for the CWC.

The post development infiltration is slightly less that that predicted by the MESP although there is still an increase over pre-development conditions. The MESP concluded that there would be no adverse impact on the receiving streams from a stream bank erosion perspective. This conclusion is still valid as the revised calculated water balance results in a smaller increase in post development infiltration and ultimately smaller potential increase in base flow to streams.

5 MONITORING

A CWC test site or prototype was designed and built to demonstrate the effectiveness of the CWC under realistic operating conditions. The results have shown the effectiveness of the system. Additional monitoring will be undertaken to understand the long-term performance, operation and maintenance.

The main objectives of the operational monitoring are to:

a) Demonstrate the effectiveness of the real CWC system to collect and infiltrate roof runoff.

b) Verify and document the operation and maintenance requirements including frequency of visits and the extent of cleaning or flushing required.

c) Demonstrate the ability of the local ground water table to accept roof runoff without adverse effects and changes in the water table.

Long-term monitoring of the Block 12 CWC system should provide data to support potential reductions in sewer sizing and stormwater management facilities. This approach will encourage and potentially off-set the costs of these systems.

Three locations have been selected in Block 12 for the installation of operational monitoring stations. These locations are shown in Figure 23, Figure 24, and Figure 25. The locations have been selected because they are distributed evenly across the Block. Each location will be instrumented to measure accumulation in the trench and groundwater impacts in the surrounding areas.

Each of the three locations will include water level sensors at three locations:

a) Trench Station: inside the CWC trench,
b) Near-Trench Station: near the trench to measure the direct impacts on the groundwater table.
c) Background Station: location removed from the trench (50 metres from the trench) to measure baseline groundwater conditions.

The Trench Station will measure the captured runoff in the trench. The Near-Trench Station, together with the Background Station, will quantify the short and long-term impacts on the groundwater. The Near-Trench and Background sensors will be at sufficient depth to capture the seasonal variation of the water table. All sensors will be installed on public lands.

Figure 26 illustrates the equipment installation approach. Since the collector system will respond to individual storm events in relatively short time, automatic sensors and integrated data loggers will be used in each piezometer. Manual measurements will be used to verify/calibrate the sensors.

A climate station will be installed in the block to quantify the rainfall and snowmelt inputs into the CWC system and standard storm sewer. The station will include a rain gauge with heater to capture snowfall events as well as a temperature gauge to aid in the modelling of snowmelt.

Water level monitoring for baseline conditions should commence as soon as the construction activities are minimal and the CWC is operational. This is likely to occur at different times at each of the three locations. Monitoring will be carried out at three locations from the time the connection is made until assumption by the City of Vaughan.

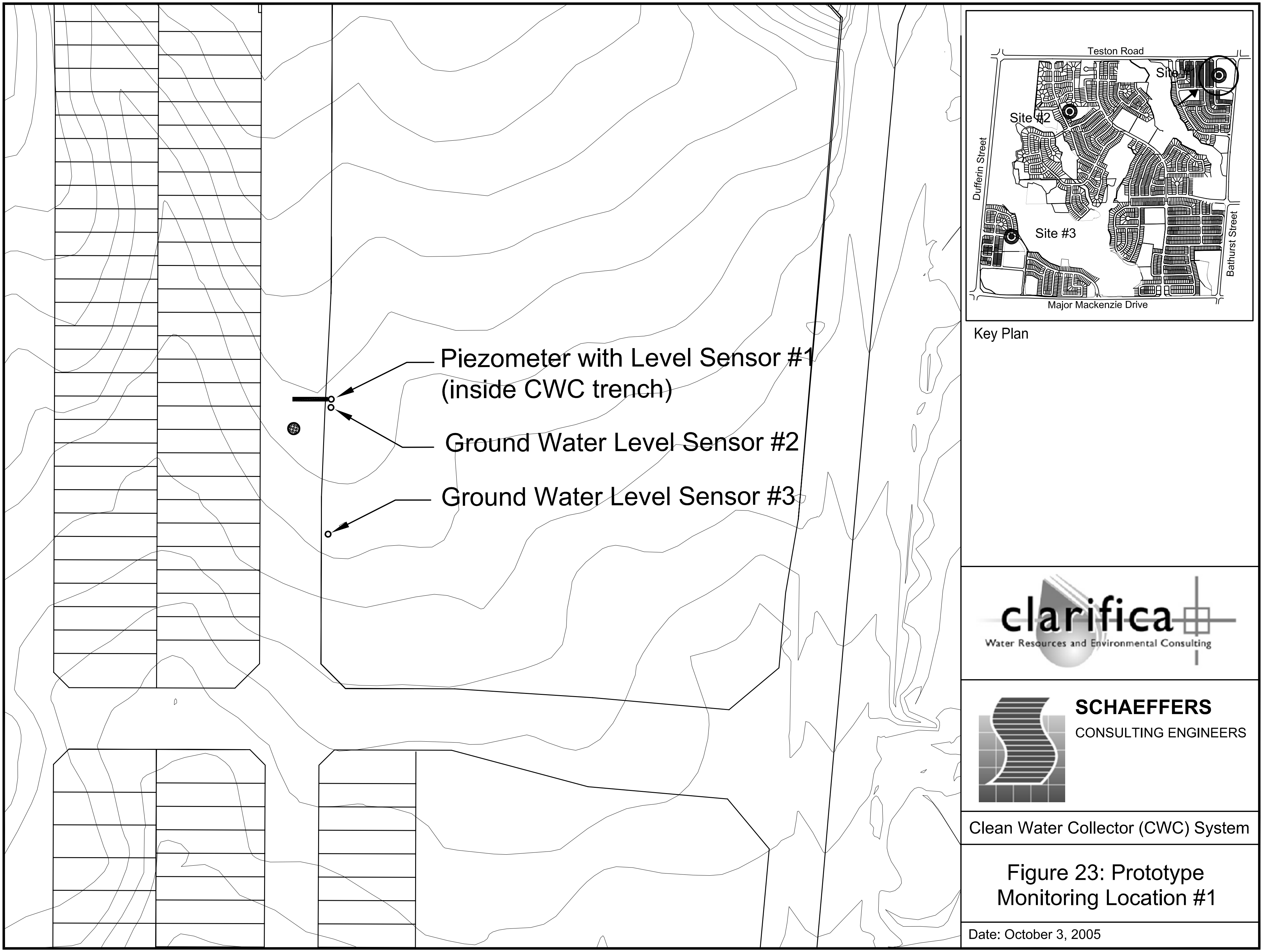

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Figure 23: Prototype Monitoring Location #1

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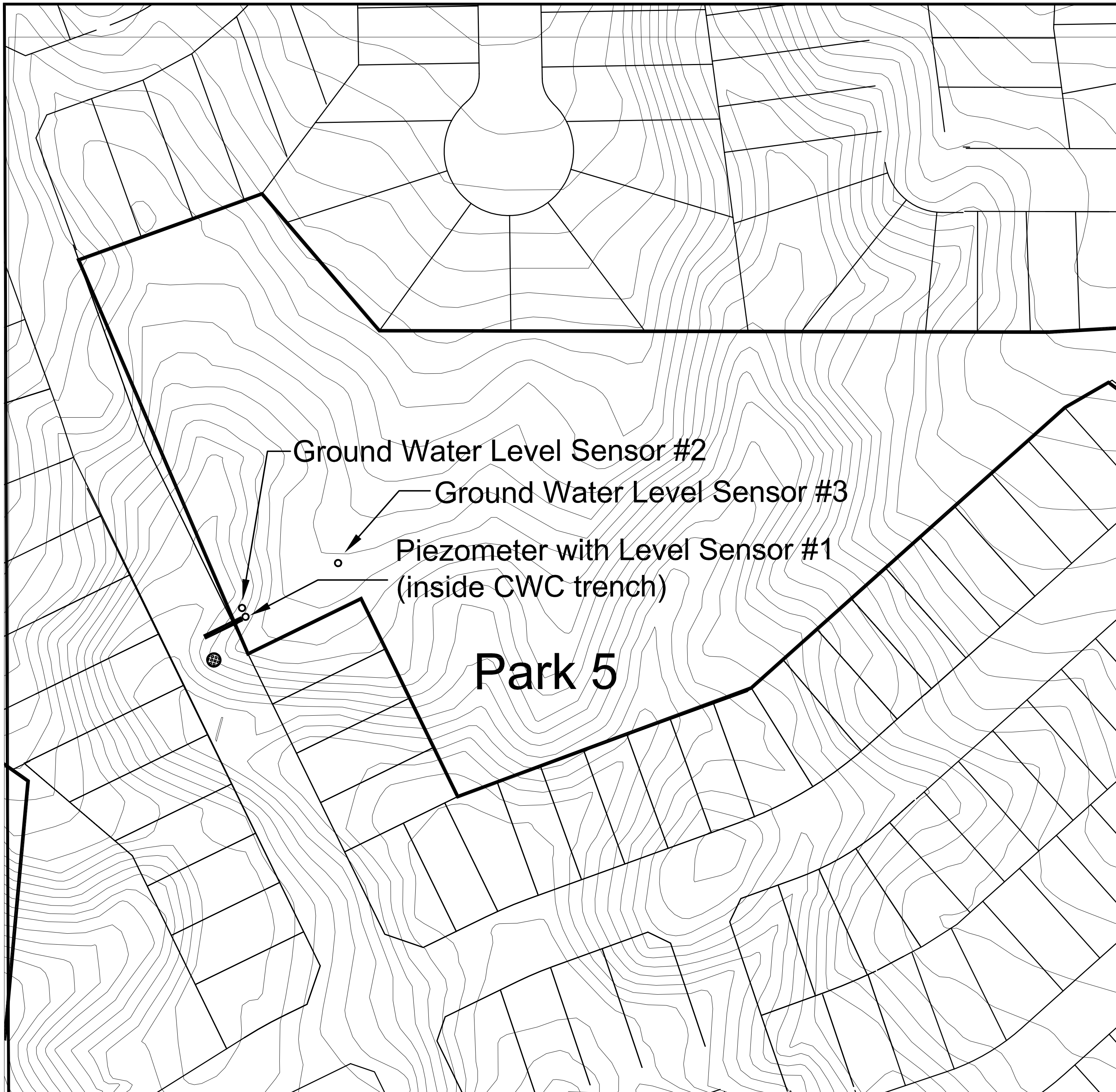

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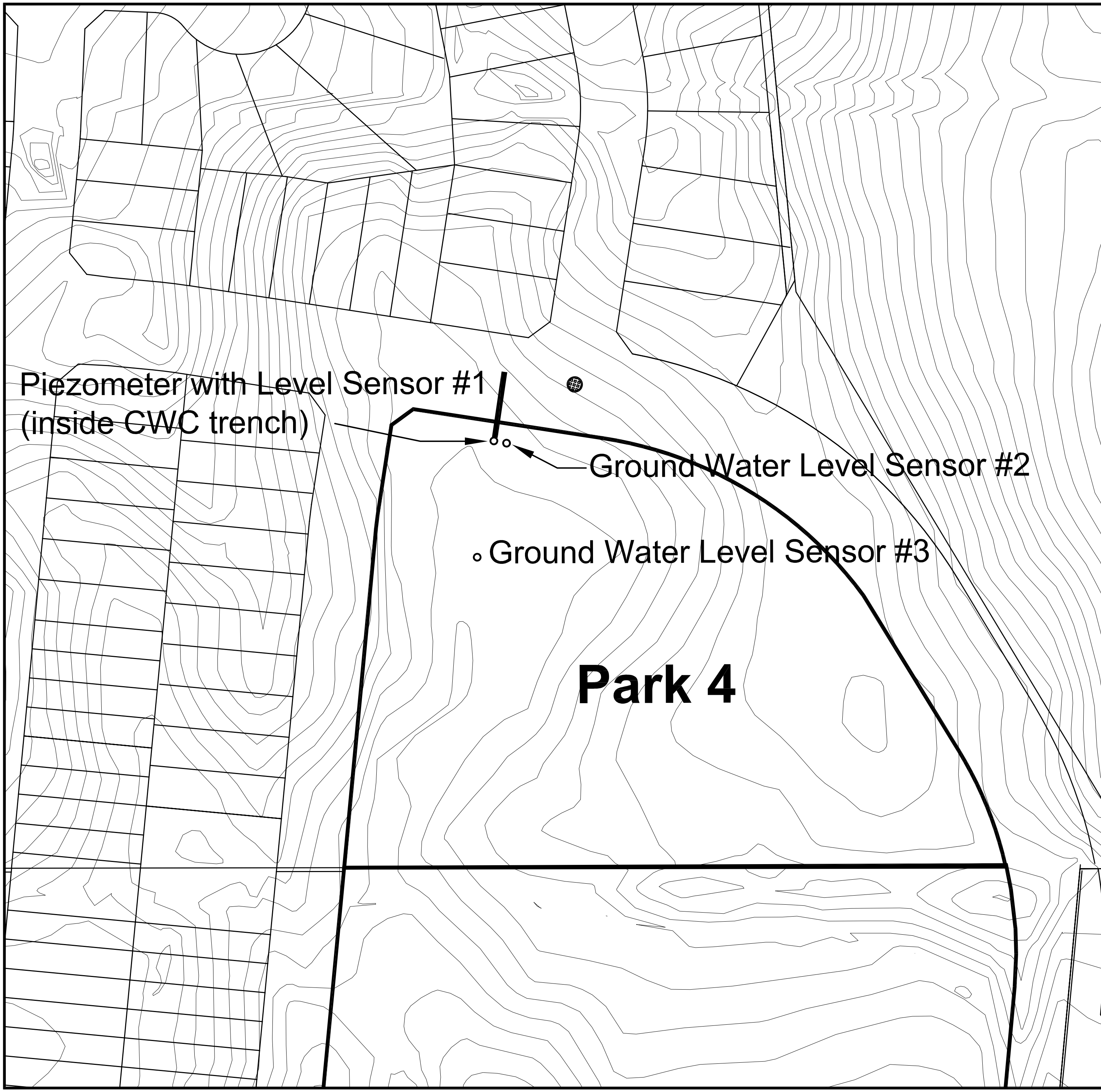
Figure 24: Prototype Monitoring Location #2

Date: October 3, 2005



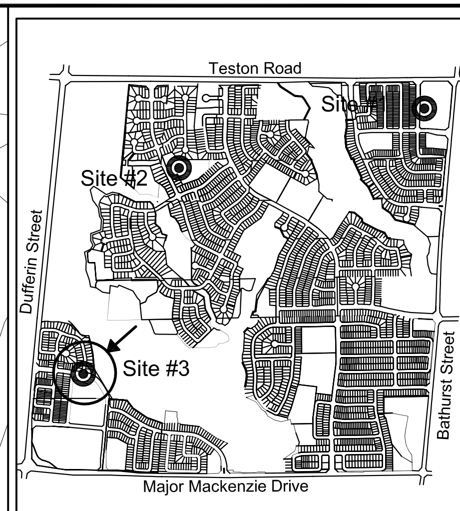


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Figure 25: Prototype Monitoring Location #3

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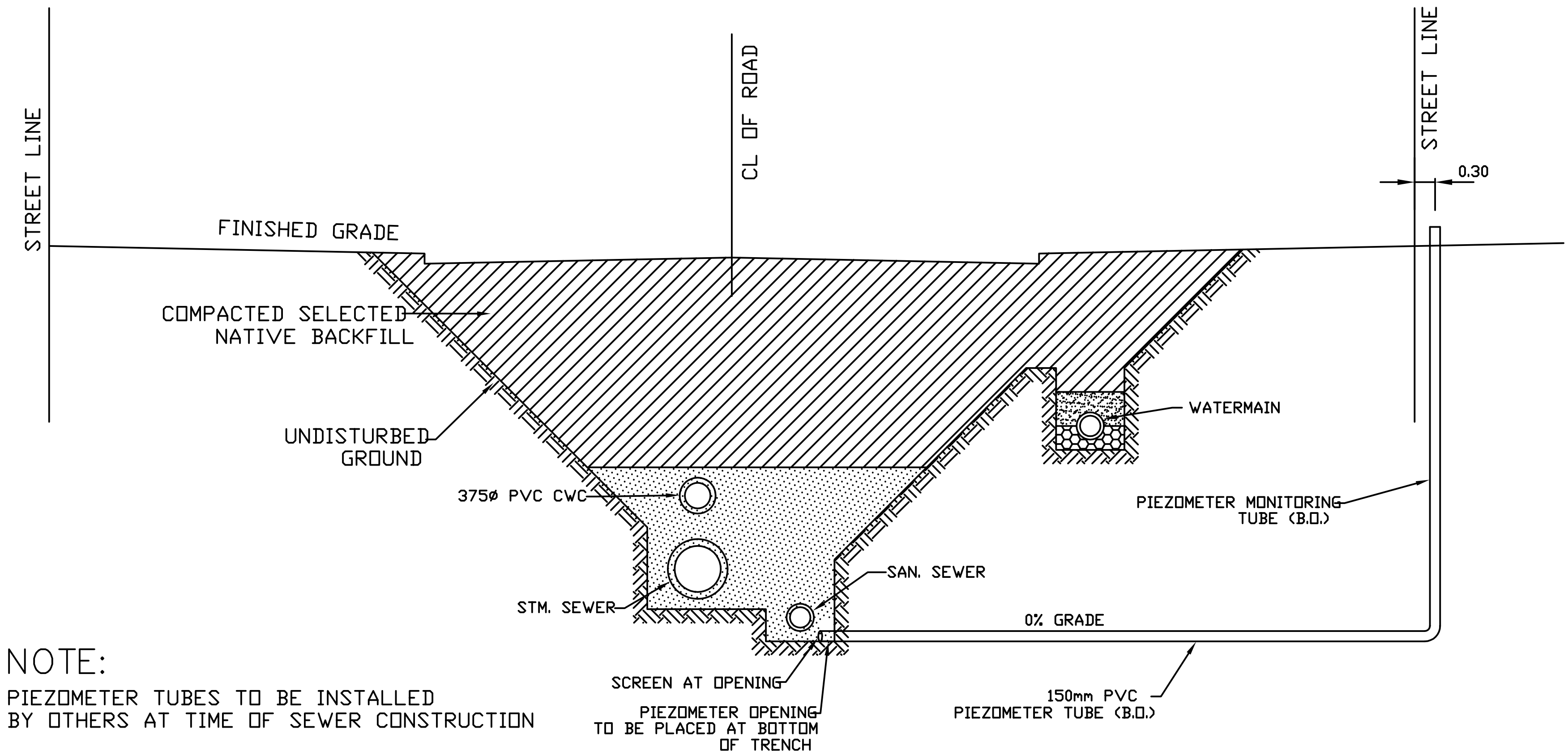
PIEZOMETER – TYPICAL DETAIL

SCALE: NTS



NOTE:

PIEZOMETER TUBES TO BE INSTALLED
BY OTHERS AT TIME OF SEWER CONSTRUCTION

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Figure 26: Monitoring Equipment Setup

Date: October 3, 2005

6 CWC MAINTENANCE

6.1 Maintenance Monitoring

The two primary objectives of the CWC system design were performance and minimal need for maintenance. The CWC pipe has been designed to be the focus of most of the maintenance activities. However, periodic clearing of the roof leader traps and roof gutters will also be required. Maintenance monitoring will include:

1. Visual inspection of roof gutters, roof leaders and roof leader filters from every house connected to the three monitored sewer segments once per year, subject to permission being granted by the owners. Photographs will be taken to monitor the accumulation of debris in the gutters.

2. Visual inspections of the three monitored clean water collector pipes every six months until completion approval of the subdivision. A further review prior to assumption will also be performed. The inspection will consist of recording sediment depths in the pipes as well as any structural or debris problems that are visible.

The short and long-term CWC maintenance will be finalized after construction and operational monitoring.

6.2 Roof Gutter and Leader Filter

Proper maintenance of the roof gutter and roof leader filter will affect the frequency of CWC pipe flushing. This will remove most of the debris and sediment from the gutters before entering the perforated pipe.

The maintenance frequency for the filters should be about twice yearly: in the spring and fall. Inspection should ensure that there are no blockages and that the screen is intact and functioning as intended. The filter should be designed to be easily removed and installed, and therefore, if a problem with the filter is found, it can be easily replaced on site by the inspector.

The monitoring program will provide a schedule for filter inspection and cleaning to minimize cost and maximize efficiency of the system. Long-term inspections and refinements will be possible by City staff to further refine the work.

6.3 Perforated Pipe Flushing

The CWC system has been designed to settle any particles reaching the pipe before distribution into the trench. There will be permanent water in the lower, non-perforated half of the pipe. This standing water will provide settling of particulate matter and storage. The design allows for pipe flushing by removing the caps at opposite manholes and allowing the accumulated debris to discharge into the standard storm sewer system and eventually to the storm water management facilities. Flushing can be accomplished using pressured water from hydrants or trucks.

6.4 Assumption Protocol

Before municipal assumption the system should be inspected and flushed as required to remove any sediment built-up during the monitoring period.

CWC lateral connections at the property line should be inspected prior to backfill by the City's plumbing inspector.

6.5 Maintenance Resource Requirements

Although the actual maintenance requirements will be established over time, it is expected that a CWC pipe flushing frequency of once every 10 years would be sufficient. Debris accumulation in the pipe and filters will be quantified during the monitoring period. Equipment and materials required for maintenance would include replacement/cleaning of roof leader filters and water supply from a hydrant and pressure hose for flushing.

7 CONCLUSIONS

7.1 Research Site

The research site operated with 100% capture effectiveness with respect to infiltrating the roof runoff. Specific recommendations resulting from the research site monitoring include:

- The size of the perforated pipe could be reduced from the original size of 525 mm.
- There may be more flexibility for the selection of trench backfill material as long as the flow rate from the pipe into the trench storage is not sacrificed.
- The area of perforations was adequate and should be maintained to maintain longevity.

The system may operate in many hydrogeologic settings.

Arrangements should be made with the CWC pipe manufacturer to supply pre-drilled pipes with all the perforations required.

7.2 Advantages and Disadvantages

The specific advantages of the Block 12 CWC system include:

- Clean water (relatively) from the roofs of houses requires little or no pre-treatment prior to infiltrating to the ground.
- Treatment is provided by filtering large debris from the roofs and within the perforated pipe by allowing settling of suspended particles and flushing.
- The system avoids the problems associated with stormwater containing high concentration of suspended solids and the tendency to clog.
- Water quality concerns associated with infiltration road runoff are virtually eliminated.
- The separation of the clean water collector system from the traditional storm water collection system minimizes contaminant pathways associated with surface spills and road-related contaminants.
- Infiltration occurs at or near the source and is distributed over a large area, as compared to centralized facilities, reducing the opportunities for groundwater mounding and reduced infiltration.
- Infiltration is initiated below the surface and, if the objective is to match or exceed

infiltration targets, this approach avoids losses to evaporation and evapotranspiration.

- Potential stormwater runoff rates and volumes are reduced, thereby decreasing peak flows, flooding and erosion in receiving streams.
- Reduce peak flows and runoff volumes should lead to a corresponding reduction in the size of storm water management facilities and storm sewers.
- There is a potential for reduced storm sewer infrastructure and end-of-pipe facilities. Although not accounted in the Block 12 development area, reduced runoff volumes and rates should allow for reduced sewer and/or storage facility requirements to compensate for the increased costs of the additional infrastructure.
- The expected maintenance requirements are minimal and longevity greater than any other infiltration system. The system incorporates maintenance features through accessible perforated pipes, flushing capabilities,
- Maintenance remains mostly within the municipal right-of-way and is readily accessible to municipal operation and maintenance staff.

Disadvantages of the CWC system include:

- Additional infrastructure requirements.
- Higher servicing costs.

The results of the monitoring will be very useful in determining the CWC benefits towards reducing overall runoff volumes and erosion potential from the site. Potential reductions in stormwater management facility volumes and sewer sizes may be justified particularly in very favourable hydrogeologic conditions. The costs of implementation may be partially recoverable through reduced land and construction requirements associated with the implementation of the standard storm sewer service and storm water management facilities.

7.3 Potential Use in Other Areas

The systems has been developed after careful consideration of various factors including physical testing on-site, material selection, geometric configurations and integration with municipal standards, groundwater and soil interactions, and future operation and maintenance. Test pits were excavated and numerous boreholes drilled to estimate the hydraulic conductivity of the native soils and assist with the determining the feasibility and sizing the system.

Although the CWC system should be applicable in many areas undergoing development, careful considerations of the hydrogeologic and geotechnical conditions of a site are particularly important when introducing CWC systems. For example, in some cases, there may be geotechnical constraints when introducing groundwater in areas adjacent to steep or vulnerable slopes or were excess groundwater is prevalent. Also, as discussed in the technical feasibility section, shallow groundwater conditions and very low permeability soils were the primary limiting factors for implementation. The CWC system may be effective in less favourable hydrogeologic conditions also because of the infiltration during inter event periods. The results to-date suggest that most of the infiltration occurs during a runoff event or soon thereafter but even with low infiltration conditions, benefits should be realized with long inter-event dry periods.

Because of the need to achieve connections within private lots and the presence of existing storm and sanitary sewers, the implementation as a retro-fit in existing areas would not be practical. However, systems similar in function to the CWC in Block 12 may be considered on publicly controlled lands or re-development areas through the use of infiltration trenches with connections to roof areas.

8 REFERENCES

Schaeffers Consulting Engineers et al. "Master Environmental Servicing Plan and Environmental Impact Statement" Block 12 – Volume 2 Technical Appendix. September 1999 (Revised October, 2001).

ASCE, 2001. "Standard Guidelines for Artificial Recharge of Ground Water". Published by th American Society of Civil Engineers. ISBN 0-7844-0548-4

American Society of Civil Engineers. 2001. "Standard Guidelines for Artificial Recharge of Ground Water". Published by American Society of Civil Engineers.

A.M. canadaras associates inc. 1997. "Post-construction Evaluation of Stormwater Exfiltration & Filtration Systems". Published by Queen's Printer for Ontario.

Graham, Edward.1990. "An urban Runoff Infiltration Basin Model". Waterloo, Ontario, Canada.

Ministry of the Environment. 2003. "Stormwater Management Planning and Design Manual". Published by Queen's Printer for Ontario.

Paul Wisner & Associates Inc. 1993. "Performance Review of Grass Swale- Perforated Pipe Stormwater Drainage Systems". Copyright: Ministry of the Environment.

Schaeffers Consulting Engineers et al. 1999. "Environmental Servicing Plan and Environmental Impact Statement" Block 12 – Volume 2 Technical Appendix.

Sediment & Stormwater Division, Stormwater Management Administration, Maryland Department of the Environment. 1984. "Maryland Standards and Specifications for Infiltration Practices".

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2002. "Performance Assessment of a Swale/ Perforated Pipe Stormwater Infiltration System - Toronto, Ontario". Copyright: Toronto and Region Conservation Authority.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2002. "Performance Assessment of a Stormwater Retrofit Pond – Harding Park, Richmond Hill, Ontario". Copyright: Toronto and Region Conservation Authority.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2002. "Performance Assessment of a Pond-Wetland Stormwater Management Facility - Markham, Ontario". Copyright: Toronto and Region Conservation Authority.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2002. "Performance Assessment of an Open and Covered Stormwater Wetland System - Aurora, Ontario". Copyright: Toronto and Region Conservation Authority.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2003. "Performance

Assessment of a Highway Stormwater Quality Retention Pond – Rouge River, Toronto, Ontario". Copyright: Toronto and Region Conservation Authority.

Stormwater Assessment Monitoring and Performance (SWAMP) Program. 2004. "Performance Assessment of Two Types of Oil& Grit Separator for Stormwater Management in Parking Lot Applications – Markham & Toronto, Ontario". Copyright: Toronto and Region Conservation Authority.

Thomas R. Schueler. 1987. "Controlling Urban Runoff: A practical Manual for Planning and Designing Urban BMPs".