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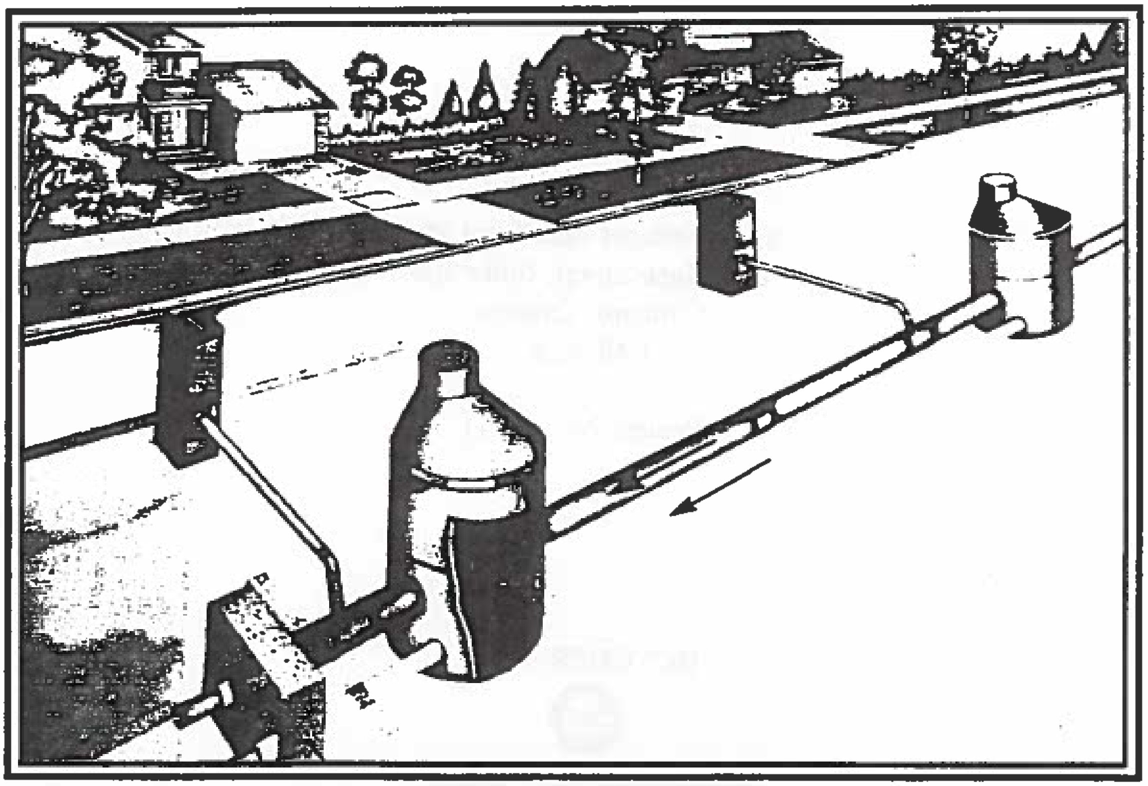
GREAT LAKES 2000 CLEANUP FUND

ETOBICOKE

Ontario
Ministry of Environment and Energy

POST-CONSTRUCTION EVALUATION OF STORMWATER EXFILTRATION & FILTRATION SYSTEMS



a.m. candaras associates inc.
consulting engineers

October 1997

ISBN 0-7778-7285-4

POST-CONSTRUCTION EVALUATION OF STORMWATER EXFILTRATION & FILTRATION SYSTEMS

a.m. candaras associates inc.
8400 Jane Street, Suite 203
Concord, Ontario
L4K 4L8

(Project No. 9321)

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EXECUTIVE SUMMARY

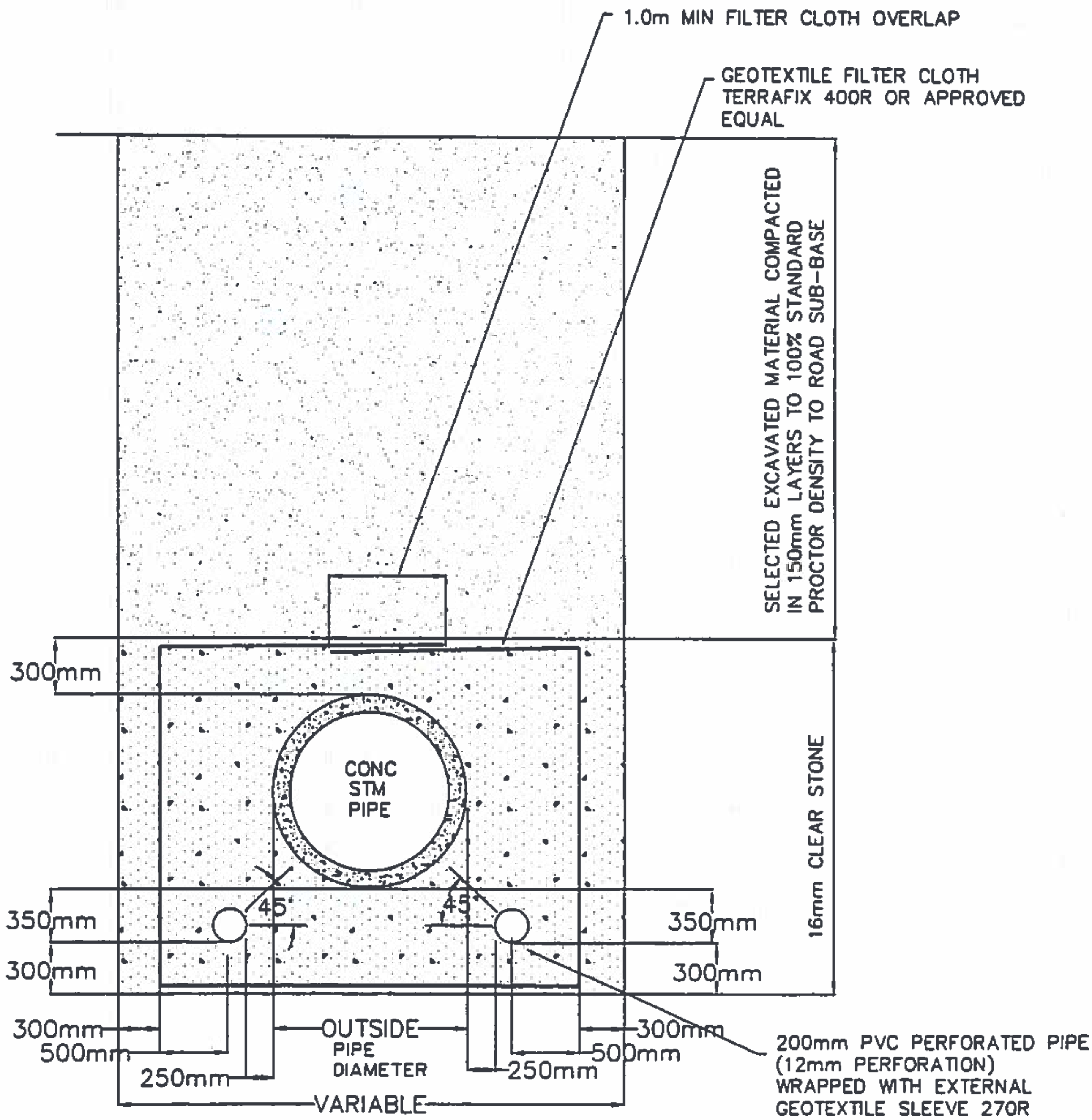
In 1993, the City of Etobicoke developed and constructed 2.1 km and 0.4 km of the Etobicoke Stormwater Exfiltration and Filtration Systems, respectively. The systems were developed as retrofit stormwater management technologies, integrated within the design of a conventional storm sewer system, to provide stormwater quality treatment for fully developed municipalities, where land for end-of-pipe treatment is not available. These systems are also well suited for new development where in addition to stormwater treatment, groundwater recharge may be required.

The systems can be described as follows:

Exfiltration System

The system consists of two 200 mm PVC perforated pipes laid below a conventional storm sewer in a granular stone trench wrapped with filter fabric (Figure 1). The perforated pipes, wrapped in filter fabric, are plugged at the downstream end (Figure 2). During a runoff event, stormwater enters the storm sewer through catchbasins and then enters the two perforated pipes at the downstream manhole, where it drains or exfiltrates to the stone trench and then into the surrounding soil. Particulate and debris carried by the stormwater that does not get trapped in the catchbasin is contained within the perforated pipes. During large runoff events, excess runoff bypasses the perforated pipe system and is conveyed through the storm sewer. This flow route is shown schematically in Figure 3. The system, designed such that the stone trench provides sufficient storage to capture the runoff from a 15 mm (AES - 1 hour) design storm, is best suited for areas having permeable soils.

EXFILTRATION SYSTEM



TYPICAL TRENCH CROSS SECTION

SCALE: N.T.S.

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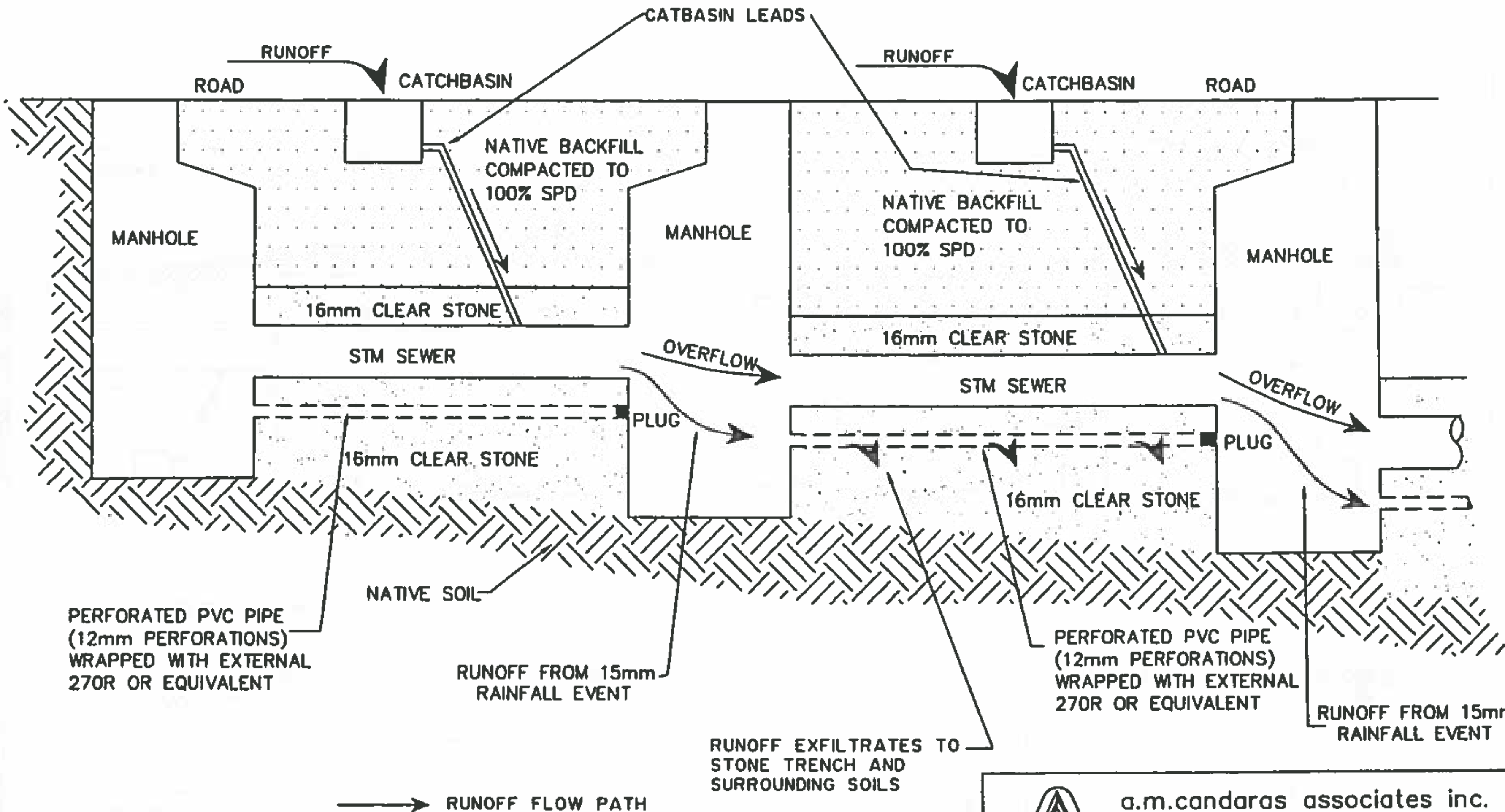
FIGURE 1

EXFILTRATION SYSTEM



TYPICAL PROFILE

SCALE: N.T.S.

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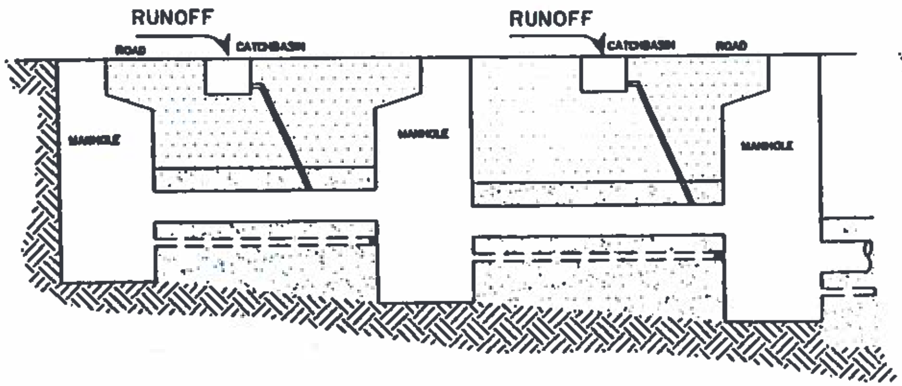
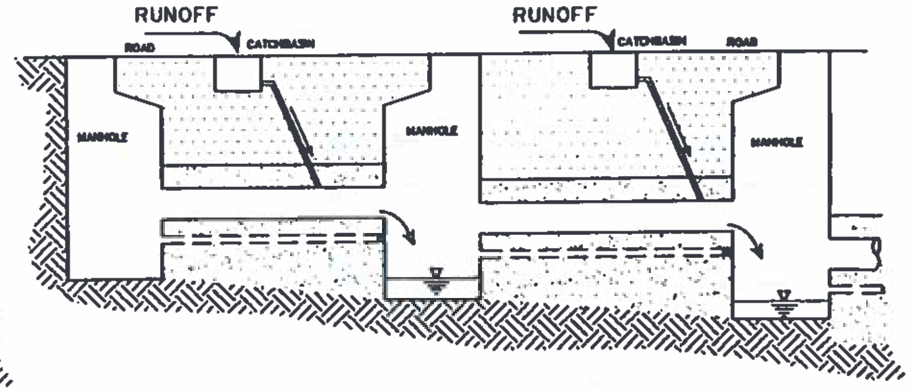
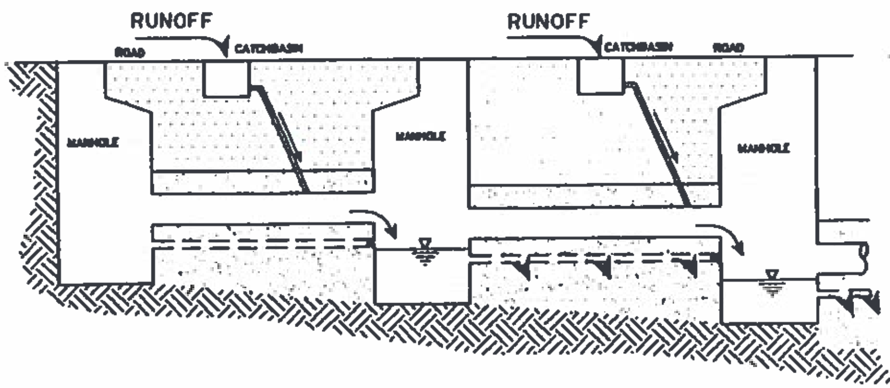
FIGURE 2



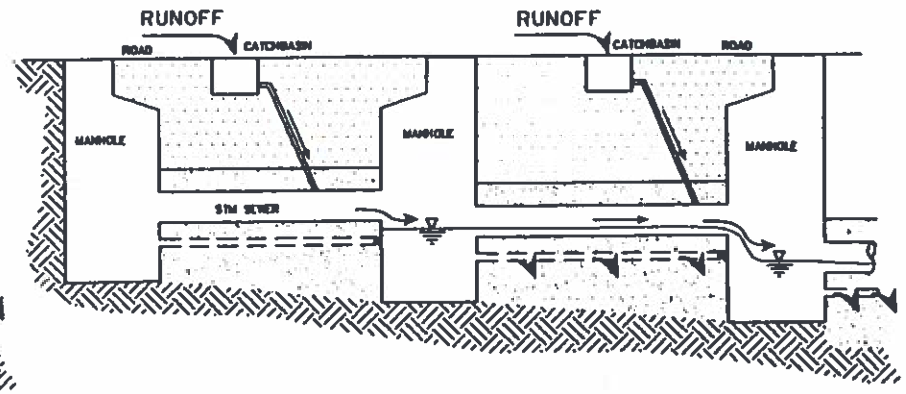
RAINFALL EVENT STARTS



RUNOFF FROM CATCHBASINS ENTER SEWER SYSTEM



STORMWATER ENTERS THE PERFORATED PIPE AND IS EXFILTRATED INTO THE STONE TRENCH



ONCE THE EXFILTRATION CAPACITY OF THE SYSTEM OR THE INLET CAPACITY OF THE PERFORATED PIPES ARE EXCEEDED OVERFLOW TO MAIN SEWER WILL OCCUR

EXFILTRATION SYSTEM:
FLOW DYNAMICS DURING A RAINFALL EVENT

SCALE: N.T.S.

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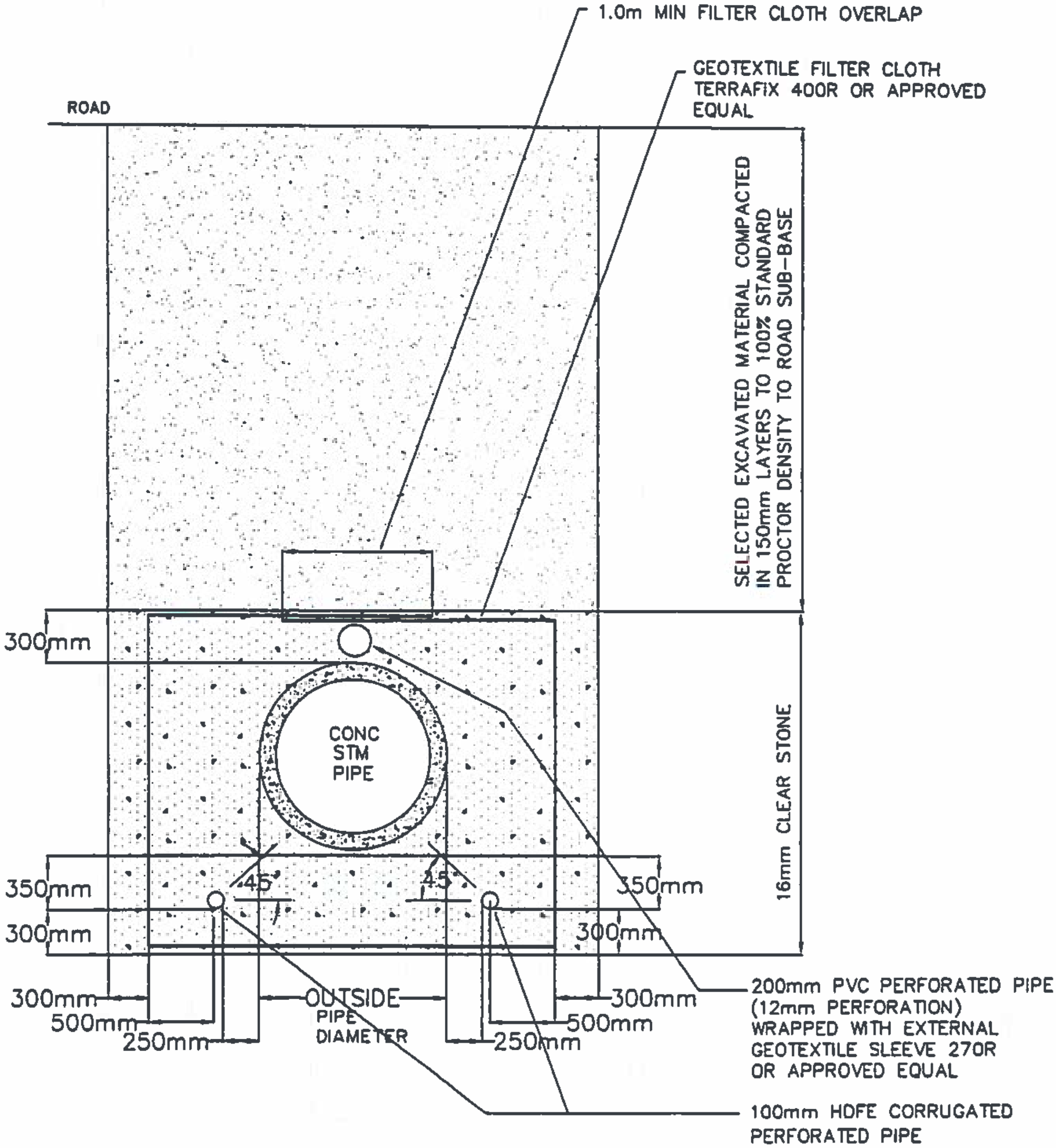
FIGURE 3

Filtration System

The system consists of a 200 mm PVC perforated pipe, wrapped in filter fabric, laid above a conventional storm sewer and a pair of 100 mm PVC perforated pipes laid below the storm sewer (Figure 4). Catchbasins used in this system have a lower and upper lead, respectively. The lower catchbasin leads are connected to the upper perforated pipes which are plugged at both ends (Figure 5). The upper catchbasin leads are connected to the storm sewer. The pipes are laid in a granular stone trench wrapped with filter fabric. During a runoff event, stormwater runoff is captured in the catchbasins and is initially discharged through the lower lead to the upper perforated pipe and then filters down through the stone trench. The perforated pipes below the storm sewer collect the filtered runoff and discharge this flow to the downstream manhole. Particulate and debris carried by the stormwater that does not get trapped in the catchbasin is contained within the upper perforated pipe. For runoff events where the flow exceeds the capacity of the lower lead or the exfiltration rate of the perforated pipe, the excess flows are conveyed by the upper catchbasin lead directly to the storm sewer. This flow route is shown schematically in Figure 6. The system, designed such that the stone trench provides sufficient storage to capture the runoff from a 15 mm (AES - 1 hour) design storm, is best suited for areas having low permeability soils.

An alternate filtration system was designed during the monitoring phase of this study which would simplify the construction of the system by reducing the number of pipes used. A sketch of the system is presented in Figure 7. The system is based on the design of the Exfiltration System and involves locating the mechanical plugs in the perforated pipes further upstream of the downstream manhole. During runoff conditions, stormwater enters the catchbasins and is discharged to the perforated pipes and then allowed to exfiltrate to the surrounding stone trench. However, because the permeability of the surrounding soils is low, the exfiltration rate would also be low, and the captured runoff would remain in place until the subsequent runoff event displaced the stored volume in the stone trench. The displaced volume would enter the perforated pipe downstream

FILTRATION SYSTEM



TYPICAL TRENCH CROSS SECTION

SCALE: N.T.S.

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FIGURE 4

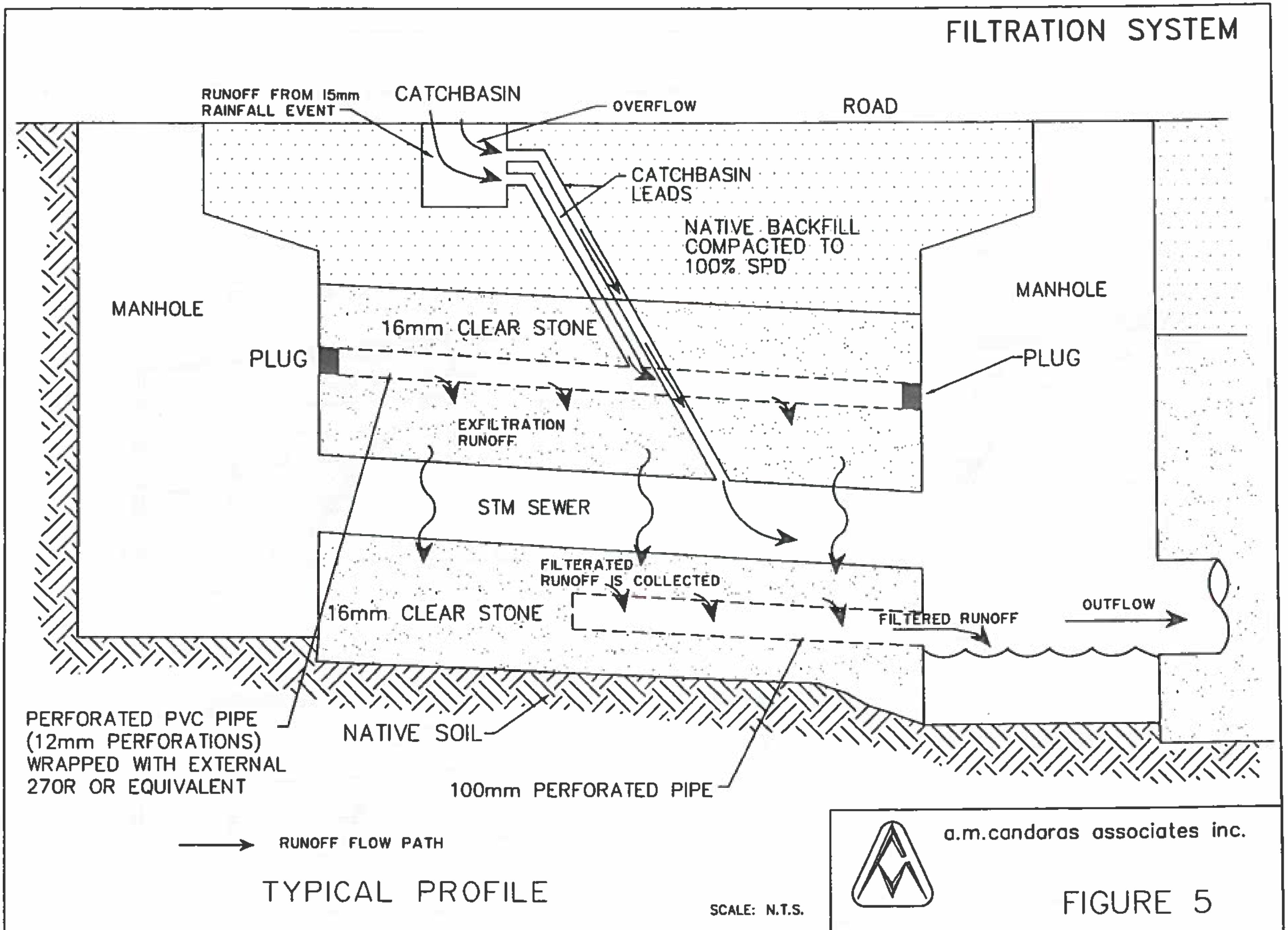
FILTRATION SYSTEM
RUNOFF FROM 15mm RAINFALL EVENT
CATCHBASIN
OVERFLOW
ROAD
CATCHBASIN LEADS
NATIVE BACKFILL COMPACTED TO 100% SPD
MANHOLE
MANHOLE
16mm CLEAR STONE
PLUG
PLUG
EXFILTRATION RUNOFF
STM SEWER
FILTERATED RUNOFF IS COLLECTED
16mm CLEAR STONE
FILTERED RUNOFF
OUTFLOW
PERFORATED PVC PIPE (12mm PERFORATIONS) WRAPPED WITH EXTERNAL 270R OR EQUIVALENT
NATIVE SOIL
100mm PERFORATED PIPE
RUNOFF FLOW PATH
TYPICAL PROFILE
SCALE: N.T.S.
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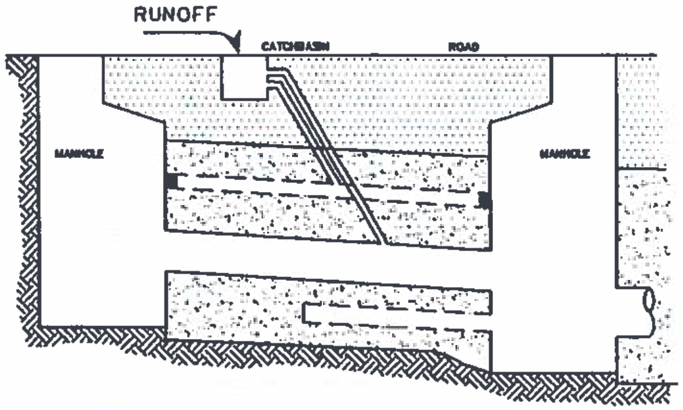
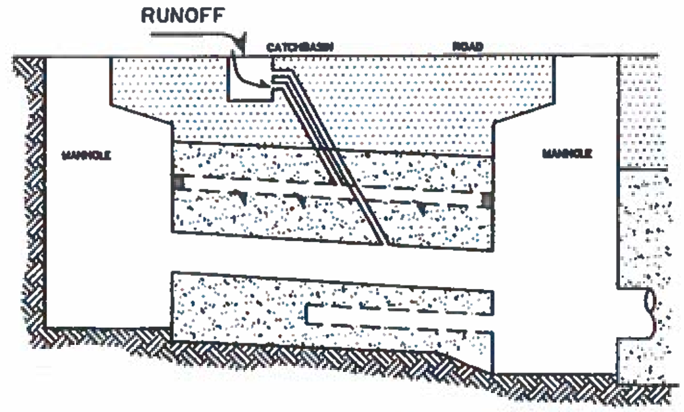
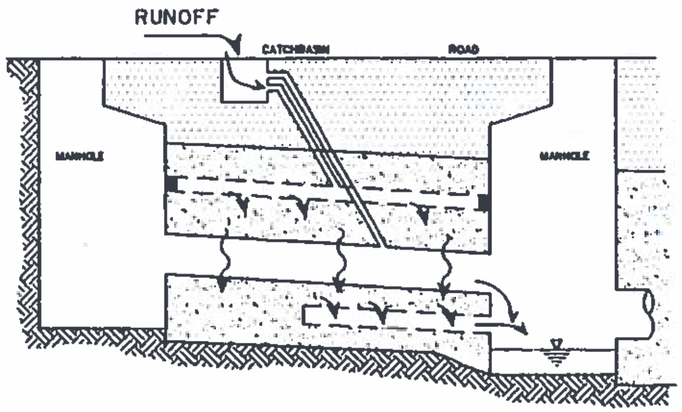
FIGURE 5



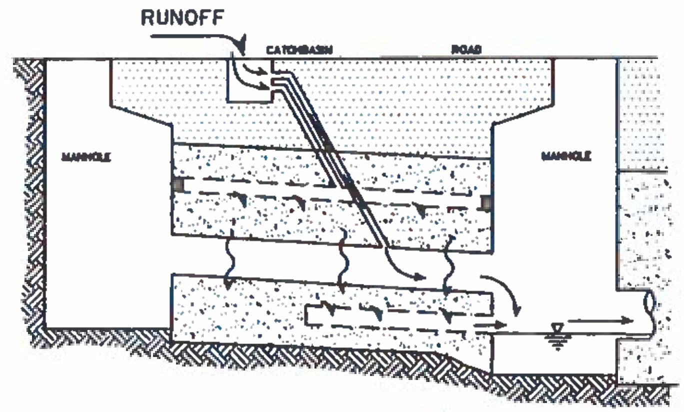
RAINFALL EVENT STARTS



RUNOFF FROM THE LOWER CATCHBASINLEAD ENTERS THE UPPER PERFORATED PIPE AND FILTERS DOWN THROUGH THE STONE TRENCH



THE FILTERED RUNOFF IS INTERCEPTED BY THE LOWER PERFORATED PIPE AND IS DISCHARGED TO THE DOWNSTREAM STORM SEWER



ONCE THE FILTRATION CAPACITY IS EXCEEDED OR THE DISCHARGE CAPACITY OF THE LOWER CATCHBASIN LEAD IS EXCEEDED, RUNOFF IS DISCHARGED DIRECTLY TO THE STORM SEWER VIA THE UPPER CATCHBASIN LEAD

FILTRATION SYSTEM:
FLOW DYNAMICS DURING RAINFALL EVENT

SCALE: N.T.S.

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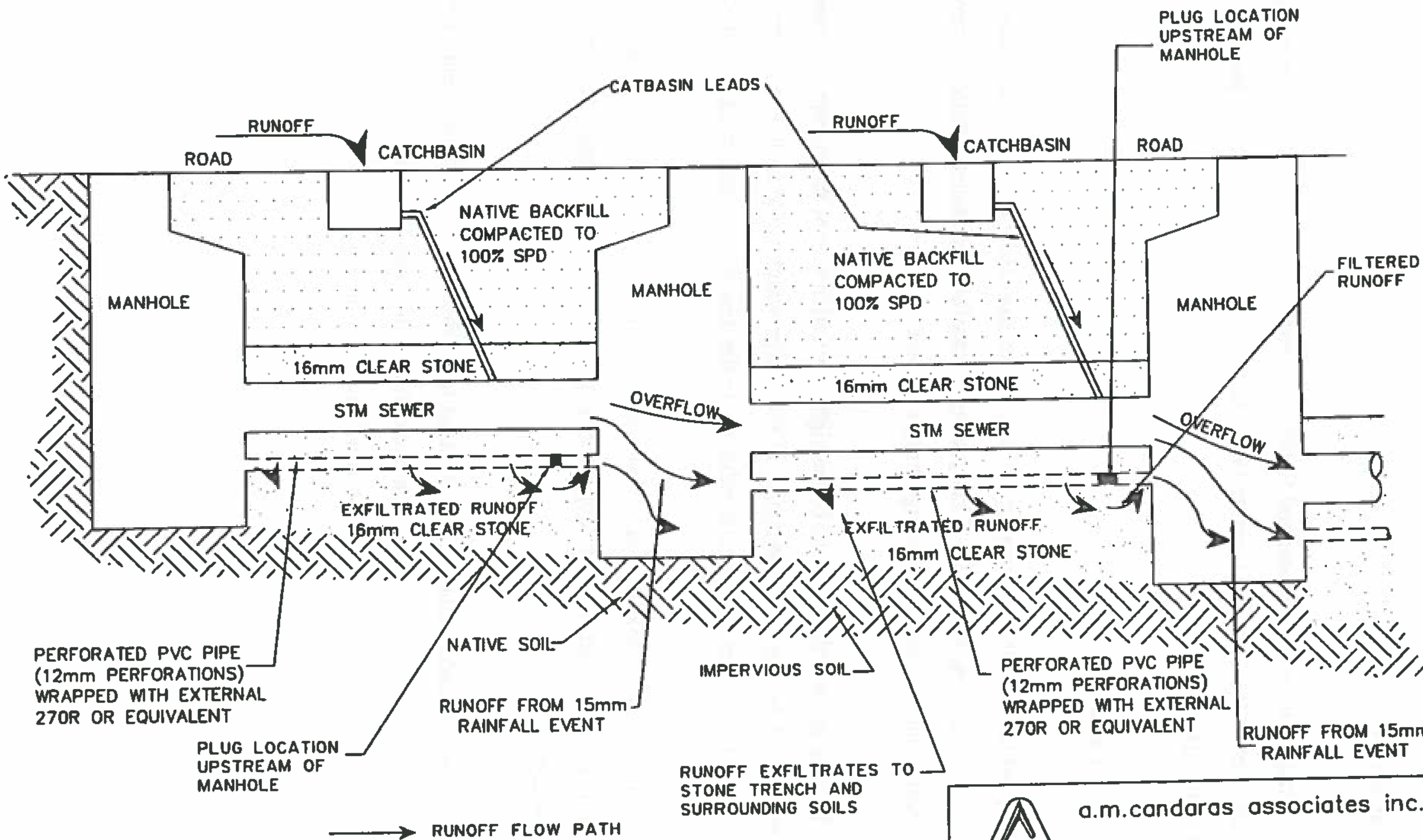
FIGURE 6

MODIFIED EXFILTRATION SYSTEM



TYPICAL PROFILE

SCALE: N.T.S.

a.m.candaras associates inc.

FIGURE 7

of the plug and be conveyed downstream.

The performance of the exfiltration and filtration systems was evaluated using monitoring data collected between May 1994 and October 1995. The following summarizes the major statements derived from this study:

System Performance

- The exfiltration/filtration capacity of the systems exceeded the design runoff from a 15 mm (AES - 1 hour) rainfall event. The systems successfully exfiltrated/filtrated stormwater for events which exceeded the design runoff volume.

- The data suggest that because of the high exfiltration rate of the system, efficiencies can be derived through an optimization of the design which could include a reduction in the sizing of the storm sewer and a reduction in the trench cross section used in the system.

- The design methodology used provides a conservative system design and should continue to be used until an alternate approach is developed and tested against monitoring data collected.

- Stormwater runoff contaminant loadings to surface waters, for catchments serviced by these systems, were virtually eliminated during the period of study. Additional study is required however, to assess the potential impact of these systems on groundwater sources.

Exfiltration System Implementation Constraints

- The system is best suited for low density residential areas where there is a minimum risk of hazardous spills. Goss traps in catchbasins, where the system is implemented, should be used to capture minor spills.

- The system should not be considered for sites close to a water supply aquifer.

- The groundwater table must be below the invert elevation of the stone trench.

- The subsurface soil should have reasonably good hydraulic conductivity (exfiltration potential). The system performed satisfactorily in areas where the hydraulic conductivity of underlying soils measured as low as 1 x 10^{-7} cm/s. While the filtration system would be better suited for low conductivity soils, a modified exfiltration system (the exfiltration system with the perforated pipe plugs placed further upstream of the downstream manhole) was proposed for these cases because construction of the infiltration system was found to be complicated by the number of pipes used.

Precautions During Construction

- Mechanical plugs should be placed on the upstream side of the perforated pipes during construction of the Exfiltration System to prevent sediment from entering the system. The plugs should be relocated at the downstream end of the perforated pipes when the construction is complete and the site stabilized.

- All catchbasins should be covered with a heavy metal plate and filter cloth to prevent sediment laden stormwater from entering the system during construction. The plates should be removed when the construction is complete and the site is stabilized.

Maintenance

- Maintenance was not required on the system over the two year post-construction operating period of this study.

- Long term system operation will be affected by the buildup of sediments collected within the perforated pipes. Video inspection of the system, after operating for the two year period, showed some sediment accumulation and suggests that video inspection should be conducted on a five year cycle.

- Standard sewer system power flushing procedures were found to be effective in cleaning the perforated pipes of the trapped debris and sediments. This approach is recommended when system cleaning is required. Power flushing should be conducted between maintenance holes. The mechanical plugs should be repositioned to the upstream end of the perforated pipes to ensure that the flushed material is trapped within the downstream maintenance hole and the material removed by vacuum truck.

- There were no visible signs of structural deterioration on road surfaces (e.g. settlement) where the systems were constructed.

Perforated Pipe Sediment

- Particle size analysis on a representative sediment sample collected from a perforated pipe showed it to be coarser (less clay size particles) than stormwater retention pond sediments. This may be attributed to the fact that the capture of smaller particles is limited by the filter cloth mesh size.

- Analysis of a limited set of sediment samples indicated that heavy metal concentrations were generally higher than those of stormwater retention pond sediments. Most parameters exceeded the MOEE's sediment quality guidelines for lowest effect levels, while copper and magnesium concentrations exceeded the severe effect levels. Zinc concentrations also exceeded the MOEE's Guideline for Use at Contaminated Sites (Industrial). These relatively high metal concentrations would suggest that special consideration may be necessary for the disposal of sediment collected.

Future Study Needs

- A monitoring program should be established to assess the overall system performance for the exfiltration system on a longer term basis.

- The longer term maintenance and operation requirements should be assessed. Additional analysis of material trapped within the perforated pipes is warranted and disposal options identified.

- A full cost-benefit analysis should be completed and compared to a conventional system with an end-of-pipe treatment facility.

- An assessment of the potential ground water impact should be conducted.

- A detailed design brief should be developed to include an evaluation of the design parameters and using available performance data, provide an optimization for the design of the exfiltration system.

ACKNOWLEDGEMENTS

The Study Team acknowledges J. Yee, M. Mansfield and J. Tran, former staff of the City of Etobicoke, for developing the systems and initiating this project. M. Mansfield and J. Tran provided direction during the study and assisted with the preparation of draft study reports. Thanks are extended to City of Etobicoke Works Department staff, responsible for the design and construction phases of the project and assisting during the monitoring phase.

The support and assistance in the preparation of this report by the project Steering Committee is gratefully acknowledged. The project Steering Committee members are listed as follows:

P. Seto	Environment Canada
S. Kok	Environment Canada
D. Henry	Ontario Ministry of Environment and Energy (MOEE)
M. Heaton	Ontario Ministry of Natural Resources
W. Snodgrass	Ontario Ministry of Transportation
W. Liang	Metropolitan Toronto and Region Conservation Authority
M. D'Andrea	City of Etobicoke (formerly with MOEE)
M. Koo	City of Etobicoke
J. Li	Ryerson Polytechnic University
D. Weatherbe	Donald G. Weatherbe Associates (consultant to Environment Canada)

The chemical analysis of stormwater samples by staff from the Ontario Ministry of Environment and Energy Laboratory Services Branch is gratefully acknowledged.

Funding for this study was provided by Environment Canada through the Great Lakes 2000 Cleanup Fund. Although the report was subjected to technical review by staff from participating agencies, the contents do not necessarily reflect the views and policies of individual agencies.

The Study Team consisted of :

A.M. Candaras	A.M. Candaras Associates Inc.
D. Dodds	A. M. Candaras Associates Inc.
P. Bowen	Terraprobe Limited
R. Brenner	

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1.0 INTRODUCTION

This study report presents the background, implementation, monitoring results and system evaluation of the Etobicoke Exfiltration System (EES) and Etobicoke Filtration Systems (EFS) Pilot/Demonstration Project. These systems were developed by the City of Etobicoke Utility Engineering Division as an alternative stormwater management approach to eliminate the discharge of storm runoff for frequent rainfall events, by utilizing exfiltration capabilities of the existing soil or filtrating through an imported stone trench medium to provide stormwater quality treatment. The Etobicoke Exfiltration and Filtration Systems were designed to complement traditional urban stormwater drainage systems.

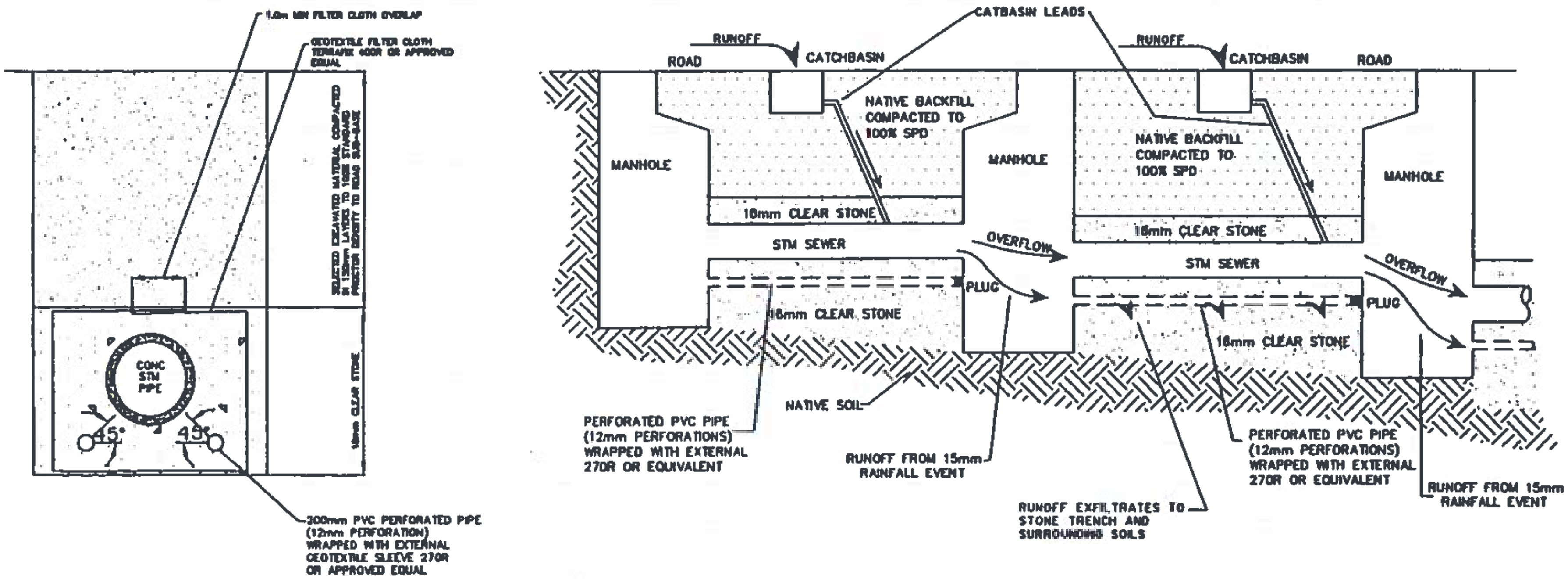
The EES and EFS technologies meet the objectives the Metropolitan Toronto and Region Remedial Action Plan pertaining to stormwater management (Metropolitan Toronto and Region RAP 1994). In addition, these technologies meet the objective of the Great Lakes Cleanup Fund which supports the development and implementation of cleanup and remedial technologies to control municipal pollution and to transfer these technologies as stated in the objectives:

> ***"To transfer information on control technologies and management options to the Remedial Action Plan Study Team, Environmental Consultants and Municipalities."***

1.1 Etobicoke Exfiltration System

The exfiltration system consists of a conventional storm sewer network comprised of lengths of storm sewers and manholes which convey runoff. However in addition to the storm sewers, there are two parallel perforated pipes located below the storm sewer. As indicated in Figure 1.1, runoff conveyed in the upstream storm sewer will discharge to the downstream manhole and be initially conveyed through the perforated pipes. The runoff will then exfiltrate into the surrounding stone trench and then infiltrate into the surrounding soils. For events which fill the stone trench, the excess runoff will overflow to the downstream storm sewer.

EXFILTRATION SYSTEM



TYPICAL TRENCH CROSS SECTION

SCALE: N.T.S.

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FIGURE 1.1

1.2 Etobicoke Filtration System

The filtration system consist of a conventional storm sewer system, however as runoff is captured in catchbasins it is initially discharged through a low level catchbasin lead to a perforated pipe, which is parallel and located above the storm sewer system as indicated in Figure 1.2. The runoff is exfiltrated from the perforated pipe and is then filtered down through the stone trench. Two perforated pipes located below the storm sewer collect the filtered runoff and discharge the flows to the downstream manhole. For storm events where the runoff either exceeds the capacity of the low level pipe or the exfiltration rate of the perforated pipe , the excess flows are conveyed by the high level outlet in the catchbasin, directly to the storm sewer.

1.3 Study Objectives

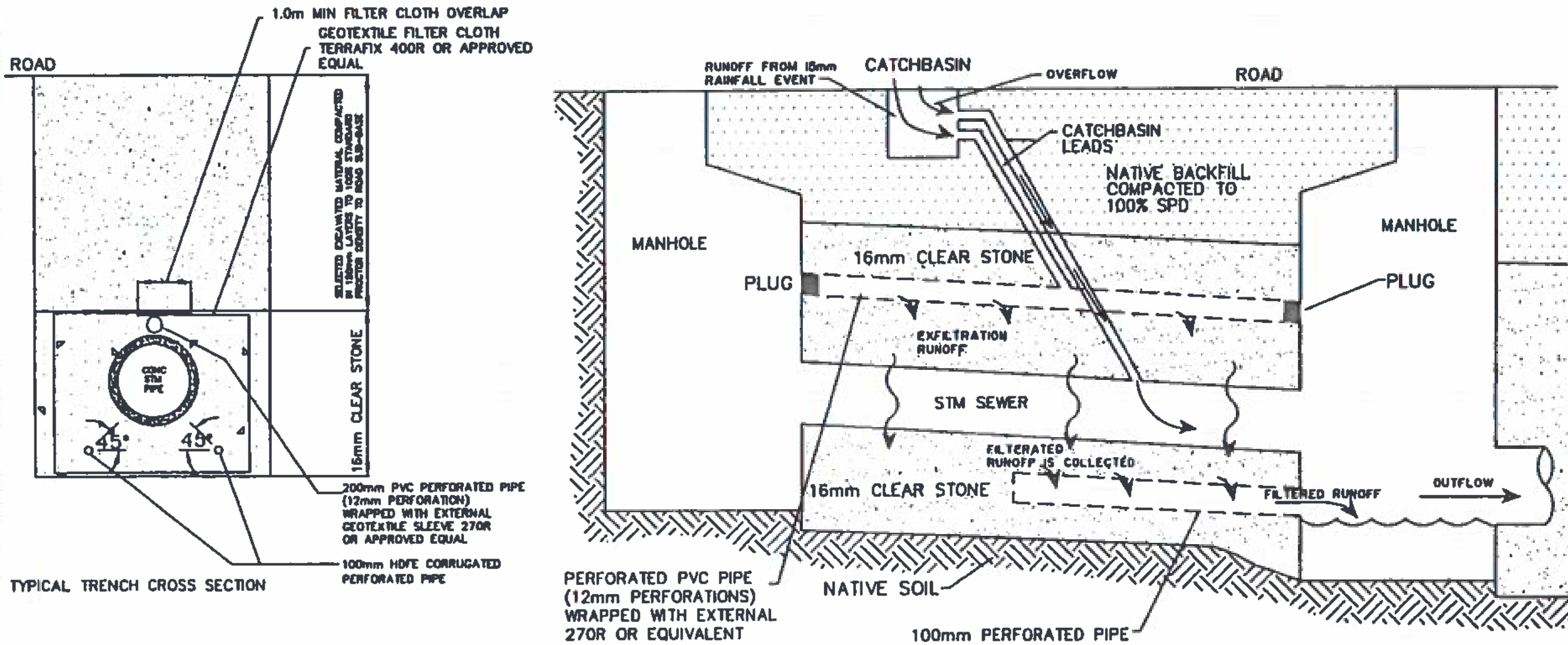
The objectives of the study were to:

1. Review design parameters used by the City of Etobicoke in the design of the EES and EFS.

2. Evaluate the performance of the systems through the establishment of a monitoring program.

This report presents the background data, implementation, monitoring results, system performance, and evaluation for both systems.

FILTRATION SYSTEM



SCALE: N.T.S.

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FIGURE 1.2

2.0 BACKGROUND

The reduction in pervious land cover due to urbanization has a direct and detrimental impact on fluvial geomorphology, and aquatic and adjacent terrestrial environments. Figure 2.1 shows the changes that occur from urbanization.

Traditionally, stormwater management techniques addressed transport, detention and reduction of peak flows using end-of-pipe solutions. In-pipe infiltration technology offers the opportunity to address stormwater management at the source. This technology reduces the volume and duration of runoff, and increases the volume and duration of baseflow during dry periods.

The Etobicoke Exfiltration and Filtration Systems were developed as a new stormwater management approach to eliminate the discharge of storm runoff for frequent rainfall events, while maintaining or improving the level of "convenience" of traditional municipal storm sewer systems. This system was designed to complement traditional stormwater management concepts by introducing a "micro" system, which increases the functionality of traditional systems while addressing stormwater quality and environmental concerns.

The City of Etobicoke has adopted a new stormwater management concept which promotes three levels of control:

- **Major systems** (ie. overland system) designed to transport runoff from large and infrequent storms such as the 100 year storm.

- **Minor systems** (ie. convenience systems) designed to transport the smaller and more frequent storms such as the 2-year and 5-year storm.

- **Micro systems** designed to eliminate runoff from the very frequent storms producing rainfall accumulation in the range of 10 to 15 mm.

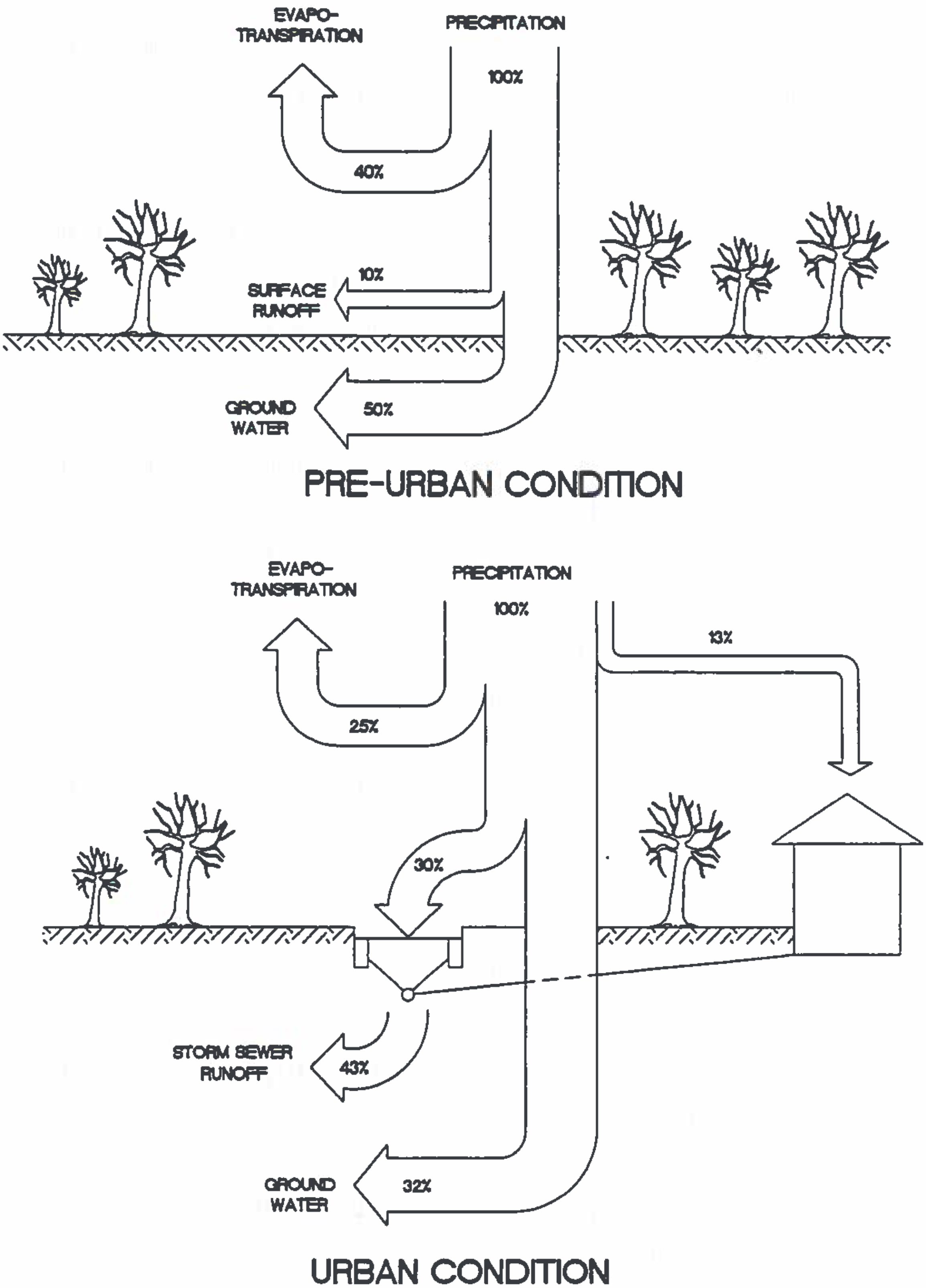


FIGURE 2.1 IMPACT DUE TO URBANIZATION

SOURCE: COA RESEARCH REPORT NO. 104, PG.13

2.1 System Development Rationale

The development of this system was a direct result of the City of Etobicoke Work Department's effort to provide solutions in response to the new direction set by the Province of Ontario Interim Storm Water Quality Control Guidelines for New Development (MOEE and MNR, 1991). In doing so, the City of Etobicoke set five requirements focusing on practical and feasible solutions.

I) **Solution must be cost-effective.** Since the City of Etobicoke is fully developed, there is little opportunity, without substantial land acquisition cost, for end-of-pipe technology commonly used in new developments. If the facilities are located entirely within existing rights of way, land acquisition is not a concern.

ii) **Solution must be simple and not rely on mechanical, or chemical treatment components.** The introduction of mechanical and chemical treatment methods creates a new level of complication (design, construction and maintenance), which is not currently desirable at the local municipal level.

iii) **Solution must be constructed using existing "off the shelf" materials and components.** The Etobicoke Exfiltration System uses standard PVC pipe, perforated by the manufacturer to the specification of the City. Granular material is a standard 16 mm clear stone as is used in type B Sewer Bedding. Filter cloth, which wraps the perforated pipes, is a widely used item in construction practice as are standard compression plugs designed to accept 30 ft (9.1 m) of head.

iv) **Solution must meet or exceed Provincial Guidelines.** In the areas selected for demonstration, the systems meet provincial "Reasonable Use Guidelines". The Etobicoke Exfiltration System was designed to capture and store the runoff resulting from 15 mm of rain, which for the City of Etobicoke exceeds the Province's Interim Stormwater Quality Guidelines.

v) **Solution must be maintained using existing equipment.** Compared to other infiltration facilities, the Etobicoke Exfiltration System is intended to eliminate the need to reconstruct and replace the filtration medium. Access to the system is provided by a standard maintenance hatch and perforated pipes are high-pressure flushed using a standard flusher. Accumulated sediments are collected by standard vacuum trucks, commonly used for catchbasin cleaning. Maintenance tests were carried out successfully on location in the fall of 1993.

2.2 System Description

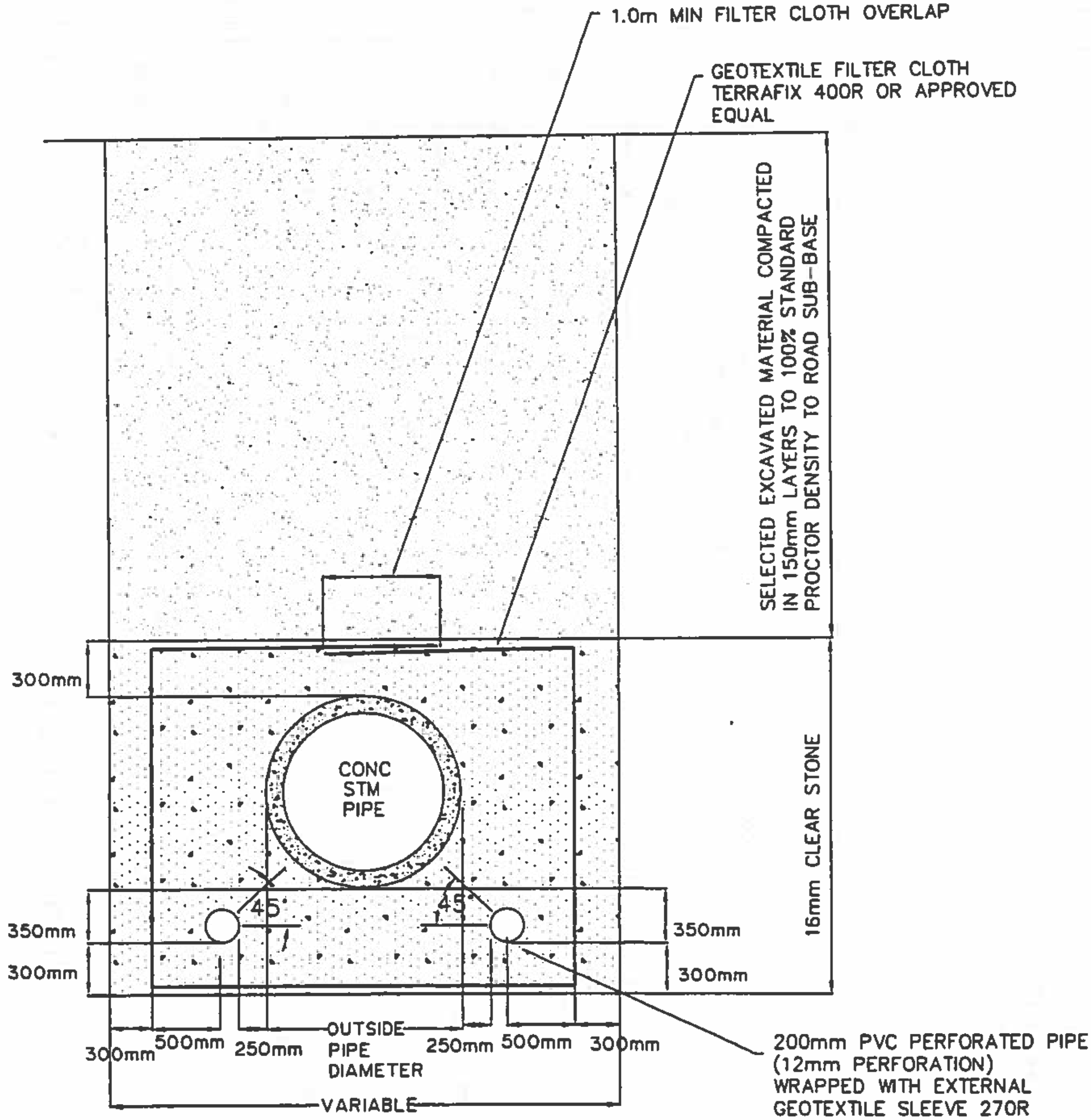
In 1992, the Works Department developed the Etobicoke Exfiltration System (EES) and the Etobicoke Filtration System (EFS) which met the above objectives. The Exfiltration System was applicable for soils with good percolation potential, while the Filtration System is suitable for soils with low percolation rates. Both systems were designed to capture the first flush of runoff and provide subsurface discharge to the surrounding soils or imported stone medium, whereas conventional sewer systems collect the remaining storm water and convey it to an outlet. In 1993, the City of Etobicoke constructed 2.5 km of Minor/Micro systems.

2.2.1 Exfiltration System

The exfiltration system consists of a conventional storm sewer system with two parallel perforated PVC pipes, wrapped in filter cloth, located below the storm sewer. The downstream ends of the perforated pipes are plugged, thereby eliminating short-circuiting of the system. The design criteria for the EES is discussed in Section 5.0. The system is illustrated in Figures 2.2, 2.3 and shown schematically in Figure 2.4. Figure 2.5 shows the EES as time progresses with constant inflow to the system. As indicated in Figure 2.3, runoff enters the upstream storm sewer "1" via catchbasins and at the downstream manhole the runoff is initially conveyed through the downstream perforated pipes to the stone trench and allowed to exfiltrate into the surrounding soil. For storm events exceeding the storage capacity of the exfiltration pipes and the void space of the

PRINCESS ANNE CRESCENT,
PRINCESS MARGARET BLVD.
& QUEEN MARY'S DRIVE

EXFILTRATION SYSTEM



TYPICAL TRENCH CROSS SECTION

SCALE: N.T.S.

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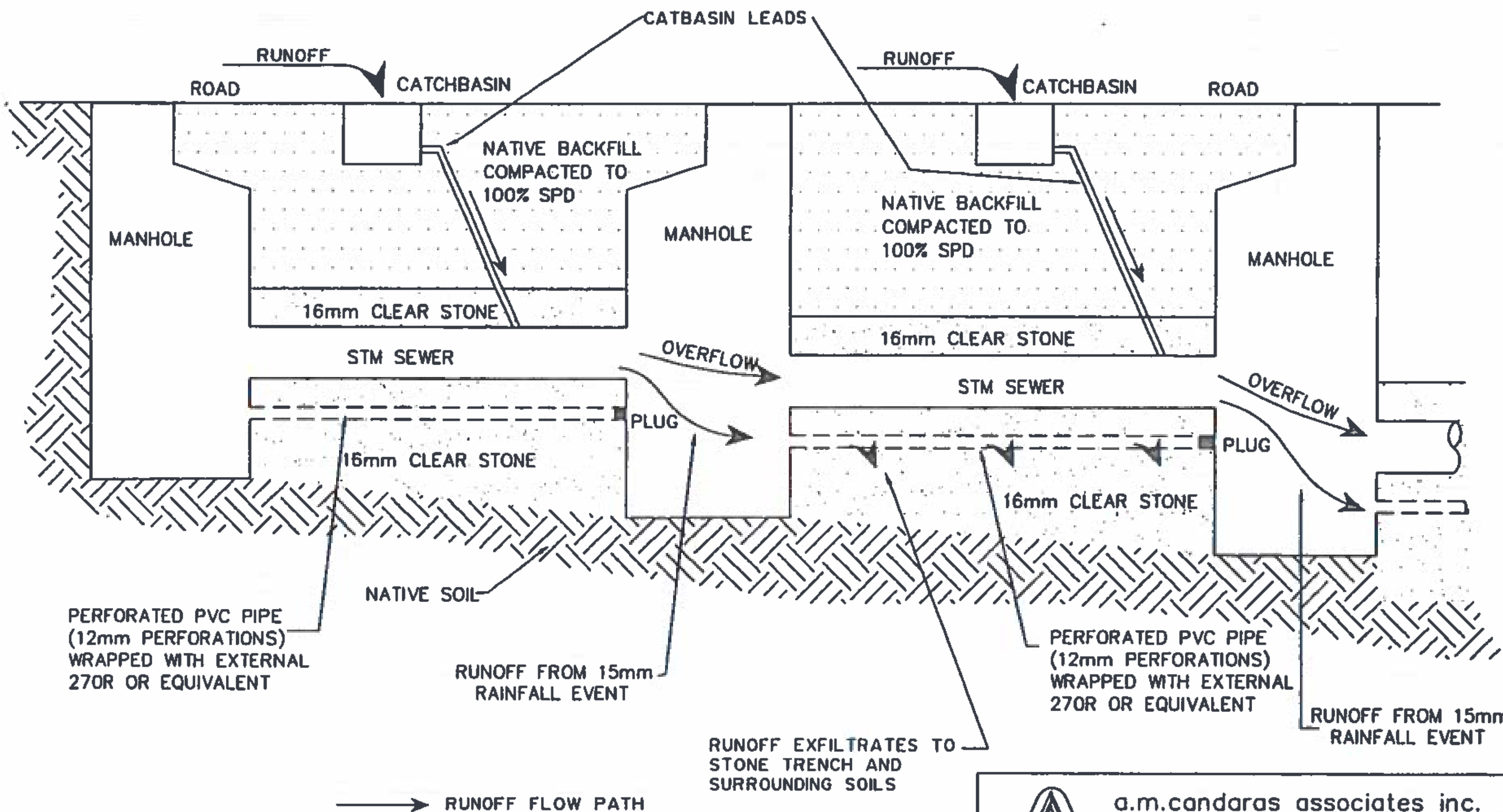
FIGURE 2.2

PRINCESS ANNE CRESCENT,
PRINCESS MARGARET BLVD.
& QUEEN MARY'S DRIVE

EXFILTRATION SYSTEM



TYPICAL PROFILE

SCALE: N.T.S.

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FIGURE 2.3

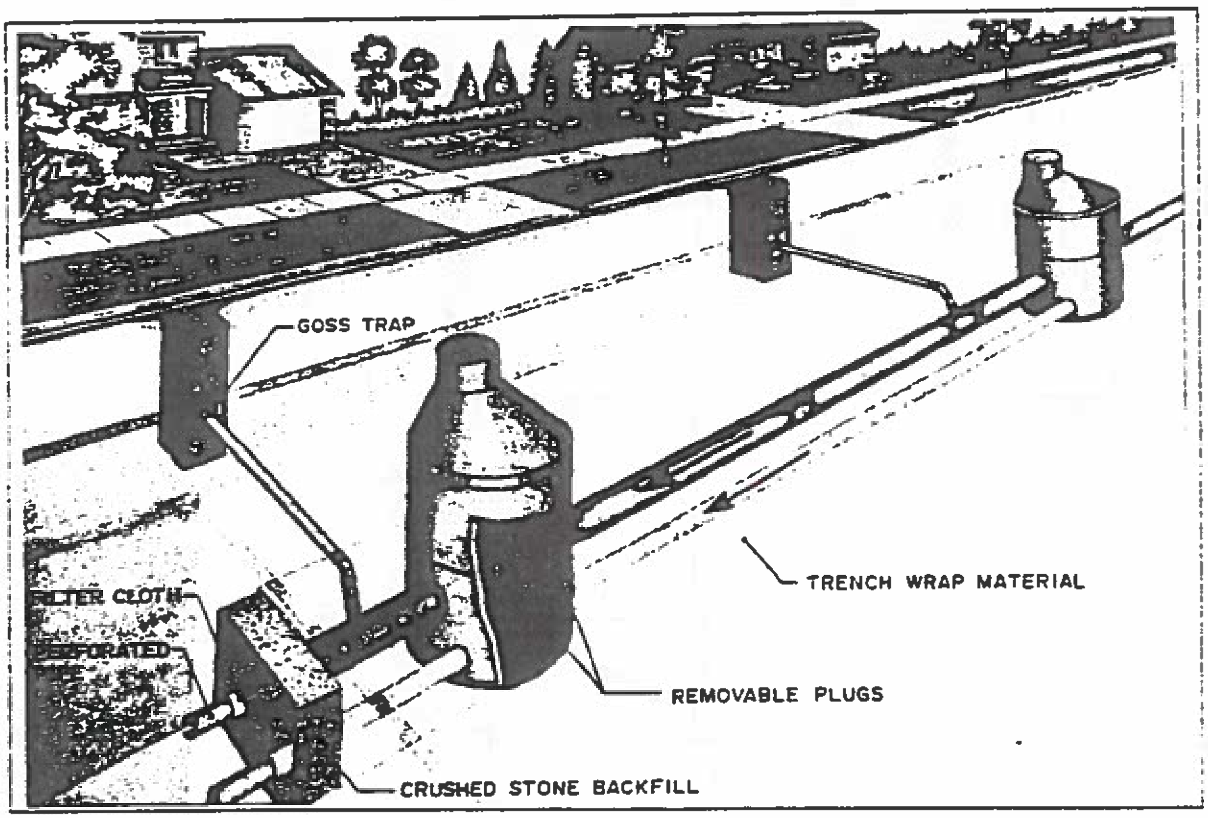
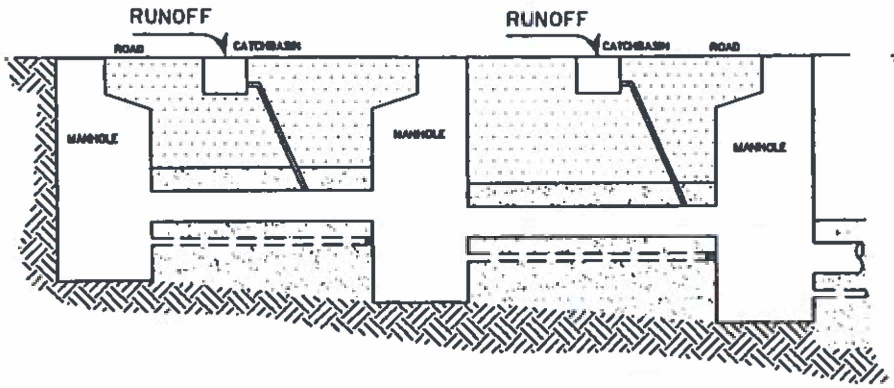
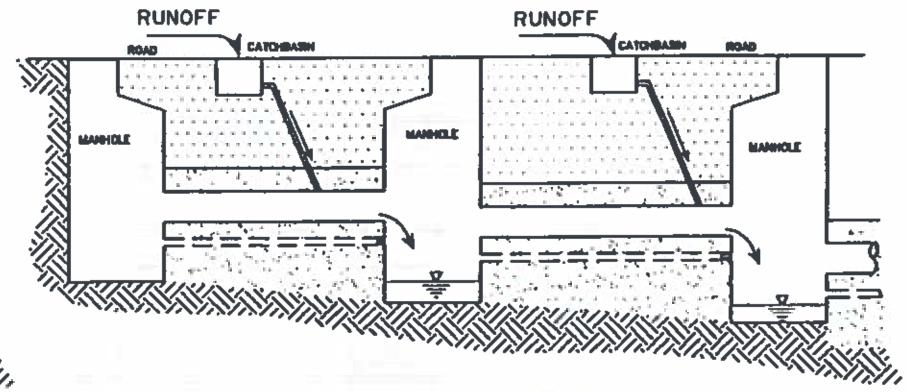


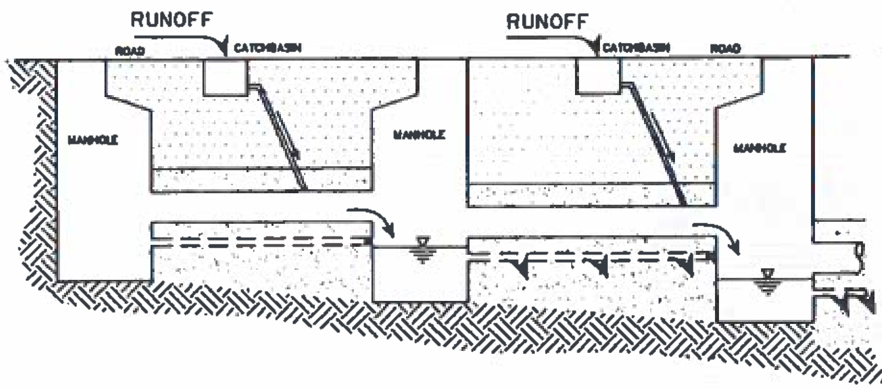
Figure 2.4: Exfiltration System Schematic



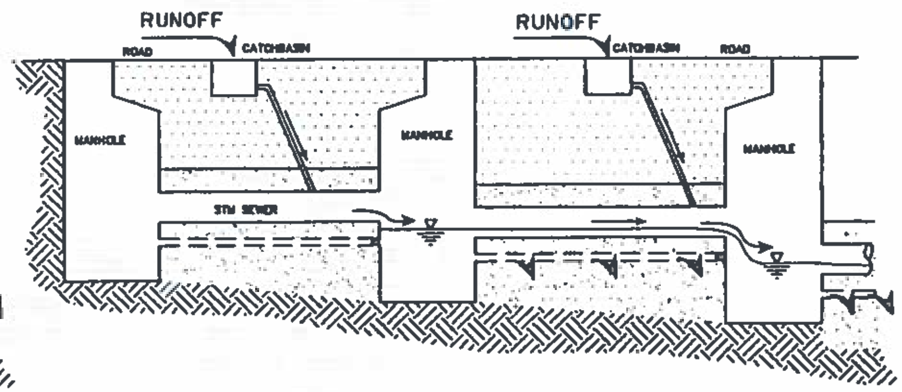
RAINFALL EVENT STARTS



RUNOFF FROM CATCHBASINS ENTER SEWER SYSTEM



STORMWATER ENTERS THE PERFORATED PIPE AND IS EXFILTRATED INTO THE STONE TRENCH



ONCE THE EXFILTRATION CAPACITY OF THE SYSTEM OR THE INLET CAPACITY OF THE PERFORATED PIPES ARE EXCEEDED OVERFLOW TO MAIN SEWER WILL OCCUR

EXFILTRATION SYSTEM:
FLOW DYNAMICS DURING A RAINFALL EVENT

SCALE: N.T.S.

a.m.candaras associates inc.

FIGURE 2.5

stone trench, the extra runoff is conveyed through the storm downstream sewer system "2". Figure 2.3 demonstrates the process.

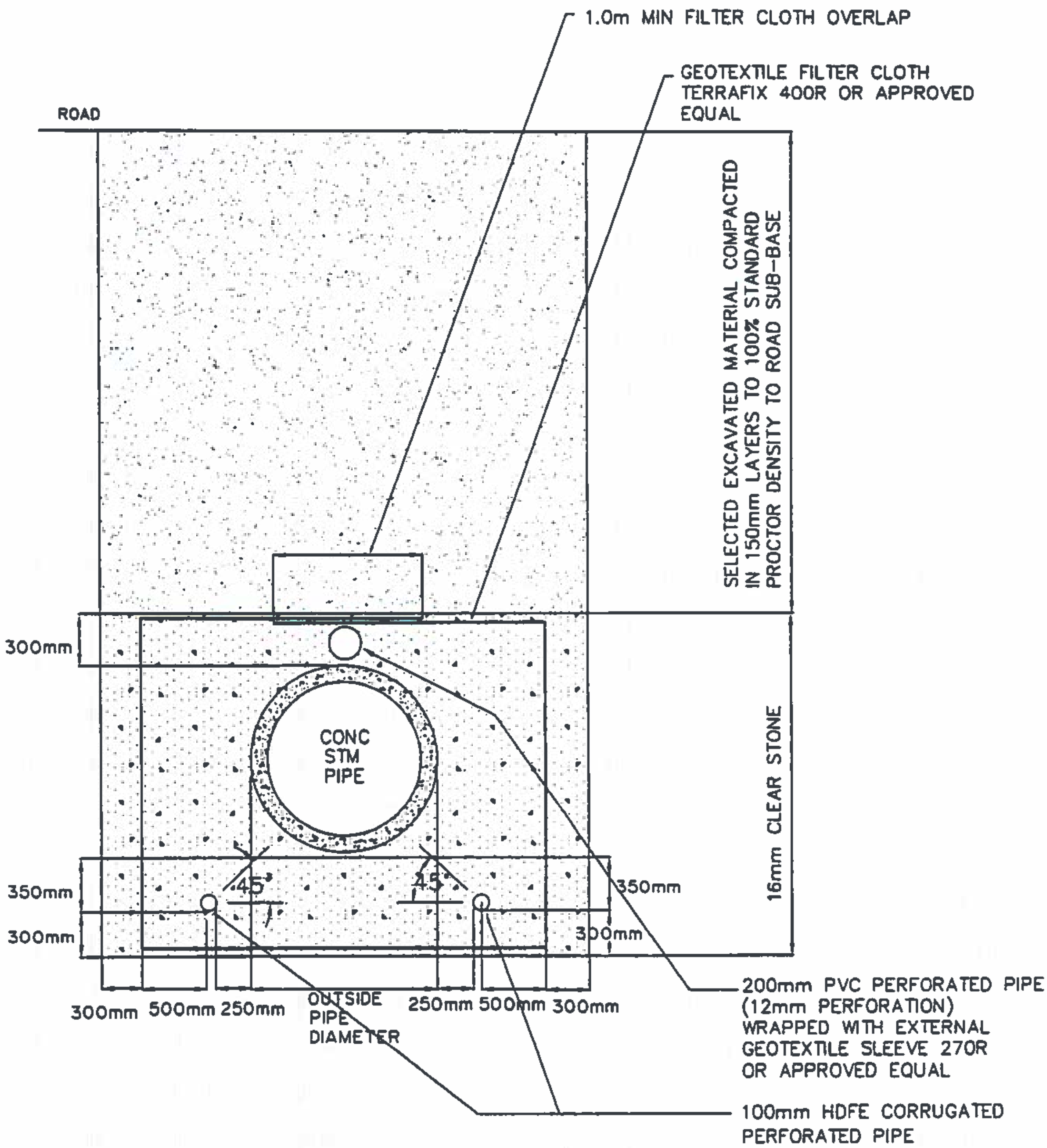
2.2.2 Filtration System

This system consists of a perforated PVC pipe, wrapped in filter cloth, located above the conventional storm sewer. In addition, smaller perforated pipes are located beneath the conventional storm sewer, extending half the length of the storm sewer. The storm sewer and the perforated pipes are all contained within a stone-filled trench wrapped in filter cloth. The filtration system is illustrated in Figures 2.6, 2.7, and shown schematically in Figure 2.8. Figure 2.9 shows the EFS as time progresses with constant inflow to the system.

Storm flows are conveyed to the system via catchbasins equipped with two leads. The lower lead, through which the first flush will be conveyed, is connected to a perforated pipe placed above a conventional storm sewer. The perforated pipe distributes and disperses the first flush into the filtration trench (Figure 2.7). The first flush percolates through the trench, and the associated sediments and pollutants may be removed. The filtered runoff is collected in the perforated pipes beneath the storm sewer and outlets to the downstream manhole. Runoff which exceeds the inlet capacity of the lower catchbasin lead, will discharge through the upper catchbasin lead which is connected directly to the storm sewer as in a conventional system.

During the evaluation and monitoring period, a modification to the Filtration System design was developed. This modification was based on the design of Exfiltration System and involved moving the plugs in the perforated pipe upstream of the downstream manhole. As illustrated in Figure 2.10 the runoff would be conveyed to the perforated pipe and then allowed to exfiltrate to the surrounding stone trench, however since the imperviousness of the surrounding soils would not exfiltrate, the runoff would remain in place until additional incoming runoff would displace the storage in the stone due to the increase in pressure. The displaced runoff would enter the perforated pipe downstream of the plug and be conveyed downstream. The advantage of this

BRAECREST AVENUE FILTRATION SYSTEM

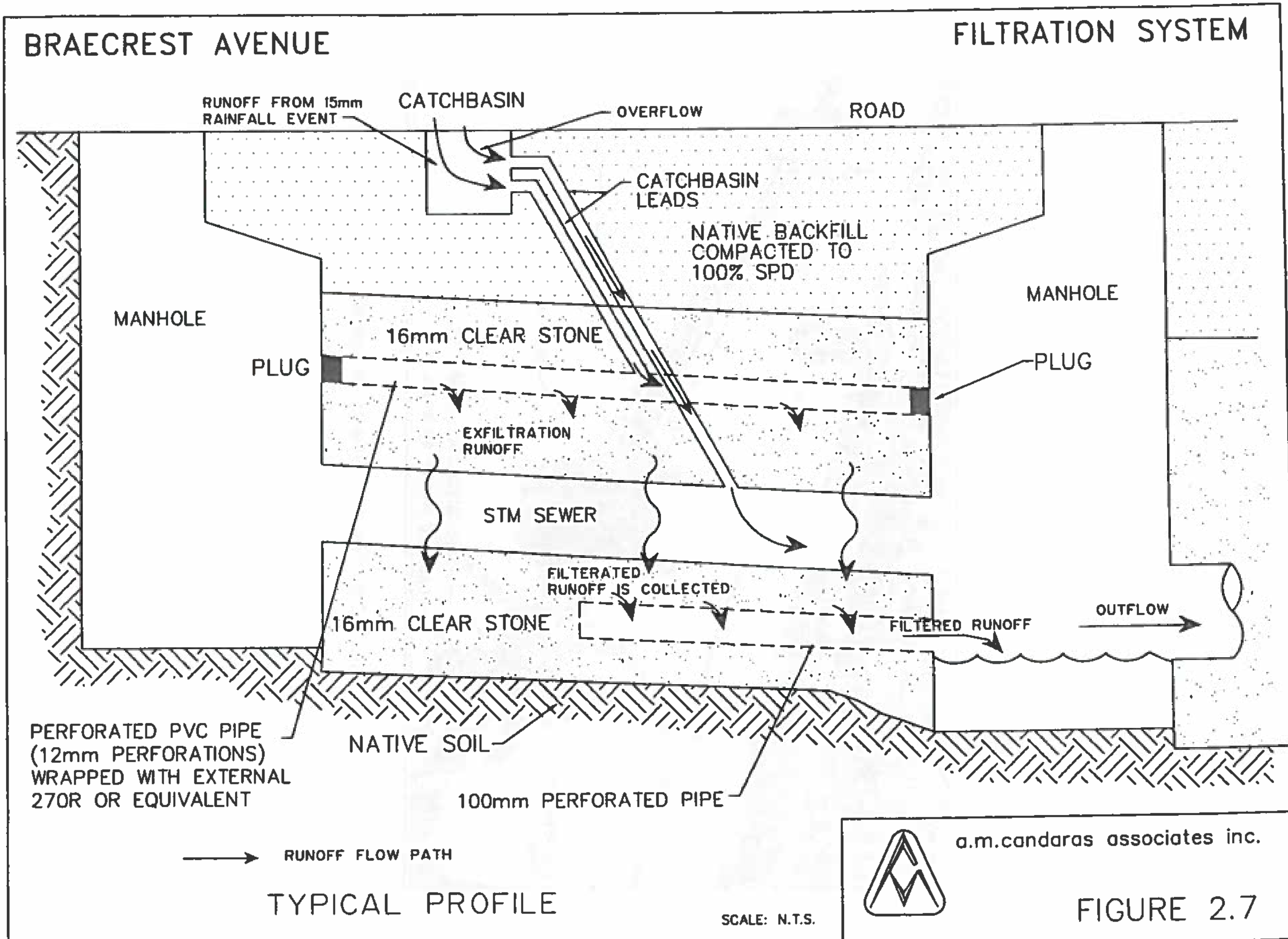


TYPICAL TRENCH CROSS SECTION

SCALE: N.T.S.

a.m.candaras associates inc.

FIGURE 2.6



a.m.candaras associates inc.

FIGURE 2.7

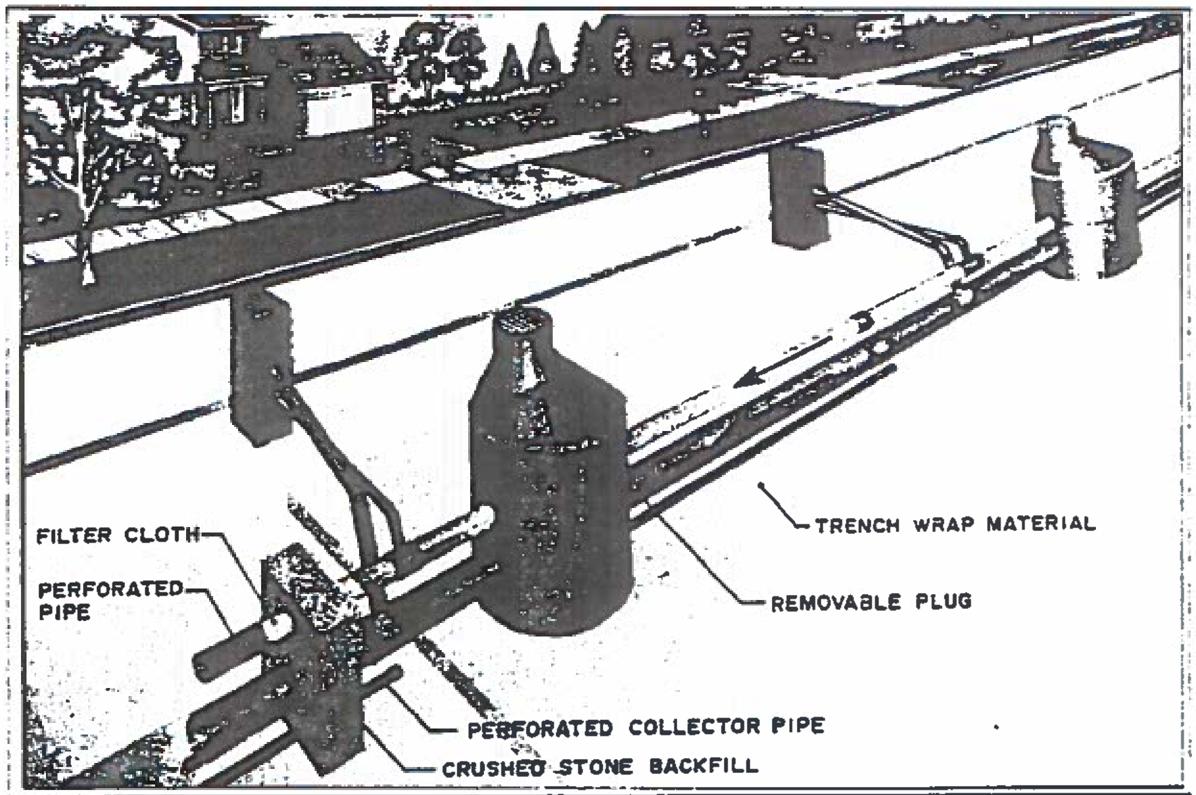
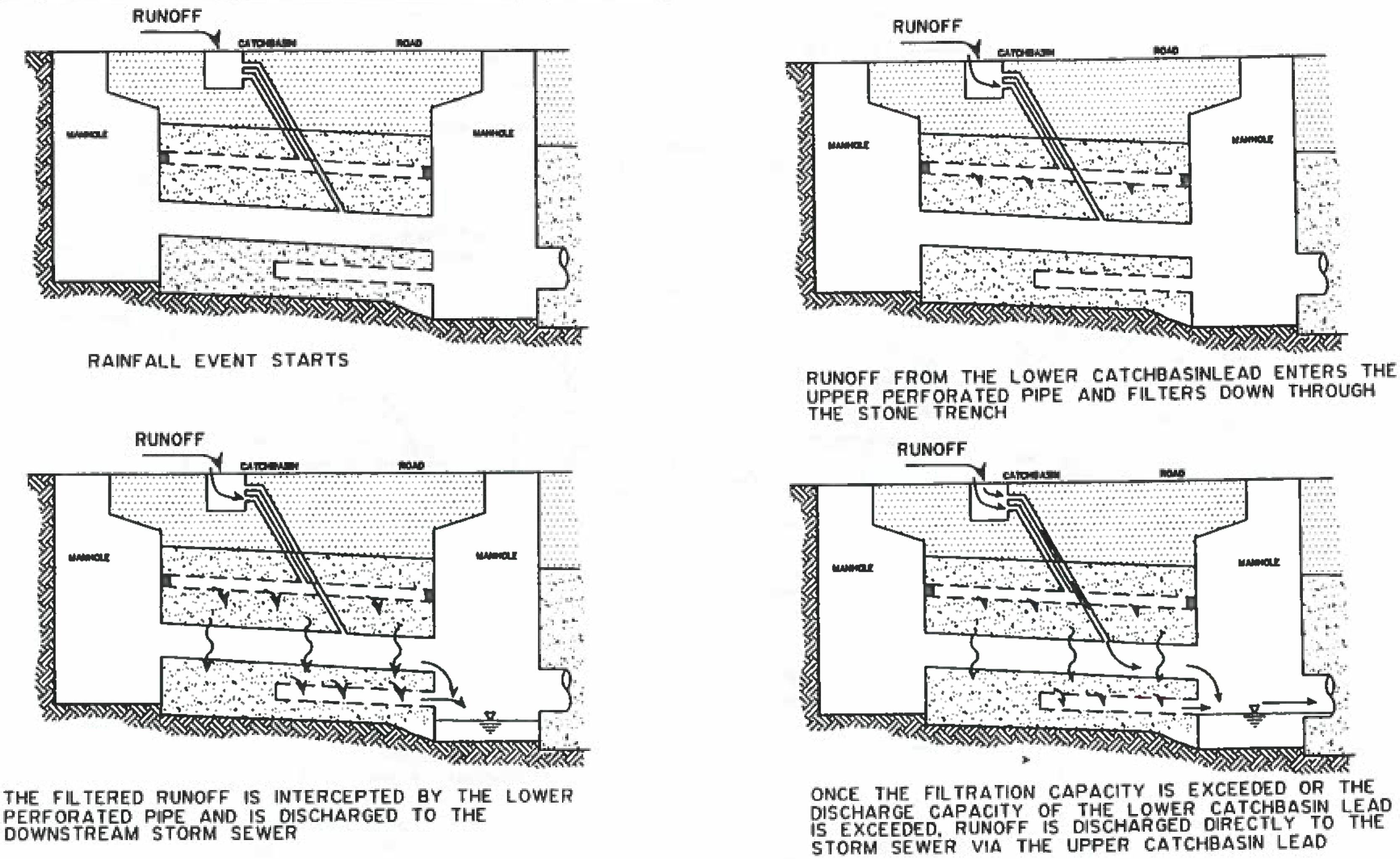


Figure 2.8: Filtration System: Schematic



FILTRATION SYSTEM:
FLOW DYNAMICS DURING A RAINFALL EVENT

SCALE: N.T.S.

a.m.candaras associates inc.

FIGURE 2.9

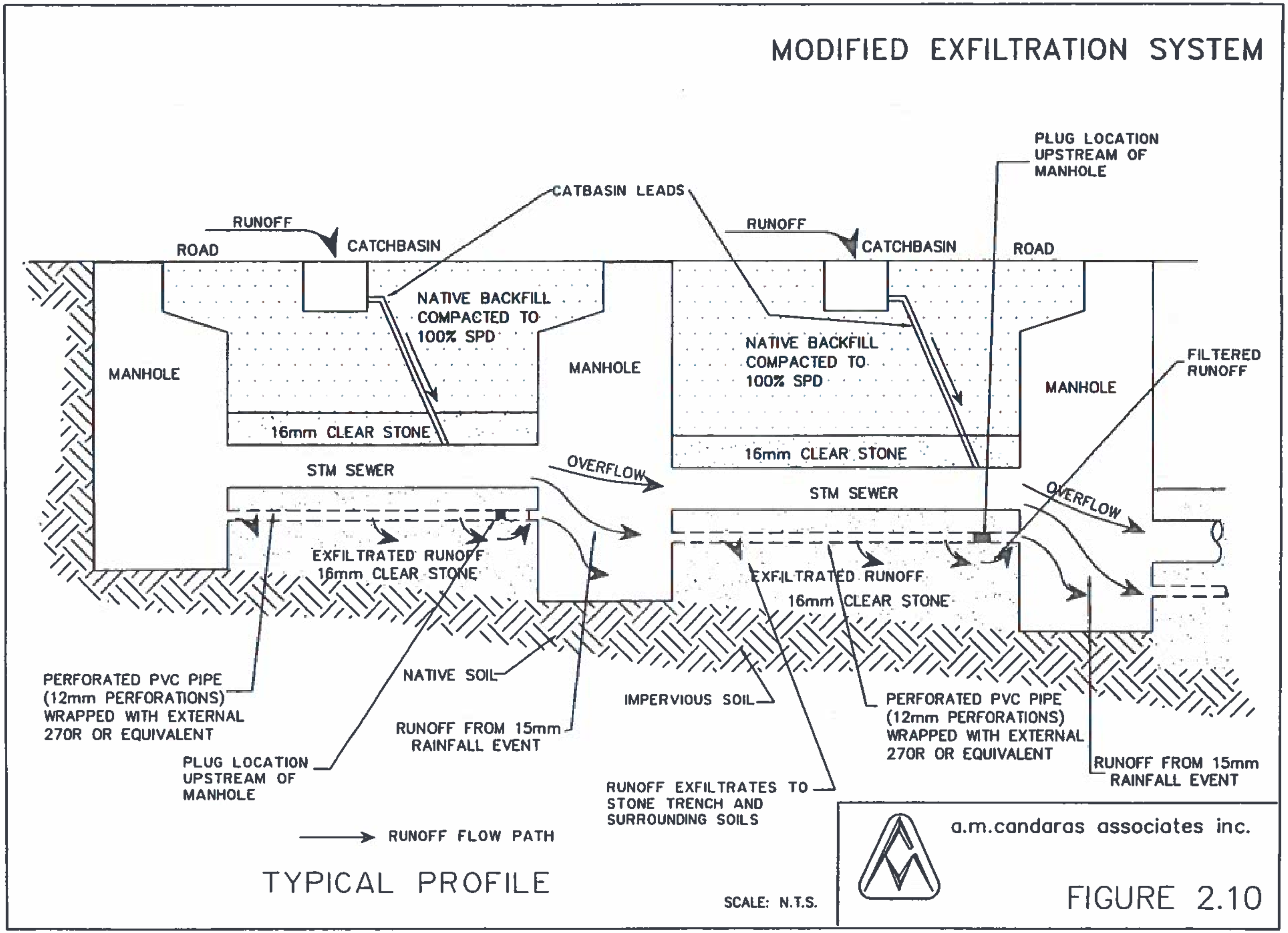

MODIFIED EXFILTRATION SYSTEM
CATBASIN LEADS
PLUG LOCATION UPSTREAM OF MANHOLE
RUNOFF
ROAD
CATCHBASIN
RUNOFF
CATCHBASIN
ROAD
MANHOLE
NATIVE BACKFILL COMPACTED TO 100% SPD
MANHOLE
NATIVE BACKFILL COMPACTED TO 100% SPD
MANHOLE
FILTERED RUNOFF
16mm CLEAR STONE
16mm CLEAR STONE
STM SEWER
OVERFLOW
STM SEWER
OVERFLOW
EXFILTRATED RUNOFF
16mm CLEAR STONE
EXFILTRATED RUNOFF
16mm CLEAR STONE
PERFORATED PVC PIPE (12mm PERFORATIONS) WRAPPED WITH EXTERNAL 270R OR EQUIVALENT
NATIVE SOIL
IMPERVIOUS SOIL
PERFORATED PVC PIPE (12mm PERFORATIONS) WRAPPED WITH EXTERNAL 270R OR EQUIVALENT
RUNOFF FROM 15mm RAINFALL EVENT
PLUG LOCATION UPSTREAM OF MANHOLE
RUNOFF FROM 15mm RAINFALL EVENT
RUNOFF EXFILTRATES TO STONE TRENCH AND SURROUNDING SOILS
RUNOFF FLOW PATH
TYPICAL PROFILE
SCALE: N.T.S.
a.m.candaras associates inc.

FIGURE 2.10

system is that it reduces the number of pipes in the configuration and uses the standard filtration system which simplifies the construction.

2.3 Environmental Assessment Requirements

If undertaken by a public sector, the installation of the Etobicoke Exfiltration System is subject to either a Class Environmental Assessment for Municipal Road Project or a Class Environmental Assessment for Municipal Water and Wastewater Projects. Exfiltration System installed under Princess Margaret Boulevard was planned under the Class Environmental Assessment for Municipal Roads Projects (April, 1987 version) because the City had proposed to reconstruct Princess Margaret Boulevard from a ditch cross section to a urban cross section with curb and gutter. On the other hand, the reconstruction of sewers and installation of the Exfiltration System under Queen Mary's Drive was planned under the 1987 Class Environmental Assessment for Municipal Sewage Works because the existing storm sewer needed to be replaced due to structural failures. Road works on Queen Mary's Drive consisted of reinstatement of pavement.

Since the 1987 MEA Class Environmental Assessment had provision in schedule A for sewers work within and existing right of way, construction of the Queen Mary's Drive was exempt from a public review. The Works Department opted to inform the public of its intention at a Public Meeting. Response from the local residents was very positive and preservation of existing trees was the only concern.

In June, 1993 MEA Class Environmental Assessment for Municipal Water and Wastewater, Stormwater Management was included in the new document and the Exfiltration System was identified as a Schedule B item. Implementation of this technology by a municipality will require that the EA process be followed. However, if implemented by the private sector, the project is not subject to the EA process. Extracts from this document are included herewith;

"2. Establish new storm retention\detention ponds and appurtenances or *__infiltration systems__* *where such facilities are not shown on an approved development plan and which are needed to service new development provided for in an approved development plan or which are required for existing developments and includes outfall to a receiving water body."*

"4. Modify, retrofit, or improve a retention\detention facility or *__infiltration system__* *for the purpose of stormwater quality control, provided no chemical or biological treatment (including establishment of constructed Wetland) or disinfection system is included."*

3.0 BASELINE MONITORING

3.1 City of Etobicoke Background Monitoring Program

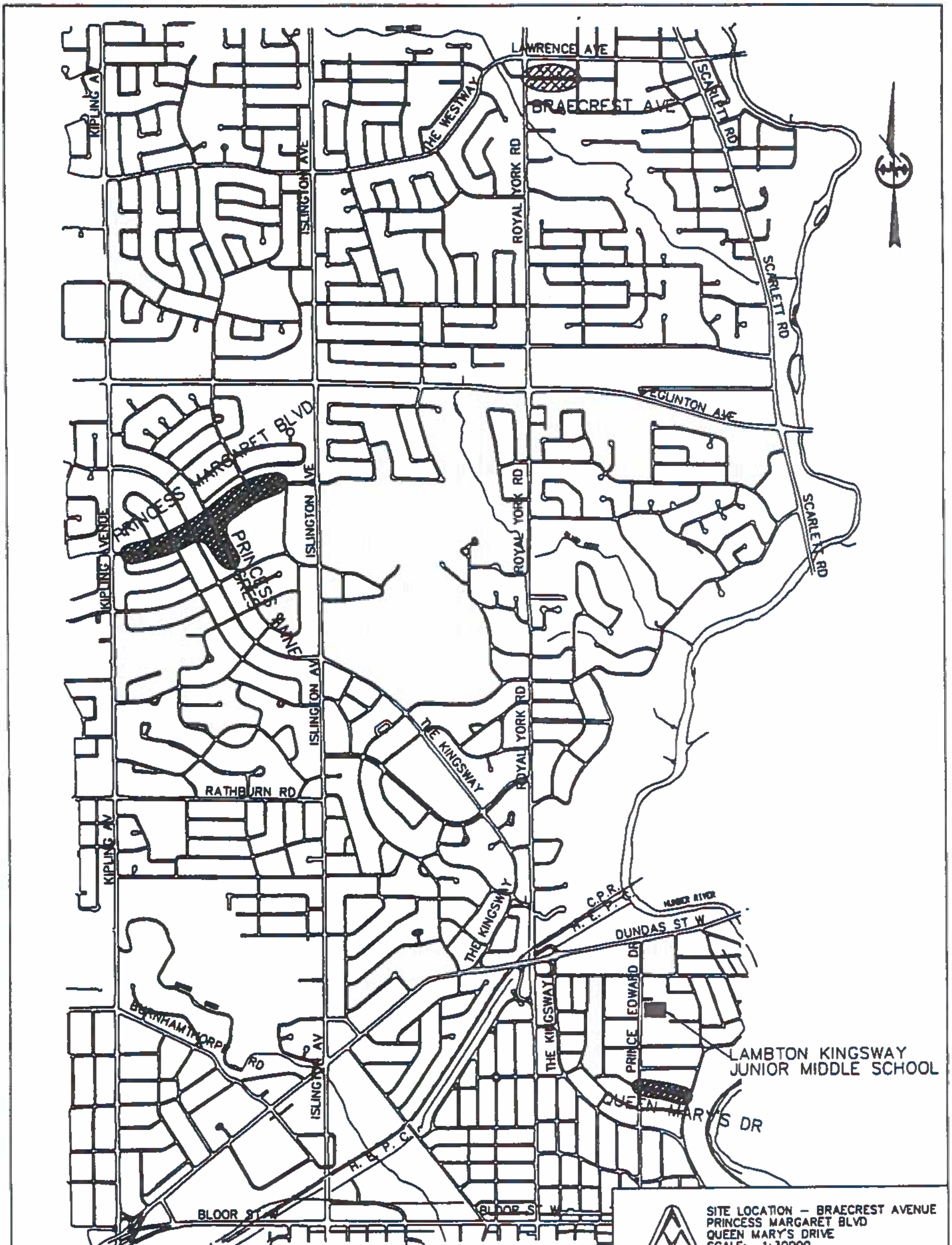
Prior to the construction of the EFS and EES a monitoring program was initiated by the City of Etobicoke. The purpose of this was to collect base line data and identify potential monitoring problems. The program consisted of measuring rainfall and discharge within the sewer on Braecrest Avenue and Queen Mary's Drive (Figure 3.1).

Water quality sampling was also incorporated and conducted as flow-weighted and grab sampling. The water quality data is of particular interest as it identifies pollutant loadings particular to this area. Having an understanding of the local loadings assisted in determining the required BMP.

Dye tests were also carried out on Braecrest Avenue and Queen Mary's Drive in the summer of 1993 to identify sources of illegal connections. Such impacts to the sewer system must be avoided to make certain that a proper assessment of the Etobicoke BMP's can be done. (See Section 3.1.5)

3.1.1 Rainfall Data

Local precipitation measurements were carried out by the City of Etobicoke at a station located on the roof of the Ecole Catholique de Youville near the intersection of Royal York Road and Norsemen Street for the period of May 1993 to August 1993. The instrument was a tipping bucket rain gauge and data logger which recorded the time of tipping for each 1 mm of rainfall collected. For comparative purposes the recorded precipitations of nearby gauging stations are also included in the monthly summary tables (Tables 3.1 - 3.4). In general, the rainfall measurements are consistent among various sites.



SITE LOCATION – BRAECREST AVENUE
PRINCESS MARGARET BLVD
QUEEN MARY'S DRIVE
SCALE: 1:30000

FIGURE 3.1

SOURCE: CITY OF ETOBICOKE, 1997

3.1.2 Flow Monitoring

A flow monitoring program was initiated on Queen Mary's Drive in May 1993. The City of Etobicoke installed an ADS Model 3500 Open Channel Flow monitor which measured depth and velocity. Data was logged in one minute intervals. Collected data was used mainly to determine base flow in the storm sewer. Using the precipitation data and the sewer flows, a calibrated model of the area was established.

3.1.3 Stormwater Quality Data

A stormwater quality sampling program was also carried out by the City of Etobicoke. An American Sigma Model 800 SL automatic sampler was used with the ADS Model 3500 Open Channel Flow Monitor. The flow monitor was equipped with a sensor that triggered sampling to start. The sensor start was set for sewer flow rates exceeding the baseflow conditions.

The automatic sampler contained 24 - 500 ml plastic bottles. The sampling program was designed to capture the first half of the "first flush" for the first 8 bottles, the second 8 in the second half, and the remaining bottled samples were discarded. The first set of bottles were mixed into one container to make a composite sample. The combined sample was subsequently divided into smaller portions according to the quality parameter to be analysed. This procedure was repeated for the second set of sample bottles. Results of the water quality monitoring program are provided in Table 3.5. Generally speaking, concentrations of parameters analyzed fall within the range previously measured by M.O.E.E. for stormwater samples collected along the City of Etobicoke waterfront (Metro Toronto Wet Weather Study - Phase 1, 1995), and it can be stated that heavy metal concentrations exceed the Provinical Water Quality Objections by 1-2 orders of magnitude, ecolic bacteria by over 3 orders of magnitude, and total Phosporus by over 2 orders of magnitude. Appendix A summarizes the results of the environmental practices for the area and provides an indication of potential contaminated sources. Grab samples were taken to supplement the automatic samples.

3.1.4 Dye Testing

Dye tests were conducted within the three study areas to determine the existence and extent of illegal connections. Illegal connections consist of sanitary service connected to the storm sewer and drains connected to either storm or sanitary sewers. This study was carried out by Thanh Le of the City of Etobicoke's Pollution Control section.

Princess Margaret Boulevard/Princess Anne Crescent

Dye tests for Princess Margaret Boulevard or Princess Anne Crescent were not carried out, since no storm sewer existed at the time of the scheduled dye testing period.

Braecrest Avenue

Only one illegal connection was found on Braecrest Avenue and was due to a downspout connected to the sanitary sewer. In general, downspouts discharge roof runoff to the residence's lot at the surface level.

Queen Mary's Drive

Dye tests were carried out on Queen Mary's Drive on July 19, 1993 to July 22, 1993. The study found a total of 4 illegal connections: 2 instances of floor drains in garages leading to the storm sewers, a basement floor drain connecting to the sanitary sewer, and a downspout connected to a sanitary sewer. Roof areas in this section are connected to the storm sewer.

3.2 Geotechnical Investigation

Detailed geotechnical investigations were undertaken within the study areas to determine the composition of the underlying soils by referencing the City of Etobicoke Soil Map.

3.2.1 Princess Margaret Boulevard/Princess Anne Crescent

A geotechnical investigation was conducted by Golder Associates for the Princess Margaret Boulevard/Princess Anne Crescent area. The investigation was carried out to determine the subsurface soil profile, soil condition and groundwater location and movement.

Seven boreholes were dug between January 18 to 20, 1993 to carry out the investigation. The borehole locations were selected based on the proximity of the storm sewer and sanitary sewer crossings. The results of the borehole tests indicated that the subsurface soil was dominated by silty clay to clayey-silt till underlain by silty-sand till. At the depth of the exfiltration trenches the dominant soil types were silty sand to sandy silt. The borehole details and soil characteristics are shown in Table 3.6.

These soils were observed to be very dense due to the geomorphological processes which caused consolidation. As a result the hydraulic conductivity of these soils were lower than normally expected of these soil types. Quantification of hydraulic conductivity was accomplished by carrying out falling head tests on all of the boreholes. The hydraulic conductivity for the silty sand to sandy silt till ranged from 6×10^{-6} cm/s to 1×10^{-7} cm/s (Table 3.6).

The boreholes extended at least 1.0 m below the proposed trench invert. The groundwater table level could not be determined since all boreholes were found to be dry as shown in Table 3.7.

3.2.2 Braecrest Avenue

A geotechnical investigation indicated that the soil types are brown silty clay and dark grey organic sand loam with organic matter. Additional soils records from the City of Etobicoke show that on Braecrest Avenue the dominant soils are clay loam. Local well records indicate that the upper soils in the area (up to 7 m deep) are brown clays. These studies support the dominance of relatively impervious soils in the area of the proposed system.

Records of water table locations were not available for this site.

3.2.3 Queen Mary's Drive

Soil and groundwater information was obtained from a nearby water well. It was identified as 69-1040 (June, 1961) and is located on Humber Boulevard close to Woodhaven Heights. The groundwater elevation at this site is approximately 1.2 m from the surface.

Further investigations were carried out by DBA Engineering Ltd. using three boreholes located along Queen Mary's Drive. Boreholes 1 and 2 were characterized by sand to sandy silt, whereas Borehole 3's top (above 0.9 m) was sand to sandy silt. Soil below the 0.9 m depth was characterized by clayey silt to a depth of 2.1 m (the end of borehole). This has been summarized in Table 3.8.

3.3 Pilot Demonstration Project

The design criteria established by the Steering Committee was:

- exfiltration or filtration of the runoff from 15 mm of rainfall, and
- complete exfiltration or filtration in two days.

Three pilot project sites were chosen, based on the soil characteristics and their suitability for implementation of the EES and EFS systems. These were:

- Queen Mary's Drive - Exfiltration System
- Princess Margaret Blvd./Princess Anne Cres. - Exfiltration System
- Braecrest Avenue - Filtration System

The reconstruction of the storm sewer on Queen Mary's Drive due to structural failure provided the opportunity to install an EES. Princess Margaret/Princess Anne were part of a road reconstruction program involving the construction of new storm sewers, and curbs and gutters. These systems have been constructed and are currently functioning. The principal purpose of the instrumentation and monitoring was to ascertain whether or not the EES and EFS meet the criteria listed above.

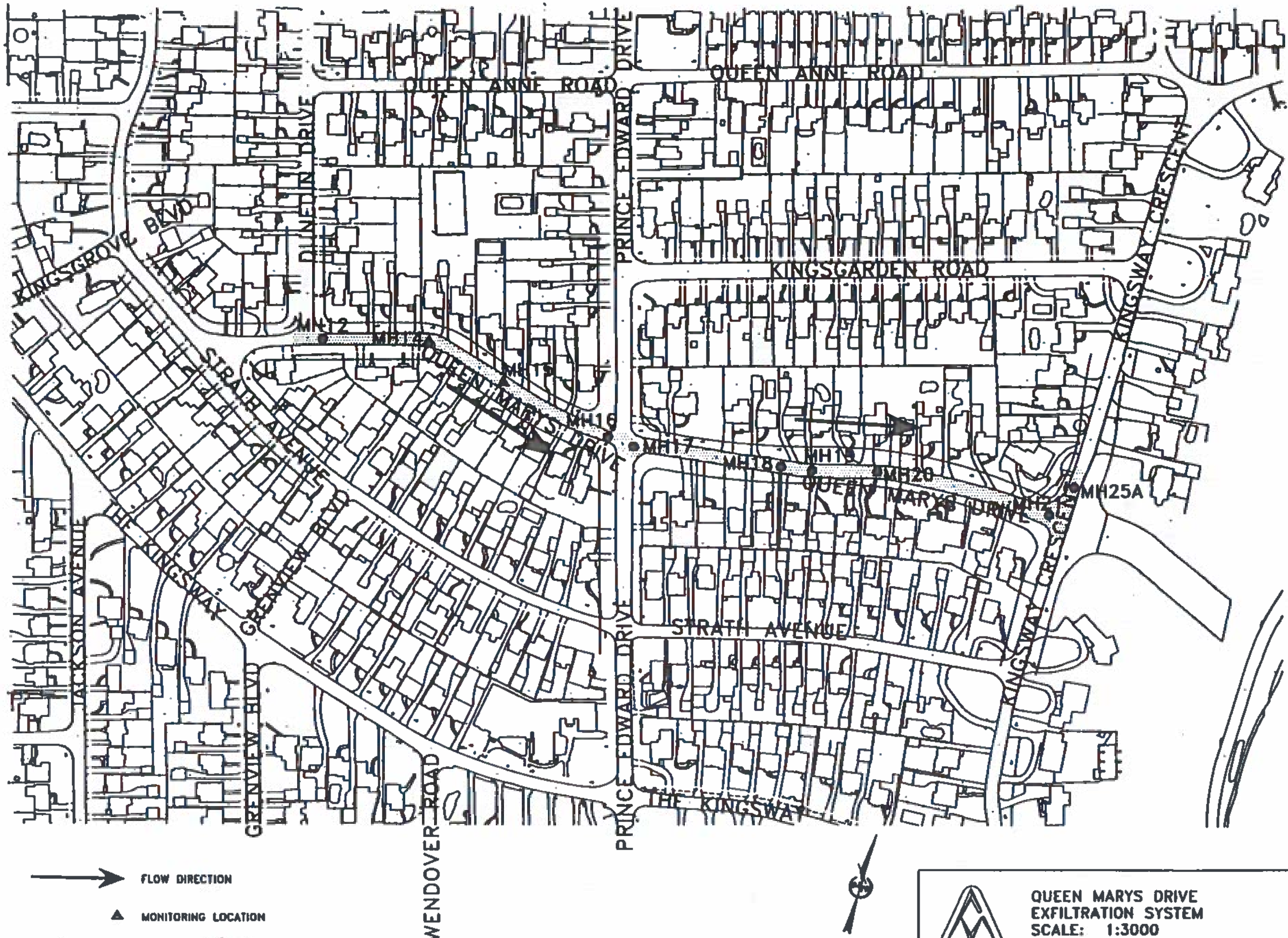
The description of the three demonstration sites are further described in the following sections and the locations indicated in Figure 3.1

3.3.1 Queen Mary's Drive - Exfiltration System

The Queen Mary's Drive study site has an area of 13.3 ha characterized by low-density residential housing (Figure 3.2). The entire area slopes gently toward the Humber River, providing adequate conveyance for storm drainage. Drainage is generally through swales created by grade differences between the pavement and boulevard. Queen Mary's Drive does not have curbs and gutters.

Soil profiles were logged during geotechnical investigations of the area along Queen Mary's Drive. The boreholes indicated soils varying from sand to sandy silt in some locations and clayey silt in other locations.

Soil and groundwater information was obtained from a nearby water well. Records from this well suggest that groundwater elevation at this site is approximately 1.2 m from the surface. This general level was confirmed by a geotechnical investigation which measured water levels at 1.6 m to 2.5 m below the ground surface. This site has high infiltration potential because of its



FLOW DIRECTION

▲ MONITORING LOCATION

SOURCE: CITY OF ETOBICOKE, 1997.

QUEEN MARYS DRIVE
EXFILTRATION SYSTEM
SCALE: 1:3000

FIGURE 3.2

pervious soils but its actual infiltration will be highly dependent on the location of the water table.

3.3.2 Princess Margaret Boulevard/Princess Anne Crescent - Exfiltration System

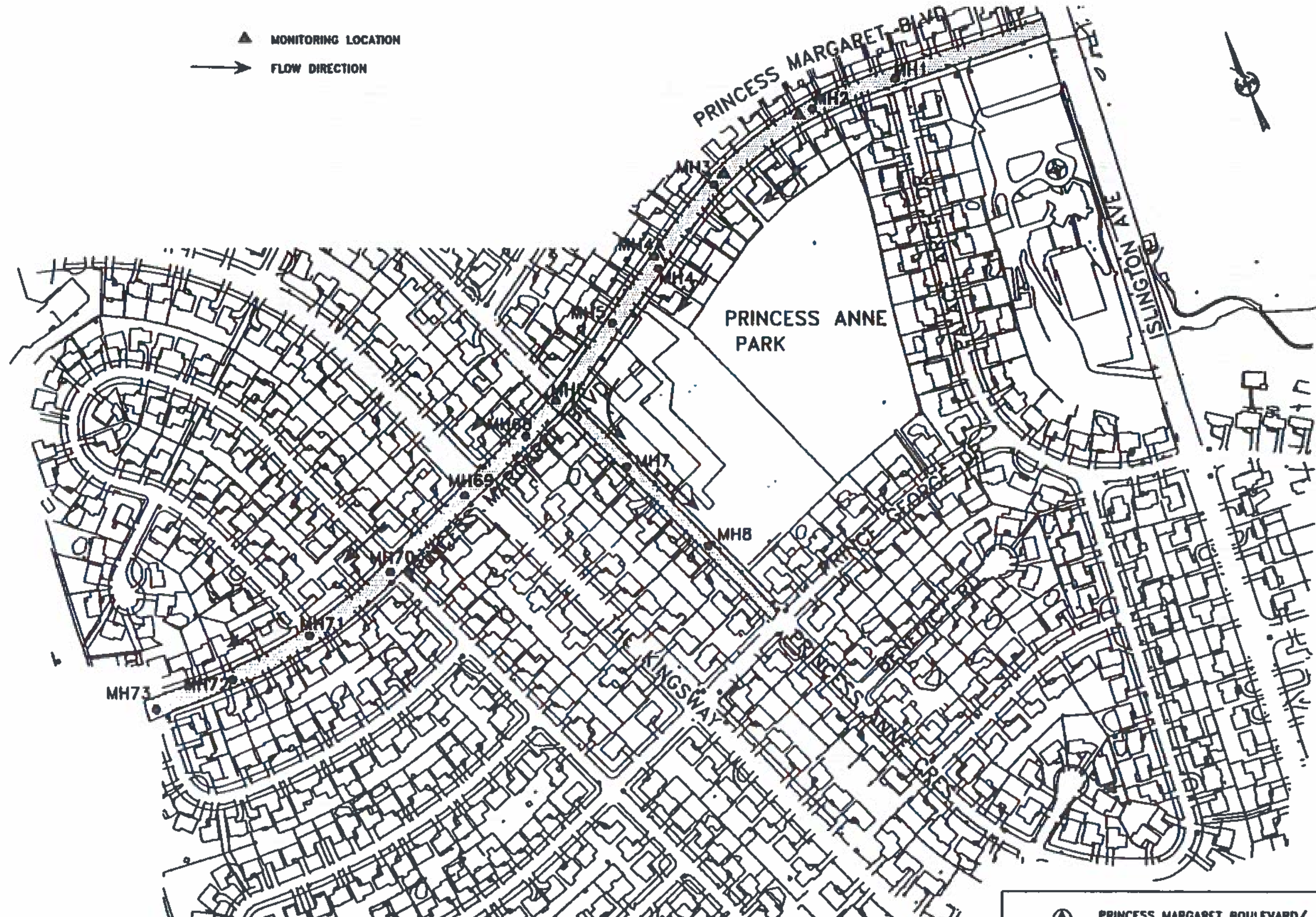
This site (Figure 3.3) is 30.5 ha characterized by low-density residential housing. The study area has two drainage paths which outlet to the Humber River and Mimico Creek drainage systems. Princess Margaret Boulevard had a ditch drainage system providing adequate overland routing for surface drainage. With the road reconstruction the overland flow drainage is now handled by a curb and gutter system.

Soil conditions in the area were identified as clay loam, Chinguacousey class, providing imperfect drainage. Geotechnical investigations found clay to clayey silt till, underlain by silty sand till.

Since the underlying soils were observed to be very dense, the hydraulic conductivity was lower than would normally be expected for these soil types. Results of falling-head tests on the soil samples indicated a hydraulic conductivity 6×10^{-6} cm/s to 1×10^{-7} cm/s. Depth of drilling ranged from approximately 4.5 m to 14.0 m below ground surface. All boreholes were dry on completion of drilling indicating no presence of groundwater at any depth.

3.3.3 Braecrest Avenue - Filtration System

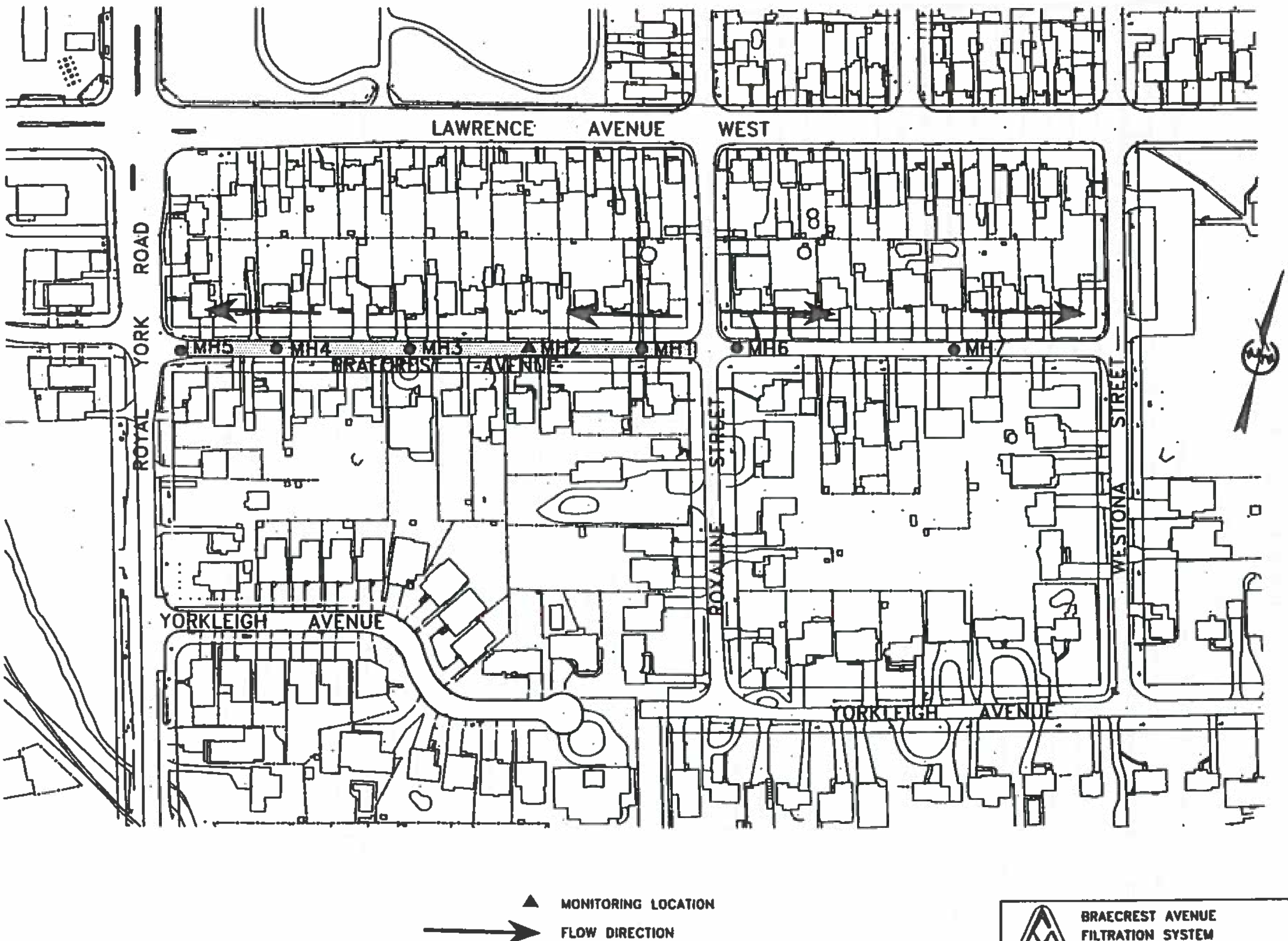
The Braecrest Road (Figure 3.4) study area has a tributary area of 2.38 ha of low-density residential housing and drains to the west towards Royal York Road. The high point of Braecrest Avenue in this area is approximately at the intersection of Braecrest Avenue and Roxaline Street. The roadway originally had a ditch type cross section and was reconstructed to curb and gutter during the installation of the Etobicoke Filtration System.



SOURCE: CITY OF ETOBICOKE, 1997.

PRINCESS MARGARET BOULEVARD/
PRINCESS ANNE CRESCENT
EXFILTRATION SYSTEM
SCALE: 1:5000

FIGURE 3.3



SOURCE: CITY OF ETOBICOKE, 1997.

BRAECREST AVENUE FILTRATION SYSTEM
SCALE: 1:2500

FIGURE 3.4

Table 3.1: Rainfall Data - May 1 to May 31, 1993

Period : May 1, 1993 to May 31, 1993

	Rainfall (mm)					
Date	Airport	Beaumon	FH#7	Martin	Ecole	
1						
2						
3						
4	2.0					
5	4.1	5.3	13.7	10.6		
6						
7						
8						
9						
10						
11						
12						
13						
14	3.8	1.6	1.8	1.8		
15	5.0	3.2	6.1	7.6		
16						
17						
18	0.2	0.2	0.2	0.1		
19	1.4	0.6	1.3	1.8		
20		4.5				
21	9.6	11.6	6.7	8.8	4.2	
22						
23	1.4	0.9	0.8	1.0	0.9	
24	4.6	4.5	4.1	2.6	3.2	
25	0.2	0.1	0.1		0.3	
26	T	0.9	0.4	0.6	0.7	
27	3.4	1.2	1.3		0.4	
28	0.3	2.6	3.1	3.1	2.7	
29						
30	T					
31	15.6	13.3	14.5	12.3	12.6	
TOTAL						

Airport -Lester B.Person Weather Station
Beaumon -Beaumonte Heights Junior Middle School
FH#7 -Fire Hall No.7
Martin -Martingrove Collegiate
Ecole -Ecole Catholique Sainte Marguerite D'Youville - Readings commenced May 20, 1993

T -Trace Amount

Table 3.2: Rainfall Data - June 1 to June 30, 1993

Period : June 1, 1993 to June 31, 1993

	Rainfall (mm)					
Date	Airport	Beaumon	FH#7	Martin	Ecole	
1	0.2			0.2		
2						
3						
4						
5	10.8	9.2	13.0	11.6		
6						
7	1.4	1.3	1.6	1.2		
8	17.2	19.7	15.4	10.3	5.1	
9	28.2	20.1	29.8	31.9	20.8	
10					0.1	
11						
12						
13						
14	0.4		0.2			
15		1.5	0.3	0.7	0.3	
16						
17						
18	1.8	0.1	1.1	1.0	1.9	
19	8.0	3.6	4.4	4.0	3.9	
20	11.9	17.9	15.9	16.0	17.4	
21	39.3	37.1	45.3	51.7	28.0	
22						
23						
24						
25	9.8	10.2	11.1	12.3	9.1	
26	4.0	6.6	6.5	6.0	5.3	
27	0.8	0.7	4.2	0.1		
28			0.1			
29						
30						
31						
TOTAL	133.8	128.0	148.9	147.0	91.9	

Airport -Lester B.Person Weather Station
Beaumon -Beaumonte Heights Junior Middle School
FH#7 -Fire Hall No.7
Martin -Martingrove Collegiate
Ecole -Ecole Catholique Sainte Marguerite D'Youville

Table 3.3: Rainfall Data - July 1 to July 31, 1993

Period : July 1, 1993 to July 31, 1993

Rainfall (mm)						
Date	Airport	Beaumon	FH#7	Martin	Ecole	
1						
2						
3			0.1			
4						
5						
6			0.7	0.5	9.6	
7						
8						
9						
10						
11			3.4			
12			0.4			
13						
14		1.0	0.6	0.7	0.2	
15				0.1		
16						
17						
18						
19		21.4	30.2	38.9	44.1	
20						
21						
22						
23						
24						
25						
26		11.8	24.1	32.2	32.8	
27						
28						
29		0.7	3.6	4.5	8.0	
30		3.9	3.6	3.9	4.1	
31						
TOTAL		38.8	66.7	80.8	98.8	

Airport -Lester B.Person Weather Station
Beaumon -Beaumonte Heights Junior Middle School
FH#7 -Fire Hall No.7
Martin -Martingrove Collegiate
Ecole -Ecole Catholique Sainte Marguerite D'Youville

Table 3.4: Rainfall Data - August 1 to August 31, 1993

Period : August 1, 1993 to August 31, 1993

	Rainfall (mm)					
Date	Airport	Beaumon	FH#7	Martin	Ecole	
1	1.6	1.1	1.4	1.2	1.9	
2			0.4		0.1	
3	1.6	1.2	1.5	1.1	0.4	
4						
5						
6	0.6		0.2	0.1		
7	9.0	23.5	21.3	19.8	7.9	
8				0.1		
9						
10	0.2		0.1		0.1	
11						
12						
13						
14						
15	2.5	1.0	0.8	1.0	1.6	
16	17.4	35.4	25.3	20.6	21.8	
17						
18						
19						
20		5.1				
21						
22						
23	0.4	0.1				
24						
25						
26						
27	3.2					
28	2.2					
29						
30						
31	1.2					
TOTAL	39.9	67.4	51.0	43.9	33.8	

Airport -Lester B.Person Weather Station
Beaumon -Beaumonte Heights Junior Middle School
FH#7 -Fire Hall No.7
Martin -Martingrove Collegiate
Ecole -Ecole Catholique Sainte Marguerite D'Youville

Table 3.5: Summary of Water Quality

Parameters	Units	City of Etobicoke		Provincial Water Quality Objectives	Recorded Data						
		SAN			June 21/93 M25-0084	June 25/93 M26-0014	June 25/93 M26-0015	July 6/93 M27-0212	July 6/93 M27-0135	July 18/93 M29-0027	July 26/93 M30-0067
Metals											
Copper	mg/l	3	10 µg/l	.005 mg/l	0.0380	0.0550	0.0170	0.0940	0.0029	0.0400	0.0080
Nickel	mg/l	3	50 µg/l	.025 mg/l	0.003<T	0.004<T	0.002<W	0.010<T	<0.002<W	0.005<T	<0.002<W
Lead	mg/l	5	50 µg/l	.025 mg/l	0.039	0.017<T	0.005<T	0.060	<0.005<W	0.032	0.008<T
Zinc	mg/l	3	50 µg/l	.030 mg/l	0.1200	0.0850	0.0360	0.4200	0.0083	0.110	0.0210
Iron	mg/l	50		.300 mg/l	1.600	1.000	0.300	9.800	0.630	2.500	0.270
Cadmium	mg/l	1	1 µg/l	.200 mg/l	0.0007<T	0.0008	0.0005	0.0012	<0.0002<W	0.0007<T	<0.0002<W
Chromium	mg/l	5	200 µg/l	.100 mg/l	0.0059	0.0034	0.0033	0.0110	<0.0005<W	0.0044	0.0022<T
Bacteria											
Fecal Coliform	counts/100 ml		200		>150000	180000.U48	910000.U48	3.00x10[illegible]	4900	670000.AJC UAU	50000<-->
Escherichia Coliform	counts/100 ml			100 mg/l	>150000	180000.U48	910000.U48	3.00x10[illegible]	3200	540000.AJC UAU	50000<-->
Conventional											
Conductivity 25C	UMHO/cm				337	371	148	608	1550	212	65
Chloride	mg/l	1500		.002 mg/l	36.20	52.00	11.70	108.20	261.50	18.40	3.70
Total Residue	mg/l				381.0	320.0	113.8	692.0	985.2	314.0	64.4
Particulate Residue	mg/l				162	74.9	14.8	297	12.2	171.0	21.9
Total P	mg/l	10		.010 mg/l	1.180	0.820	0.390	2.05	0.056	1.180	0.205
Phosphates	mg/l				0.3620	0.4300	0.2600	0.56	0.0075	0.0880	0.1300
Total Kjeld Nitrate	mg/l	100			5.900	5.700	2.250	13	0.580	4.700	0.800
Total Ammonium	mg/l			-	1.340	1.950	0.676	2.14	0.232	0.252	0.148
Total Nitrates	mg/l				0.065	0.45	0.520	0.065	4.170	0.450	0.375
Nitrite	mg/l				0.0130	0.012	0.190	0.0470	0.0610	1.6400	0.0270
Phenolics	µg/l *	1		.001 mg/l		3.8	3.2	---	<0.2<W	6.8	0.4<T
BOD	mg/l	300	15		49.9	13.4	5.4	33.5	<0.2<W	15.6	0.9<T
COD	mg/l				115.0	91.0	38.3	279.0	9.5	174.0	16.0

Definitions:

Definitions:	<-->	Approximate Result
	<T	A measurable Trace Amount: Interpret with Caution
	<W	No Measurable Response (Zero)
	UAU	Unreliable: Sample Age Unknown
	AJC	Approximage Result: Total Count Exceeds 300 Colonies
	U48	Unreliable: Sample Age Exceeds 48 hours

Table 3.6: Princess Margaret Blvd./Princess Anne Crescent Hydraulic Conductivity Test Results

Borehole	Elevation Screen Interval (m)	Soil Type	Hydraulic Conductivity, K Measured (cm/s)	Trench Invert (m)	Soil Type	Hydraulic * Conductivity, K Documented Range **
BH1	145.5 to 147.0	Silty Sand	7 x 10^{-7}	149.2	Silty Sand	1x10^{-3} to 1x10^{-5}
BH2	150.0 to 151.5	Silty Sand	2 x 10^{-7}	151.0	Silty Sand	1x10^{-3} to 1x10^{-5}
BH3	151.1 to 152.6	Silty Sand to Clayey Silt/Silty Clay	1 x 10^{-7}	152.4	Clayey Silt to Silty Clay	1x10^{-6} & less
BH4	151.6 to 153.1	Silty Sand to Clayey Silt	4 x 10^{-7}	152.9	Calyey Silt to Silty Clay	1x10^{-6} & less
BH5	151.1 to 152.6	Sandy Silt	1 x 10^{-7}	n/a	----	----
BH6	152.3 to 153.8	Sandy Silt to Silty Sand	7 x 10^{-7}	154.3	Sandy Silt to Silty Sand	1x10^{-3} to 1x10^{-5}
BH7	151.1 to 153.8	Sand	6 x 10^{-6}	n/a	----	----

* Does not account for compaction

** Source: Freeze, R.A., A. Cherry, Groundwater, 1979

Table 3.7: Princess Margaret Blvd./Princess Anne Cres. - Groundwater Results

Borehole	Surface Elevation (m)	Piezometer			Trench Invert (m)
		Depth (m)	Invert Elevation (m)	Condition	
BH1	154.52	7.1	147.42	dry	149.2
BH2	154.52	4.5	150.02	dry	151.0
BH3	155.59	4.5	151.09	dry	152.4
BH4	156.13	4.5	151.63	dry	152.9
BH5	155.37	4.4	150.97	dry	----
BH6	156.80	4.5	152.30	dry	154.3
BH7	158.74	14.0	144.74	dry	----

Table 3.8: Queen Mary's Dr. Borehole Results

Borehole	Depth (m)	Soil Type
BH1	0.3 - 6.2	Silty Sand
BH1	0.3 - 2.7	Silty Sand
BH3	0.9 - 2.1	Clayey Silt

4.0 SITE CONSTRAINT ASSESSMENT OF SUITABILITY FOR EXFILTRATION TECHNOLOGY

A two-step evaluation procedure has been developed for the Etobicoke Exfiltration System (Dubyk, 1994; Li, 1996). The first step comprises the most critical screening questions which determine the physical suitability of the Etobicoke Exfiltration System for a site of interest. All of these questions must be answered affirmatively without exception in order to continue to the second step. The second evaluation step comprises secondary questions, which further examine the suitability of the Etobicoke Exfiltration System. All of the questions in the second step should also be answered affirmatively, either with or without implementation of engineering measures designed to remediate the associated environmental impacts. If there are additional environmental impacts associated with the engineering remediation measures, then the Etobicoke Exfiltration System is not suitable for the site of interest.

4.1 Priority One Screening Questions

4.1.1 Is water supply aquifer absent at the site of interest?

The Etobicoke exfiltration system is not a suitable retrofit stormwater management measure if a water supply aquifer is below or very close to the site of interest. The potential groundwater contamination from stormwater exfiltration must be taken into consideration in the site constraint assessment. The regional office of the Ministry of Environment & Energy should be consulted regarding any concern over Reasonable Use Policy.

4.1.2 Is the site of interest a low density residential area?

The stormwater exfiltration system is suitable for low density residential areas where the chance of dry spills from industrial operations such as fuel and hazardous waste transport is minimal.

4.1.3 Is the site of interest served by local roads and lateral sewers?

The Etobicoke exfiltration system is primarily designed for local roads and small drainage systems. Major roads (e.g., arterial roads) or large trunk sewer systems are not suitable for the exfiltration system due to their greater potential for high levels of pollutant.

4.1.4 Is the groundwater table below the invert of the exfiltration pipes?

In order for the exfiltration system to perform as designed, the groundwater table must be below the invert of the exfiltration pipe. Otherwise, the exfiltration rate may be low or groundwater may flow into the system.

4.2 Priority Two Evaluation Questions

4.2.1 Is sandy soil present?

Sandy soil allows the exfiltration system to empty itself within a reasonable time before the next runoff event. For clayey soil, the Etobicoke filtration system should be used.

4.2.2 Are the roads and/or sewers in poor condition?

Roads and sewers which are in poor condition are more likely to be rehabilitated or replaced. As a result, the exfiltration system can be integrated with road/sewer rehabilitation and replacement projects, becoming cost effective.

4.2.3 Is the tree root problem absent at the site of interest?

Tree roots can be a problem for the exfiltration system if they penetrate the porous pipes through the filter fabric and clog the opening. A root encroachment problem may be solved by the relocation of trees from the exfiltration system.

4.2.4 Is the required maintenance equipment available at the municipality?

Exfiltration systems require a periodic flushing in order to clear the accumulated sediments. An adequate pump and a drumshear rotary screen can then be used to remove the accumulated sediments from the system. Municipalities may contract out the maintenance works of exfiltration systems to private contractors if they do not have the equipment.

An evaluation of the Etobicoke Exfiltration System is shown in Table 4.1.

Table 4.1: Evaluation Table for Exfiltration System

Priority One Screening Questions	Yes/No	Information sources
1.1) Is water supply aquifer absent at the site of interest?		Well and borehole records; in-site measurements; MOEE Regional offices
1.2) Is the site of interest a low density residential area?		Municipal land use maps (e.g., Official and Secondary Plans); roads with truck traffic designation
1.3) Is the site of interest served by local roads and lateral sewers?		Road and sewer maps
1.4) Is the ground water table below the invert of the exfiltration pipes?		Borehole and well records; in-site measurements; MOEE Regional offices
Priority Two Evaluation Questions	Yes/No	
2.1) Is sandy soil present?		Borehole records; soil maps; in-site measurements
2.2) Are the roads and/or sewers in poor condition?		Municipal road appraisal sheets; capital works and operating schedules
2.3) Is the tree root problem absent at the site of interest?		Field observation; municipal parks and recreation departments.
2.4) Is the required maintenance equipment available at the municipality?		Municipal works departments.
RECOMMENDATION:		

5.0 DESIGN METHODOLOGY

5.1 Design Objectives

The design objectives of EES and EFS are listed below:

- to reduce contaminant loading to receiving water bodies (both systems)
- to reduce erosion at receiving water bodies (both systems)
- to recharge groundwater (EES only)

In order to achieve the above objectives, the system should be able to

- capture storm runoff and associated sediment generated by frequent rain storms
- reduce peak flow at storm outfalls
- seep captured storm runoff into surrounding soil

5.2 Design Criteria

5.2.1 Exfiltration System

The exfiltration system consists of a concrete main pipe to convey storm runoff to the downstream manhole and a trench system to capture and exfiltrate stormwater to the surrounding soil. Two perforated PVC pipes embedded in clear stones formed the trench system. Design of the exfiltration system included design of the main pipe and the trench system.

Design criteria are discussed in subsequent sections.

1. The main storm sewer pipe was designed to the City of Etobicoke conventional storm sewer design standards. Accordingly, the pipe was sized to convey the flow generated by a 2-year design storm.

2. The trench system was designed to store and exfiltrate runoff volume generated by a 15 mm design storm.

   In 1992, Etobicoke staff analyzed Lambton rain gauge records and observed that 88% of the recorded rainfall were less than or equal to 15 mm (Figure 5.1). This design criterion ensures that EES can intercept storm runoff generated by most storms and achieve the criteria recommended by the Interim Stormwater Quality Control Guidelines for New Development (MOE, MNR 1991).

3. The system was designed to exfiltrate the captured storm runoff in two days. This constraint was established based on an average inter-event storm period of three days.

5.2.2 Filtration System

The filtration system consists of a concrete main pipe to convey storm runoff to the downstream manhole, a perforated PVC pipe to capture sediments in storm runoff, and a trench system to convey filtered storm runoff to the downstream manhole. Two perforated PVC pipes embedded in clear stones formed the trench system. Design of the filtration system included design of the main storm sewer pipe and the trench system.

Lambton Rain Gauge Record

1987 - 1990

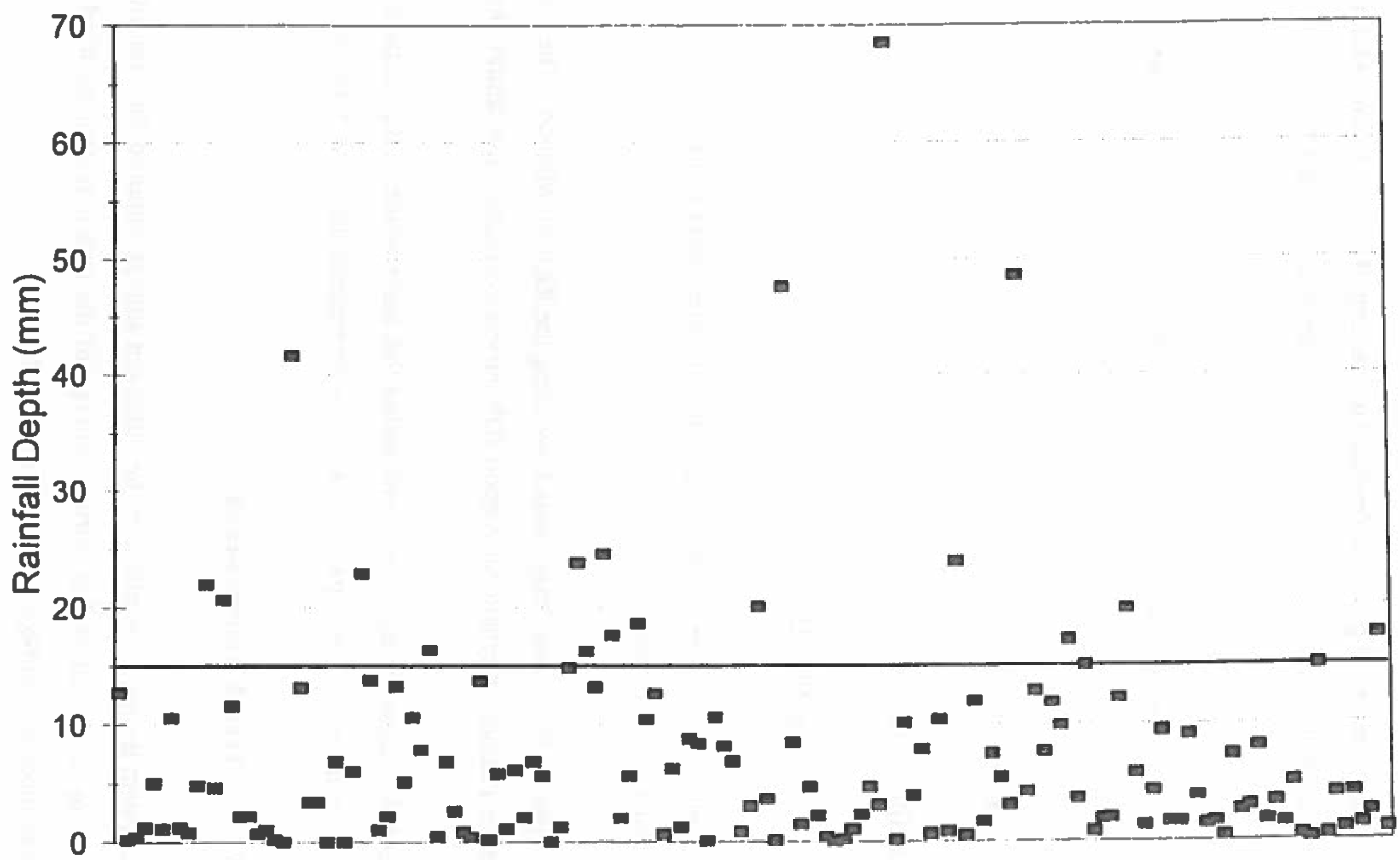


Figure 5.1

Design criteria of EFS are similar to EES. They are summarized as follows:

1. The main storm sewer pipe was designed to the City of Etobicoke conventional storm sewer design standards. Accordingly, the pipe was sized to convey the flow generated by a 2-year design storm

2. The trench system was designed to store and exfiltrate runoff volume generated by a 15 mm design storm.

5.3 Design Algorithm

5.3.1 Exfiltration System

5.3.1.1 Main Pipe Design

The main pipe was designed using a conventional storm sewer design method. The procedures are summarized as follows:

1. Calculate of the 2-year design peak flow using the Rational-Method. The City of Etobicoke uses the Pearson International Airport IDF curves to calculate the rainfall intensity.

2. Select pipe diameter and slope combination that can provide enough capacity to convey the design peak flow. The capacity of a pipe is determined using the Manning's Equation.

5.3.1.2 Trench System Design

Trench system design is to calculate the minimum storage required for capturing storm runoff generated by a 15 mm design storm. Storage of the trench system included storage in two perforated pipes and storage in voids of clear stones.

The method of the trench system design is similar to the storage indication method used for reservoir routing. Storage was calculated by solving two equations. The first one was the water balance equation:

$$I - Q = dS/dt$$

where

I = inflow per unit time
Q = outflow per unit time
dS/dt = change in storage within the system per unit time

The second equation is Darcy's law:

$$Q = -KAi$$

where

A = exfiltration area
K = hydraulic conductivity of the soil
Q = flow rate across the area A

In this equation,

$$i = h/l$$

where

h = piezometric head

l = flow distance

A spreadsheet macro was developed to facilitate the design which incorporated the following procedures (shown on Figure 5.2):

1. A hydrologic model using OTTHYMO 89 was prepared for the catchment.

2. A hydrograph was generated from the model by using a 15 mm AES 1-hour design storm. This was used as the inflow hydrograph of the trench system. Since the trench system design is a volume based design, the effect of the design storm distribution is not significant. Therefore, using the AES 1-hour distribution was considered to be adequate.

3. The inflow hydrograph generated in step 2 was input into the spreadsheet.

4. The outflow rate was evaluated by Darcy's law.

5. The required storage was evaluated using the water balance equation.

6. Repeat steps 4 and 5 for the next time step until both inflow and storage become zero.

7. A check of the system water balance for the entire event was computed at the end of the simulation. The time required to drain the system storage was also calculated.

8. The design storage volume was sized to provide at least the maximum storage required at any one time step in step 5.

This design storage indicates the minimum requirement for the trench system. The actual available storage may be larger due to the arrangement of pipes in the trench.

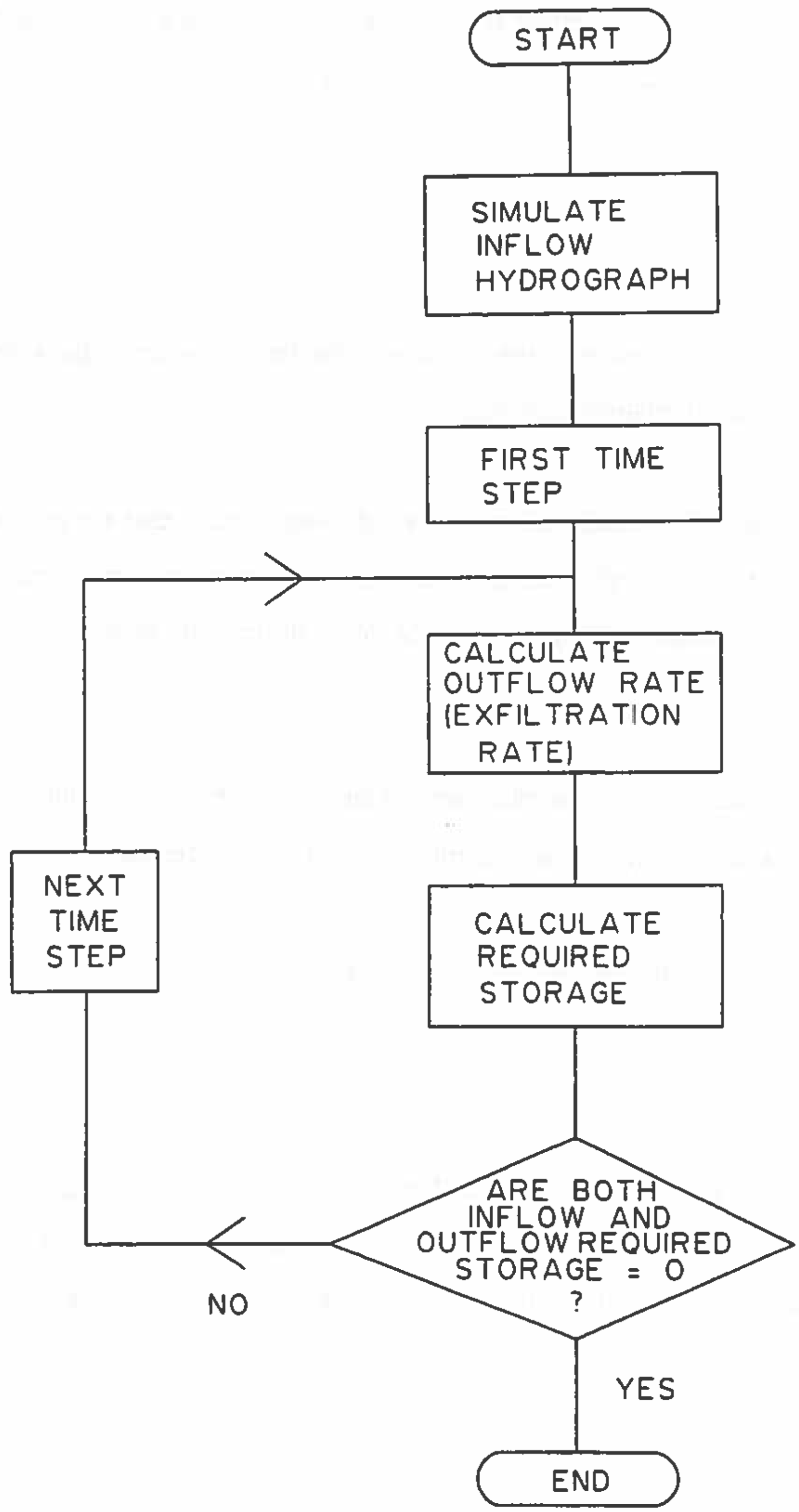


FIGURE 5.2 DESIGN FLOWCHART

In order to facilitate the calculation, an in-house spreadsheet macro was created to solve these two equations. A sample of the spreadsheet is shown in Appendix B. The spreadsheet has five sections, identified as:

1. Title section.

2. "Given Data" section. This section specifies the size of the trench system, characteristics of the soil, safety factor, and simulation time step.

3. "Calculated Data" section. This section shows some calculated results that are required in the simulation section. The area of exfiltration includes the bottom of the trench and both side walls beginning at the bottom and extending up to the invert of the main pipe. Other items are self-explanatory.

4. "Check Water Balance" section. This section uses the simulation results from the next section to check the water balance and shows the minimum system storage required.

5. The simulation section calculates the outflow and storage for every time steps.

5.3.2 Filtration System

The design procedure of the EFS is similar to the design of the EES. The design includes the main pipe design and the trench system design. The main pipe design is exactly the same as the EES. The trench system is designed by solving the water balance equation and the following orifice equation:

$$Q = 0.6A\sqrt{2gh}$$

where

A = cross-sectional area of outlet pipe

g = gravitational acceleration

h = the piezometric head

Q = the outflow rate of the bottom drainage pipe

5.4 Pipe Arrangement

The arrangement of pipes in both systems is discussed as follows:

1. Trench geometry was designed based on the experience of the designer, common practices, ease of construction, etc.

2. Perforated pipe size was determined based on ease of maintenance and providing adequate space for sediment accumulation.

3. Perforation size and spacing were determined by common practices.

4. Perforation orientation was determined based on ease of maintenance.

6.0 CONSTRUCTION PROCEDURE

6.1 Pre-Construction

The construction procedure followed for the installation of the EES and EFS are outlined in this section along with photographs of the procedure and materials.

- Sediment traps, such as rock check dams or straw bales were installed at the outlet points.

- Sediment/silt fences (that can also act as a construction barrier) were installed wherever overland flow occurred.

- The Contractor was required to maintain all of the above, to ensure that they continually worked as intended.

6.2 Construction

- Excavation of the proposed sewers is undertaken using standard construction techniques. For the trench with the perforated pipes, stone and storm sewer, vertical walls may be used provided the native soil and the depth of the excavation met the safety code requirements. Alternatively a trench box should be used, as was the case in the Braecrest Avenue construction, where the native soils did not have choesive strength for vertical excavation.

- Excavated material was placed on the side of the trench. If the material was considered suitable for backfill, it was placed back into the trench after the installation of required aggregates. Material not suitable as backfill, was loaded directly into a truck and removed off site. For the three sites, existing material was used for backfill. Similarly excess material from the excavation was also loaded onto a dump truck, and removed off site.

At the completion of the excavation the elevation of the bottom of the trench was checked to ensure that there was adequate room for the proposed granular fill material.

- Place filter cloth on the bottom and sides of the trench. The filter cloth was secured on the sides of the trench by various methods, including stakes or long nails.

- The proper thickness of granulars was placed on the filter cloth and the depth of the granulars was checked.

- The perforated pipes are placed on the granular fill and the elevation of the invert of the pipe was checked, and adjusted as necessary.

- Mechanical plugs were placed on the upstream of the perforated pipes to prevent sediment from entering the stone trench via the perforated pipes.

- The next layer of granular fill was placed over and around the perforated pipes, followed by placement of the storm sewer.

- The last amount of granular fill was placed around the storm sewer.

- During the placement of the granular material, special care was taken to ensure that the material and compaction around the manholes would not allow any seepage to undermine the manhole.

- The filter cloth was wrapped over the granular fill with an overlap of 1.0 m over the top of the trench.

- Acceptable backfill material was placed over the filter cloth in layers appropriate for suitable compaction and protection of the integrity of the pipe below. During backfilling and compaction, a soil engineering inspector was required to take compaction tests of the backfill to insure that the integrity of the road was maintained.

- The catchbasins were equipped with a goss trap including a clean out which was equipped with a plug. The plug prevented debris, such as rocks, leaves and small sticks, from entering the system.

- During construction the catchbasins were covered with a heavy metal plate and filter cloth to prevent sediment ladened surface water from entering the EES or EFS. When construction activity was completed and the site was stabilized, the plates were removed and the catchbasins were adjusted to final elevation before placement of the asphalt and curb works.

- The design of both the EES and EFS did not require the manholes to be benched.

- After the construction period, the mechanical plugs which were installed on the upstream end of the perforated pipes, were removed and relocated to the downstream end.

The following photos (Photo 6.1 to 6.8) show various aspects of the installation of the Etobicoke Exfiltration System.

Photo 6.1: **Site identification**

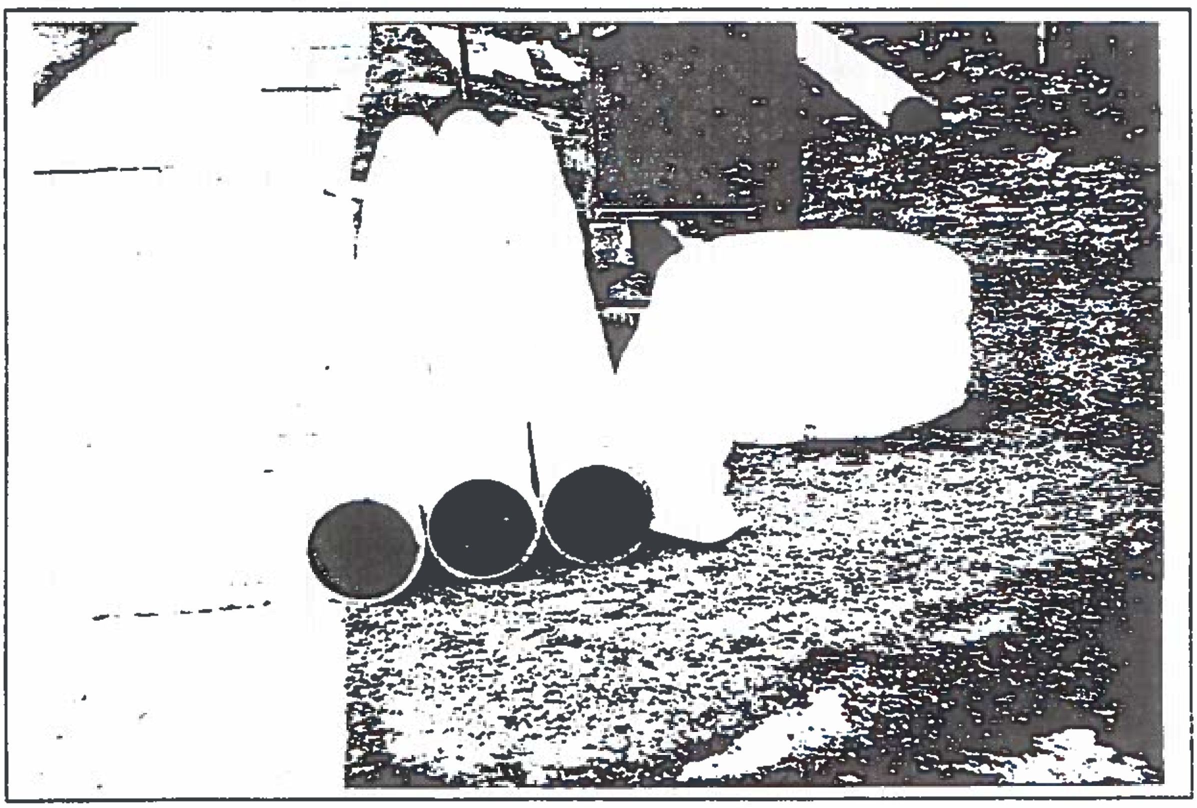


Photo 6.2: **Perforated pipe wrapped in filter cloth prior to placing in exfiltration trench**

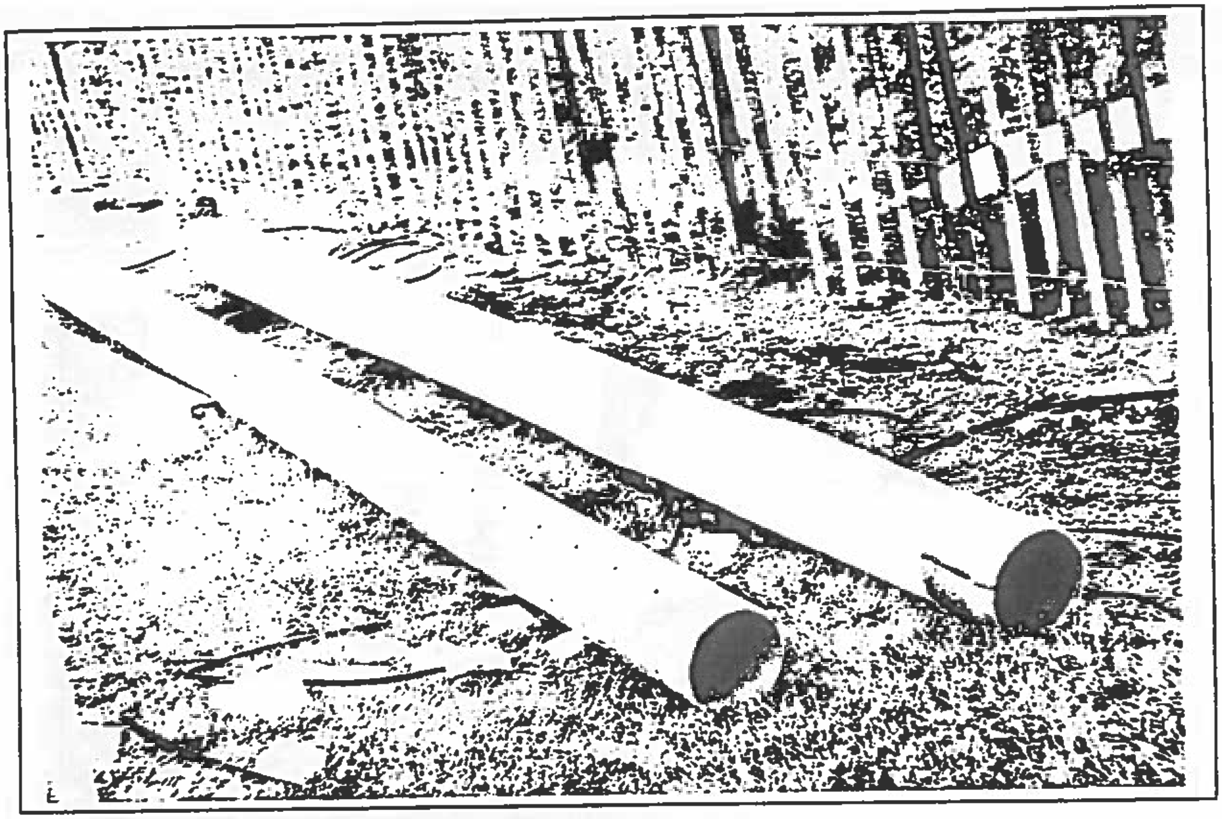


Photo 6.3: Perforated pipe prior to being wrapped in filter cloth

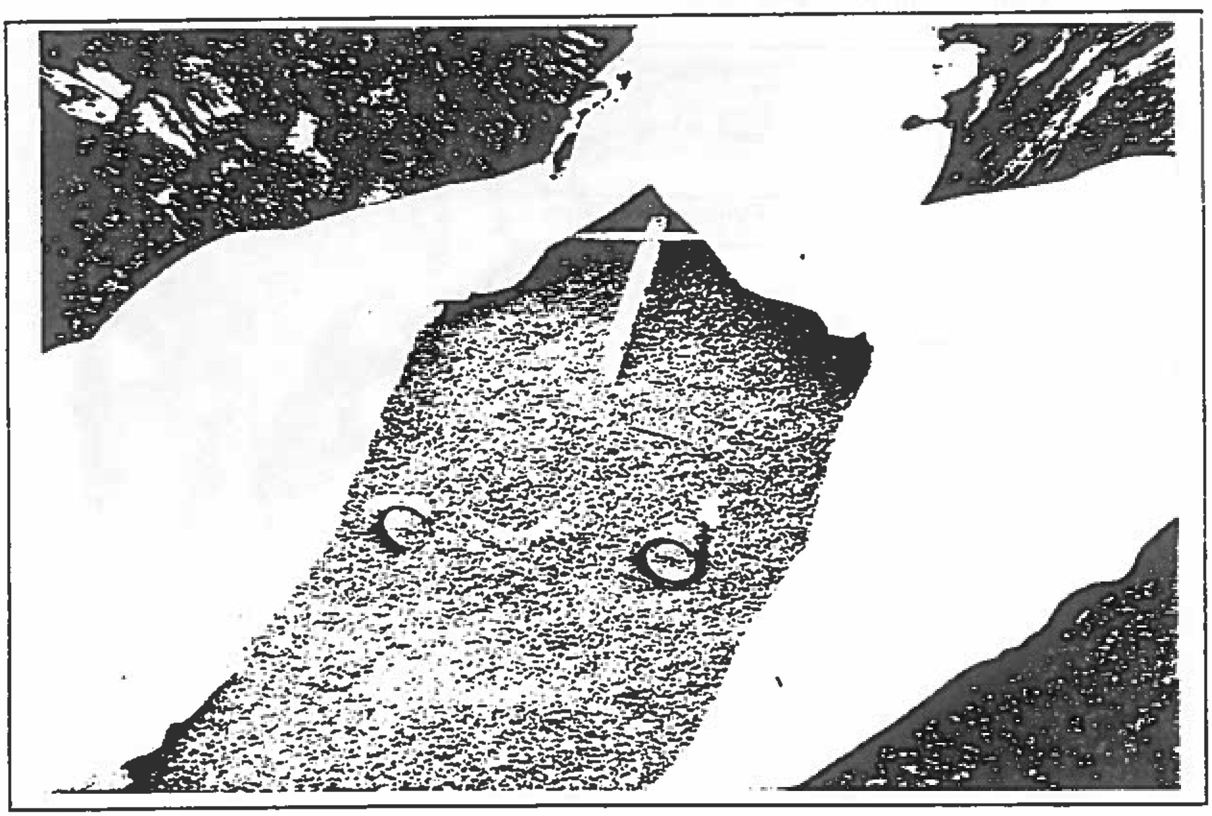


Photo 6.4: Perforated pipe wrapped in filter cloth placed in crushed stone exfiltration trench surrounded by filter cloth

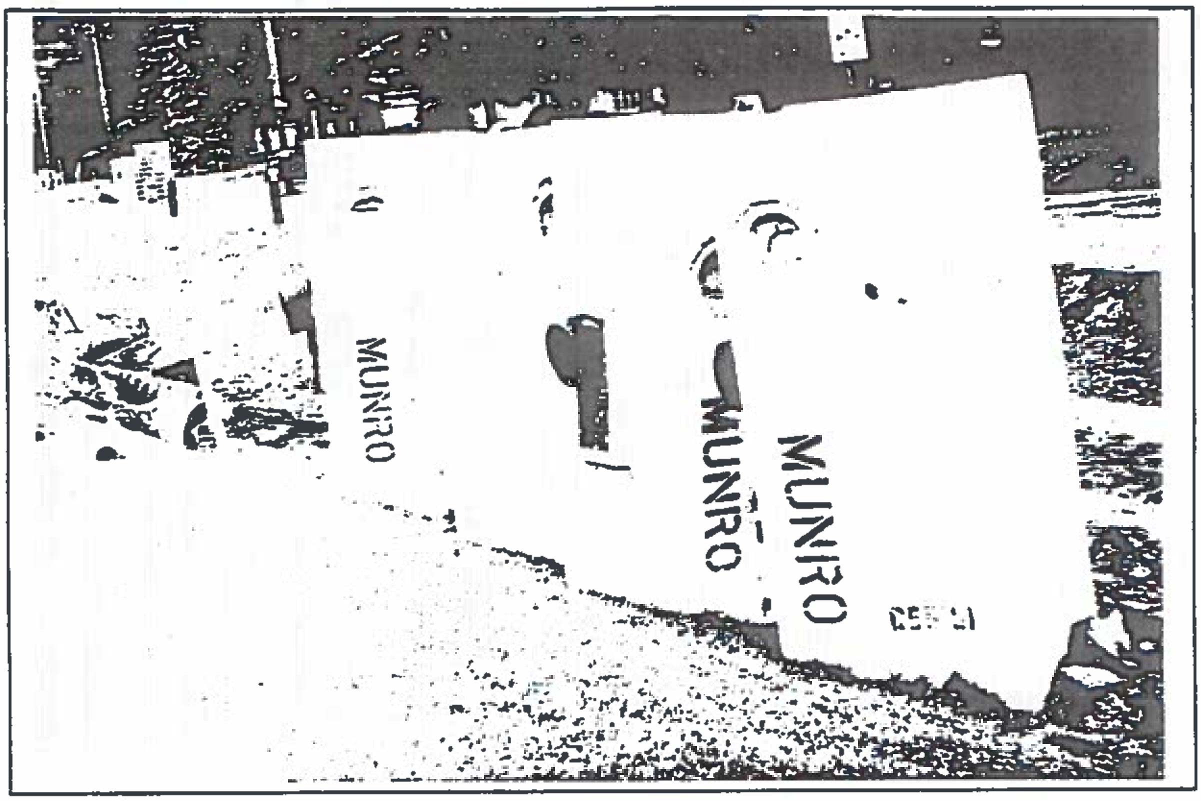


Photo 6.5: **Catchbasin with goss trap**

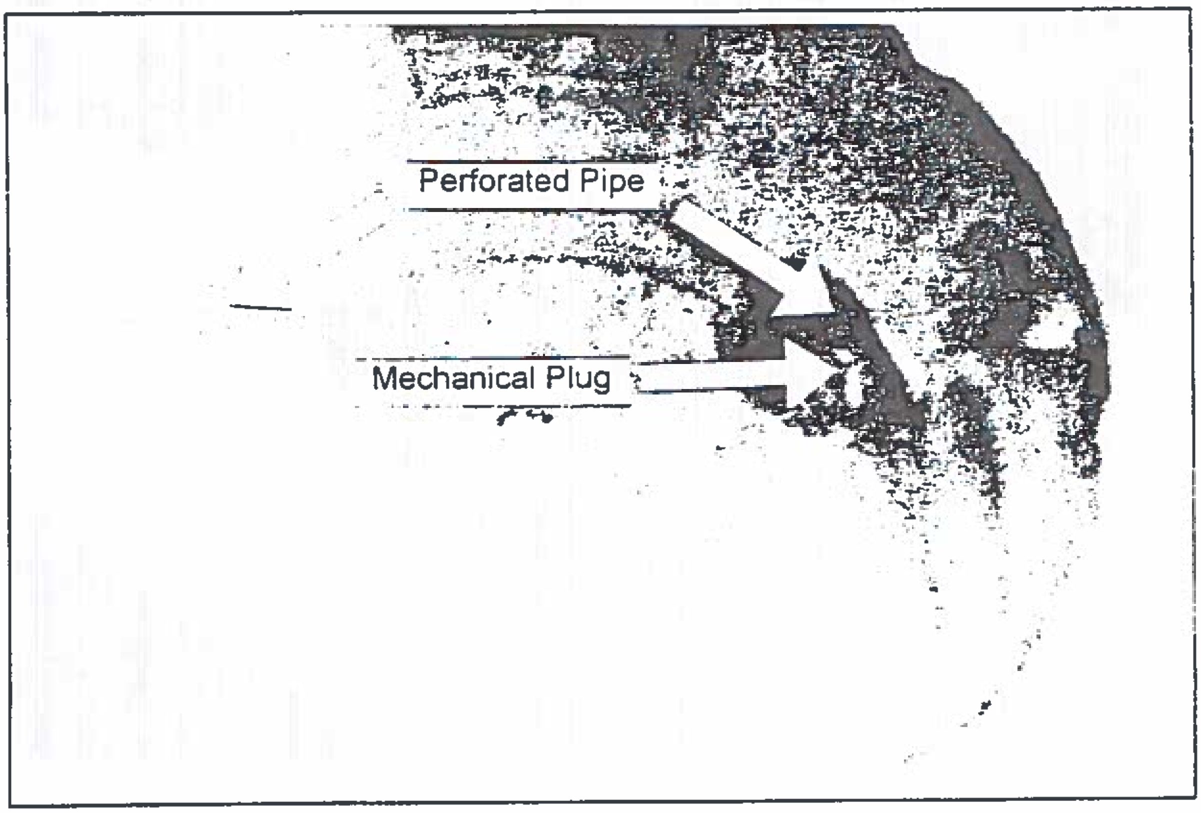


Photo 6.6: **View of completed manhole showing 2 year storm sewer and perforated pipe with mechanical plug**

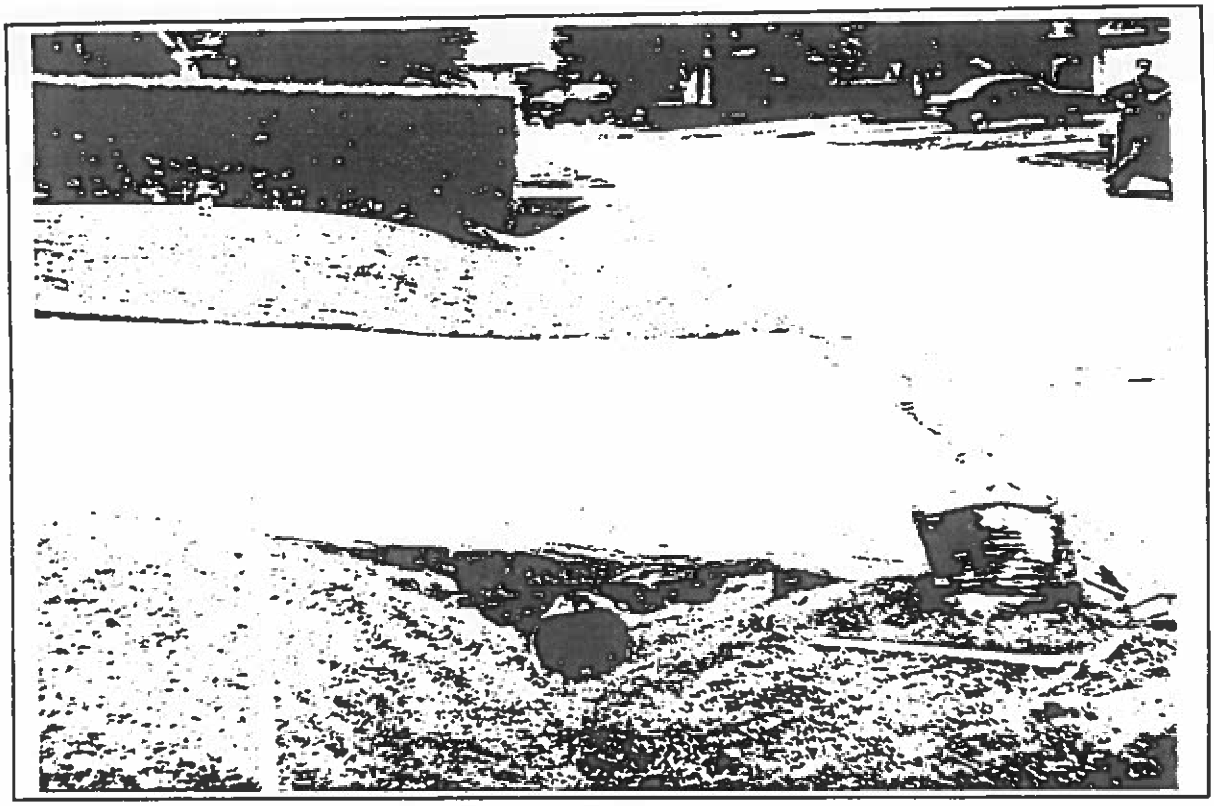


Photo 6.7: Road crossection prior to installation of exfiltration system. NOTE: existing grass swales which allow for stormwater infiltration and pollutant removal.

Photo 6.8: Road crossing after installation of exfiltration system and prior to reconstruction of roadway with curbs and gutters

7.0 MONITORING/RESULTS AND DISCUSSIONS

The performance evaluation of the EES and EFS included field observations as well as flow monitoring. Throughout the study, visual inspections of the system were carried out by both the City and the study team. The following observations were made during field visits.

- The EES and EFS continued to function during winter and spring thaw. No monitoring equipment were installed during these months due to possible equipment damage. These observations were based on the absence of water marks on the upstream conventional storm sewer (ie. no overflow).

- Soil bioengineering works carried out at the south end of Queen Mary's Drive indicated no additional bank seepage.

- No loss of mature trees were observed along Queen Mary's Drive and Breacrest Avenue.

- No sign of structural deficiency were found at inlet and outlet connections.

- No pavement settlement on streets occurred in or along either EES and EFS.

- Video inspection of the EES and EFS perforated pipes in November 1994 and December 1995 indicated generally clean pipes other than some minor sediment accumulations in the last 20 m of the system. (Refer to Section 9.6 and Photos 9.2 and 9.4).

7.1 Monitoring Location and Equipment

7.1.1 Queen Mary's Drive

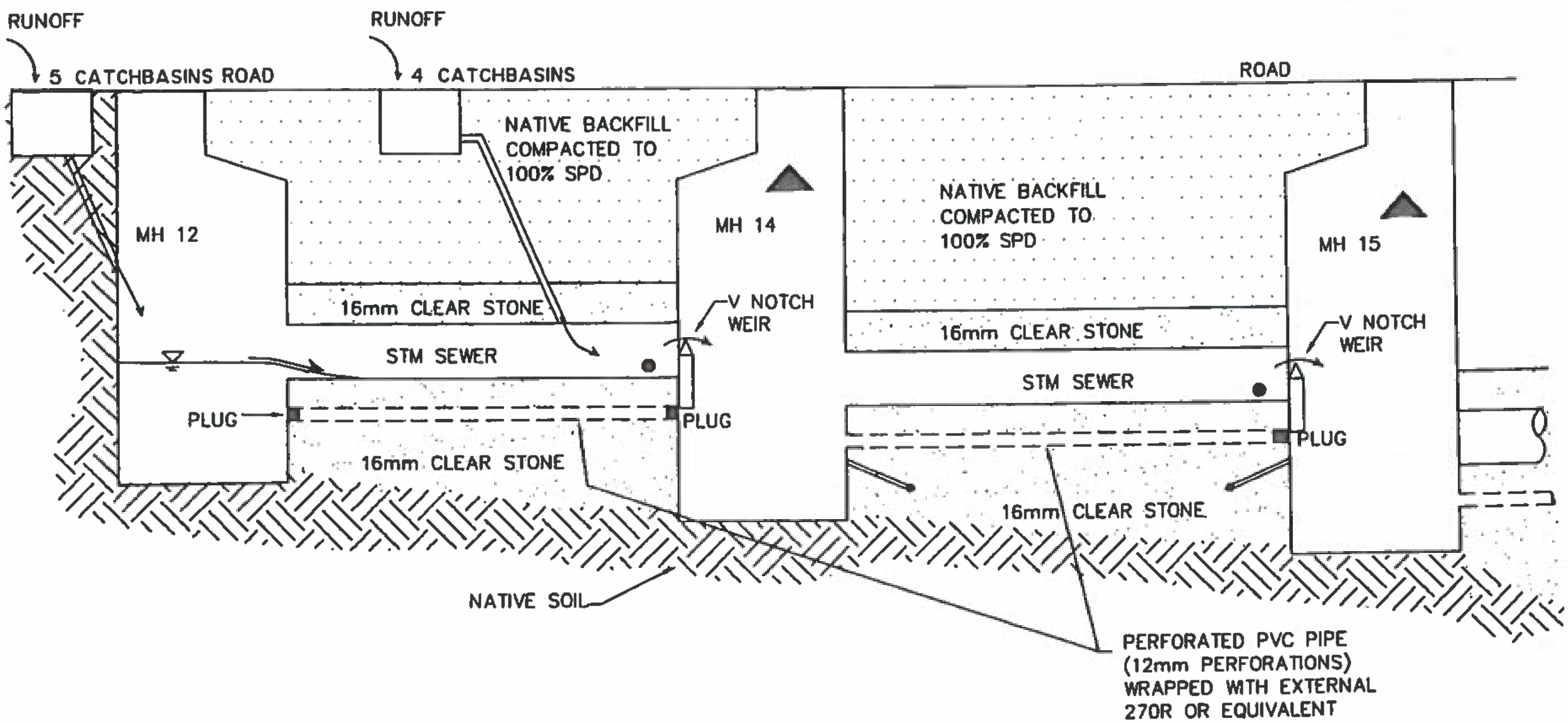
Monitoring was conducted at the upper end of the system (MH 12, 14 & 15) between manholes 14 and 15 as indicated in Figure 7.1. Nine catchbasins drain the upstream area, five are connected to MH 12 by three catchbasin leads and four are connected to the sewer between MH12 and MH14. The exfiltration system upstream of MH14 was temporarily put off-line by plugging the perforated PVC pipes between manholes 12 and 14. This allowed the total upstream runoff to be measured before reaching the monitored section between MH14 and MH15. No additional catchbasin leads occur between MH14 & MH15. Inflow to the system was measured with a low head pressure transducer in the sewer, fitted with a weir, entering MH14, with a second flow measuring pressure transducer, with weir, located in the sewer immediately upstream of MH15.

The difference between the volume entering MH14 and entering MH15 is the volume which drains into the exfiltration trench. An ISCO 3700 sampler was located in MH15 and operated like the sampler in MH14.

The rate at which the trench exfiltrated was measured through the use of two pressure transducers within the clear stone trench. Both the flow and trench pressure transducers were connected to a data logger which recorded data at 5 minute intervals.

QUEEN MARY'S DRIVE

EXFILTRATION MONITORING SYSTEM



MH MANHOLE

▲ DATA LOGGER

● PRESSURE TRANSDUCER

SCALE: N.T.S.

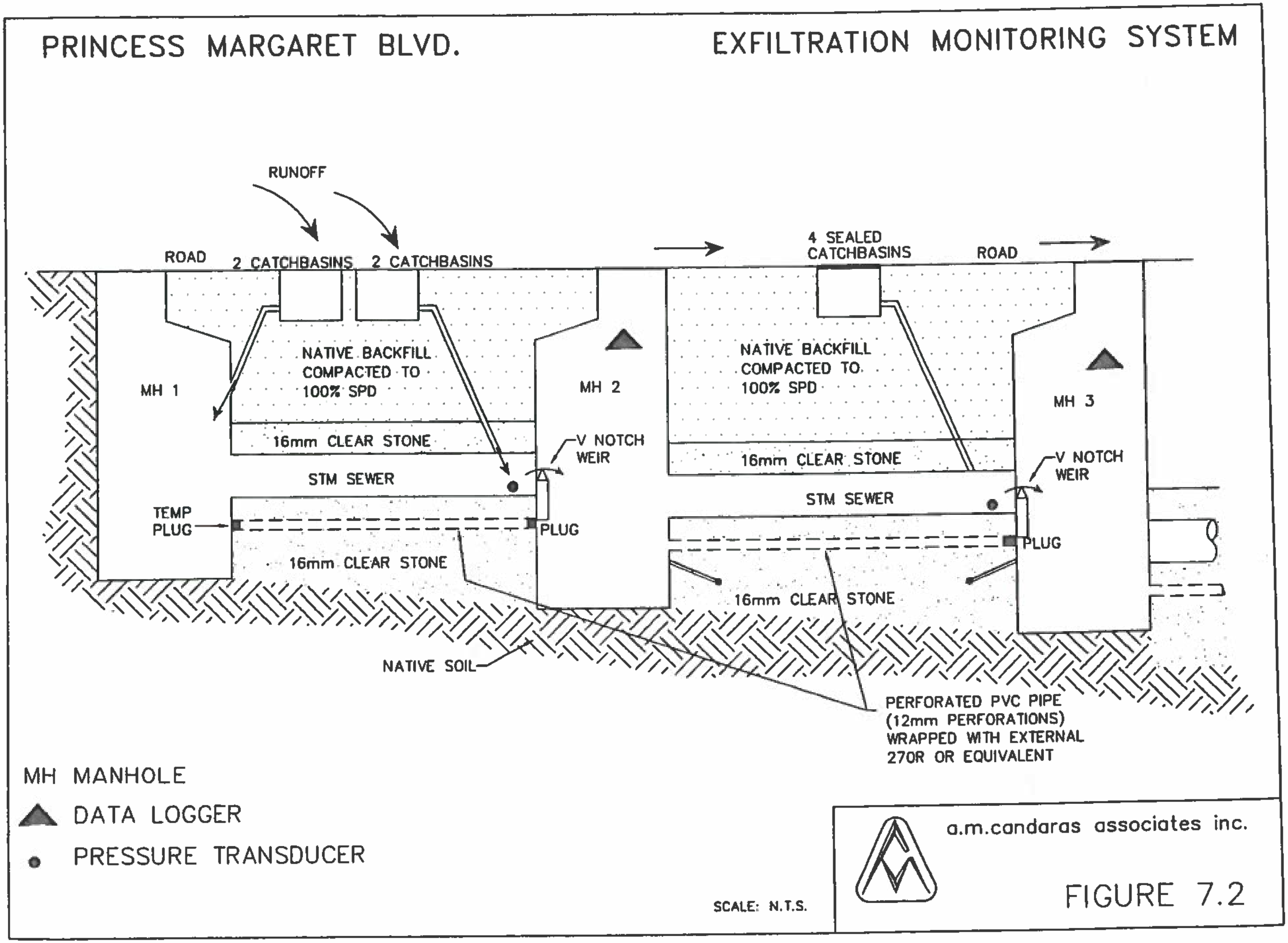
a.m.candaras associates inc.

FIGURE 7.1

7.1.2 Princess Margaret Boulevard/Princess Anne Crescent

The monitoring program for the Princess Anne Crescent/Princess Margaret Boulevard monitoring site focussed on an EES section on Princess Margaret Boulevard just west of Palace Arch Drive as indicated in Figure 7.2. Two catchbasins drain into MH1 through a single lead and two catchbasins connect directly to the storm sewer between MH1 and MH2 at the upstream end of the local drainage system. The four catchbasins connecting to the storm sewer between MH2 and MH3 were temporarily sealed to prevent runoff entering the monitored section. Only one runoff input source to the monitored section (at MH2) was allowed in order to simplify monitoring and reduce equipment cost. The existing road grades conveyed the surface runoff downstream of MH3 to the catchbasins between MH3 and MH4.

The exfiltration system upstream of MH2 was temporarily put off-line by plugging the perforated PVC pipes between MH1 and MH2. System monitoring within the section was essentially identical to that which will be undertaken in the Queen Mary's Drive Site.


PRINCESS MARGARET BLVD.
EXFILTRATION MONITORING SYSTEM
RUNOFF
ROAD
2 CATCHBASINS
2 CATCHBASINS
4 SEALED CATCHBASINS
ROAD
MH 1
NATIVE BACKFILL COMPACTED TO 100% SPD
MH 2
NATIVE BACKFILL COMPACTED TO 100% SPD
MH 3
16mm CLEAR STONE
V NOTCH WEIR
16mm CLEAR STONE
V NOTCH WEIR
STM SEWER
STM SEWER
TEMP PLUG
PLUG
PLUG
16mm CLEAR STONE
16mm CLEAR STONE
NATIVE SOIL
PERFORATED PVC PIPE (12mm PERFORATIONS) WRAPPED WITH EXTERNAL 270R OR EQUIVALENT
MH MANHOLE
DATA LOGGER
PRESSURE TRANSDUCER
SCALE: N.T.S.
a.m.candaras associates inc.
FIGURE 7.2

7.1.3 Braecrest Avenue

Monitoring of the EFS was conducted at the upstream end of the drainage basin. A single catchbasin drains directly into the upstream manhole (MH1) and two catchbasins connect directly into the storm sewer between MH1 and MH2. The catchbasin connected to MH1 and the catchbasin north of the storm sewer between MH1 and MH2 were temporarily plugged as indicated in Figure 7.3. This ensured that the only input to the EFS at this section was the single catchbasin.

To monitor the input runoff to the EFS the catchbasin was equipped with a low head pressure transducer with weir and connected to a data logger to record the changes in head. The head on the pressure transducer in the catchbasin indicated when the capacity of the lead to the trench was exceeded. At this point runoff from the catchbasin flowed into the storm sewer between MH1 and MH2 through the upper catchbasin lead. This flow rate was measured in the sewer, immediately upstream of MH2 with a second pressure transducer and weir arrangement. Stormwater which drained into the trench flowed through the clean stone to the perforated pipe under the storm sewer and outlets into MH2.

A third pressure transducer and weir in MH2 measured the total inflow rate to the manhole. The total outflow from the manhole could be calculated, from the measured flow in the sewer and the flow from the trench.

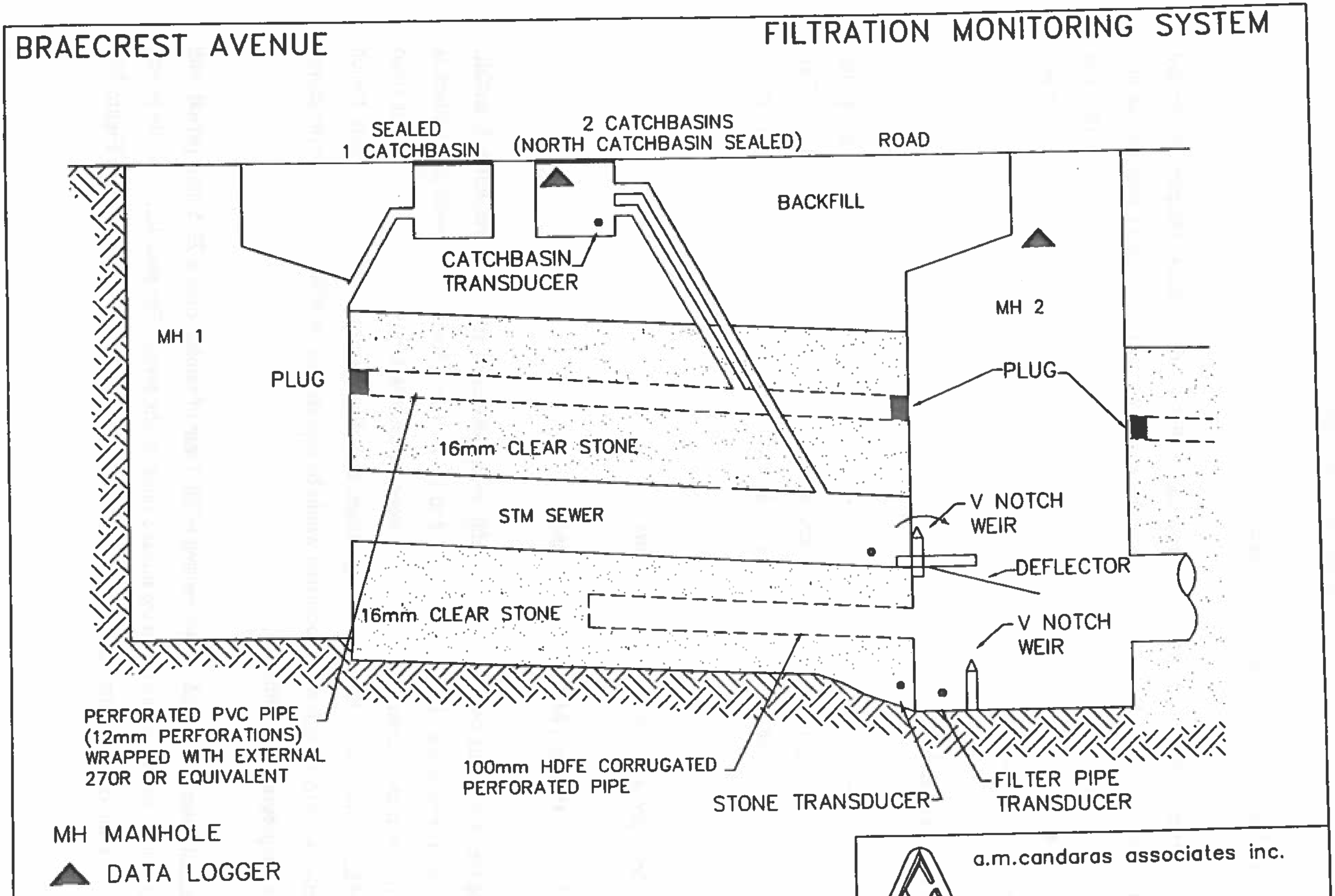

BRAECREST AVENUE
FILTRATION MONITORING SYSTEM
SEALED
1 CATCHBASIN
2 CATCHBASINS
(NORTH CATCHBASIN SEALED)
ROAD
BACKFILL
CATCHBASIN TRANSDUCER
MH 1
MH 2
PLUG
PLUG
16mm CLEAR STONE
STM SEWER
V NOTCH WEIR
DEFLECTOR
16mm CLEAR STONE
V NOTCH WEIR
PERFORATED PVC PIPE
(12mm PERFORATIONS)
WRAPPED WITH EXTERNAL
270R OR EQUIVALENT
100mm HDFE CORRUGATED
PERFORATED PIPE
STONE TRANSDUCER
FILTER PIPE TRANSDUCER
MH MANHOLE
DATA LOGGER
PRESSURE TRANSDUCER
SCALE: N.T.S.
a.m.candaras associates inc.

FIGURE 7.3

7.3 Monitoring Results and Interpretation

The monitoring program commenced in the spring of 1994 for the Princess Margaret Boulevard and Braecrest Avenue sites. At that time the Queen Mary's Drive was under construction and monitoring commenced the Fall of 1994. In the winter of 1995 the monitoring program was terminated at the direction of the City of Etobicoke. The monitoring program restarted in late Summer 1995 and continued until the end of October 1995.

7.3.1 Selection Rainfall Events

The rainfall events which exceeded 10 mm were selected from the rainfall data recorded during the monitoring periods from April 1994 to October 1994 and August 1995 to October 1995. This rainfall data is presented in Tables 7.6 and 7.7. Selected storms are shown graphically in Figures 7.4 to 7.7.

7.3.2 Interpretation of Monitoring Events

7.3.2.1 Princess Margaret Boulevard

During the monitoring period, four (4) rainfall events exceeded 10 mm of accumulated rainfall. The four (4) events are plotted in Figures 7.8 to 7.11. The inflow to the system is identified as MH2 flow with the accumulated depth in the stone trench represented by MH2 Stone Filter Head and MH3 Stone Filter Head at the upstream and downstream limits of the stone trench respectively. Any overflow that occurred would be represented by MH3 Flow. The monitored results are presented in Table 7.8.

The rainfall event of May 26,1994 consisted of 28.3 mm of rainfall over a 22.5 hour period with approximately 12 mm occurring in the initial 3 hours of the event. The peak inflow to the system was 9.7 l/s and occurred approximately 2 hours into the rainfall event as indicated in Figure 7.8.

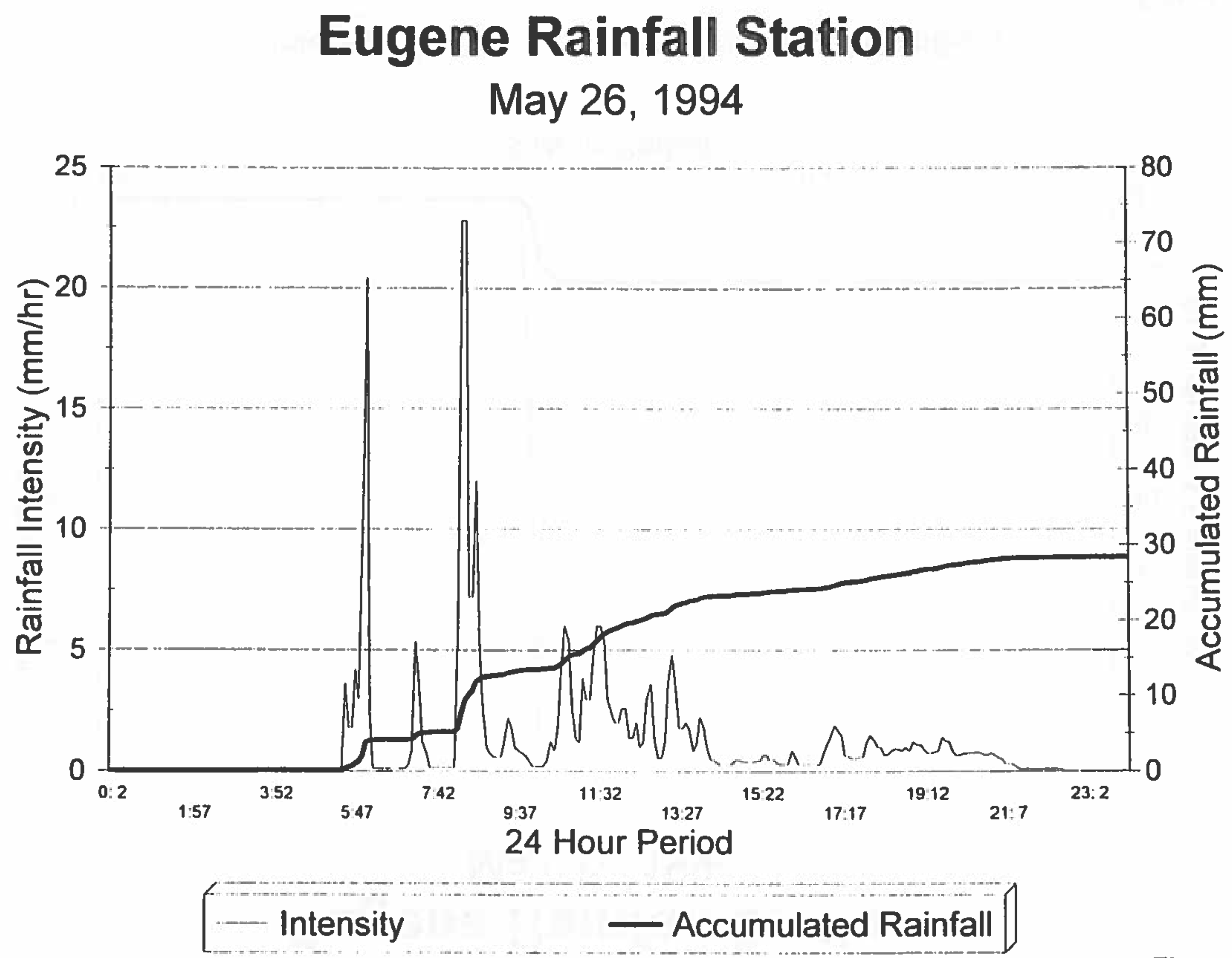
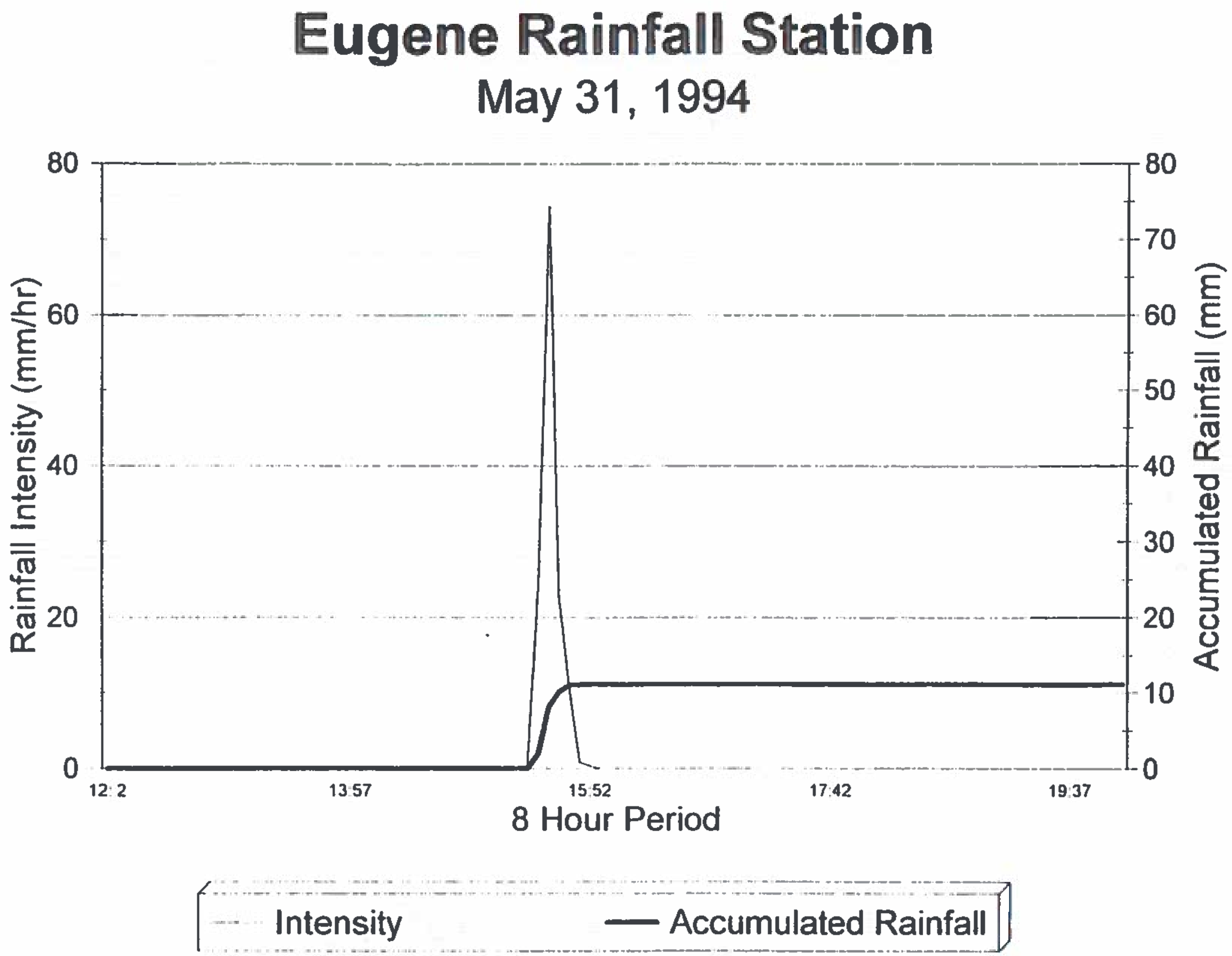

Eugene Rainfall Station
May 26, 1994
Rainfall Intensity (mm/hr)
25
20
15
10
5
0
80
70
60
50
40
30
20
10
0
Accumulated Rainfall (mm)
0:2
1:57
3:52
5:47
7:42
9:37
11:32
13:27
15:22
17:17
19:12
21:7
23:2
24 Hour Period
Intensity
Accumulated Rainfall

Figure 7.4



Eugene Rainfall Station
May 31, 1994
Rainfall Intensity (mm/hr)
80
60
40
20
0
12:2
13:57
15:52
17:42
19:37
8 Hour Period
80
70
60
50
40
30
20
10
0
Accumulated Rainfall (mm)
Intensity
Accumulated Rainfall

Figure 7.5

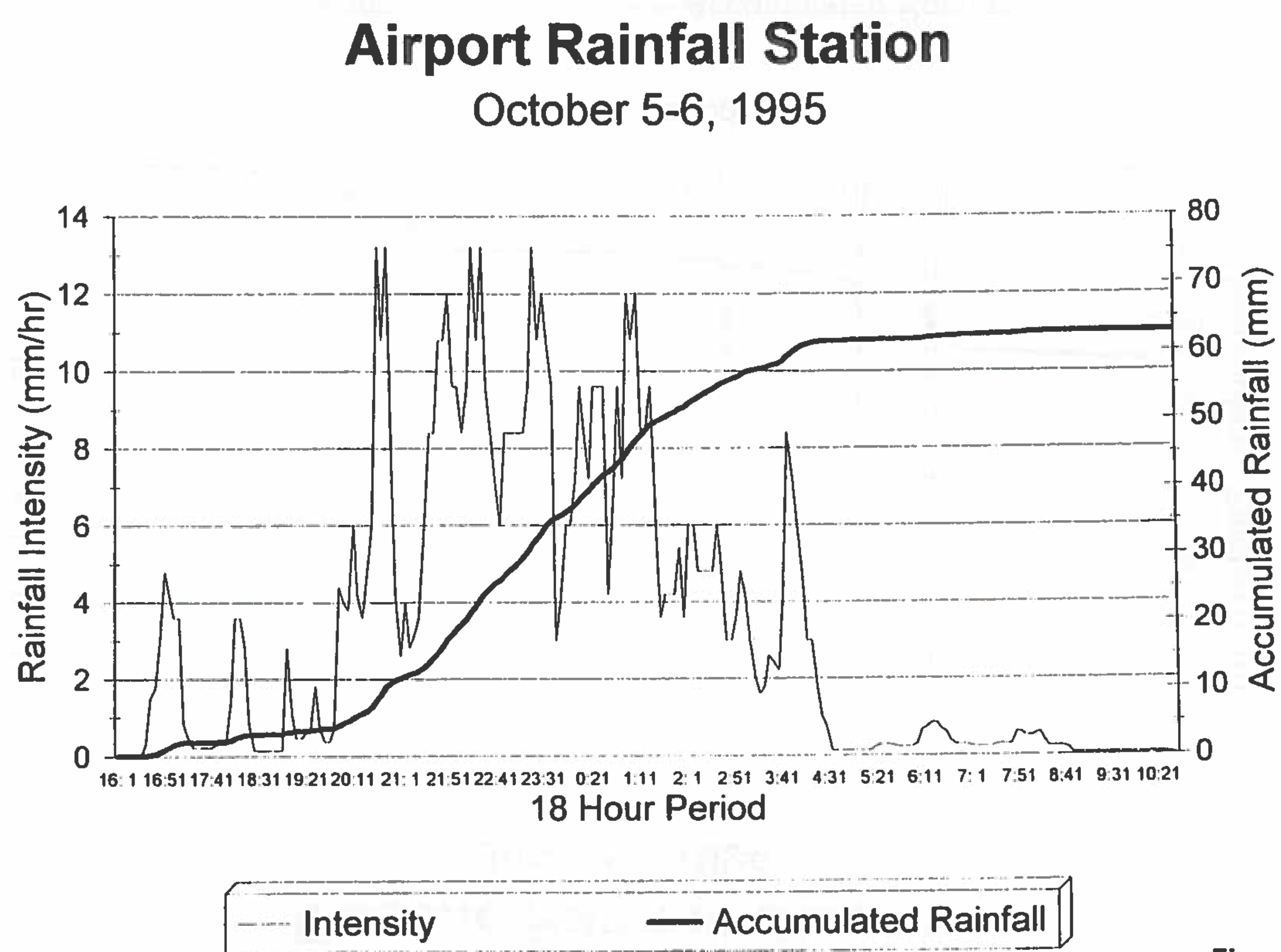
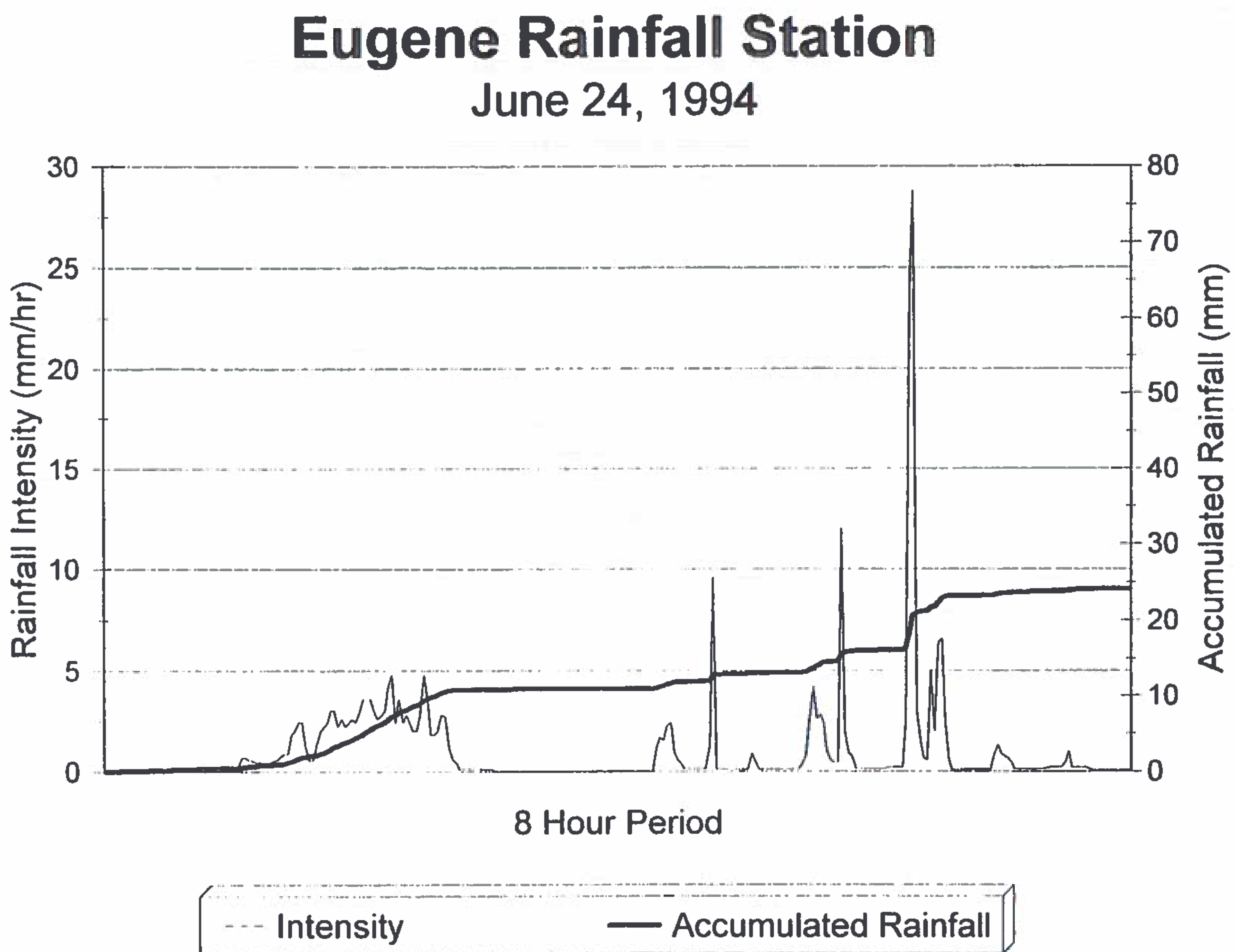

Airport Rainfall Station
October 5-6, 1995
Rainfall Intensity (mm/hr)
14
12
10
8
6
4
2
0
Accumulated Rainfall (mm)
80
70
60
50
40
30
20
10
0
16:1 16:51 17:41 18:31 19:21 20:11 21:1 21:51 22:41 23:31 0:21 1:11 2:1 2:51 3:41 4:31 5:21 6:11 7:1 7:51 8:41 9:31 10:21
18 Hour Period
Intensity
Accumulated Rainfall

Figure 7.6



Eugene Rainfall Station
June 24, 1994
Rainfall Intensity (mm/hr)
30
25
20
15
10
5
0
80
70
60
50
40
30
20
10
0
Accumulated Rainfall (mm)
8 Hour Period
Intensity
Accumulated Rainfall

Figure 7.7

Princess Margaret Blvd.

May 26, 1994

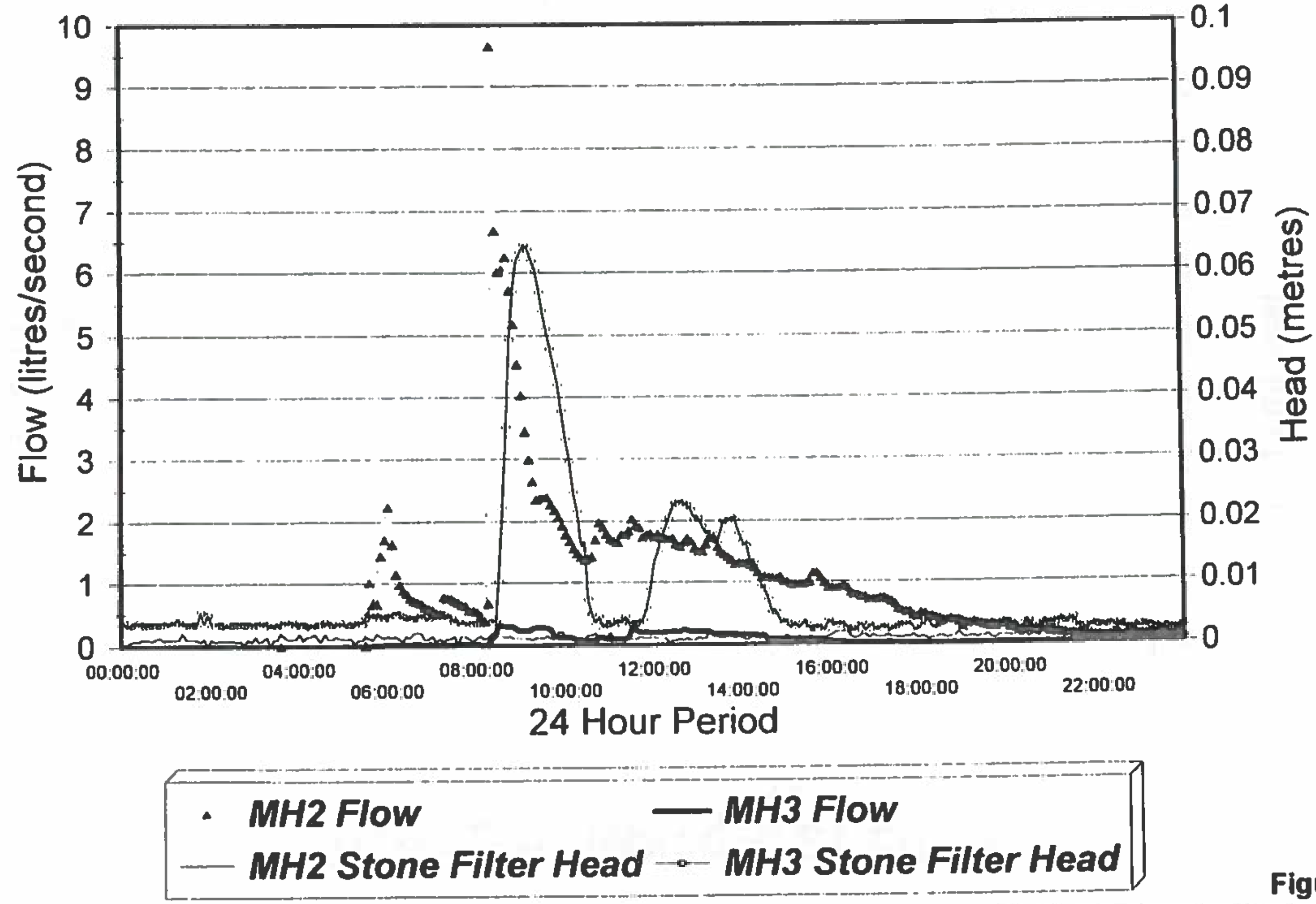
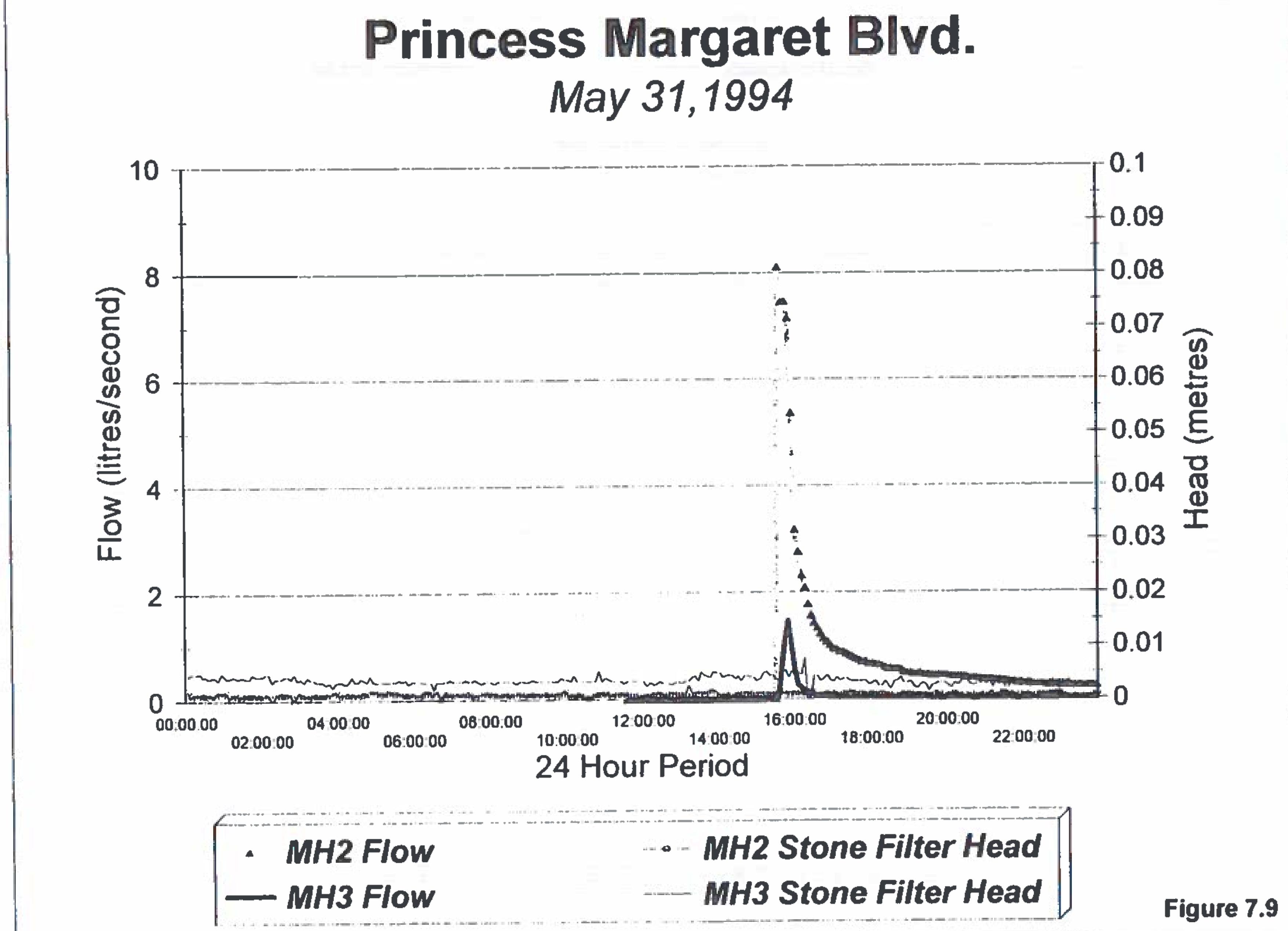


Figure 7.8



Princess Margaret Blvd.
May 31, 1994
Flow (litres/second)
Head (metres)
24 Hour Period
MH2 Flow
MH3 Flow
MH2 Stone Filter Head
MH3 Stone Filter Head

Figure 7.9

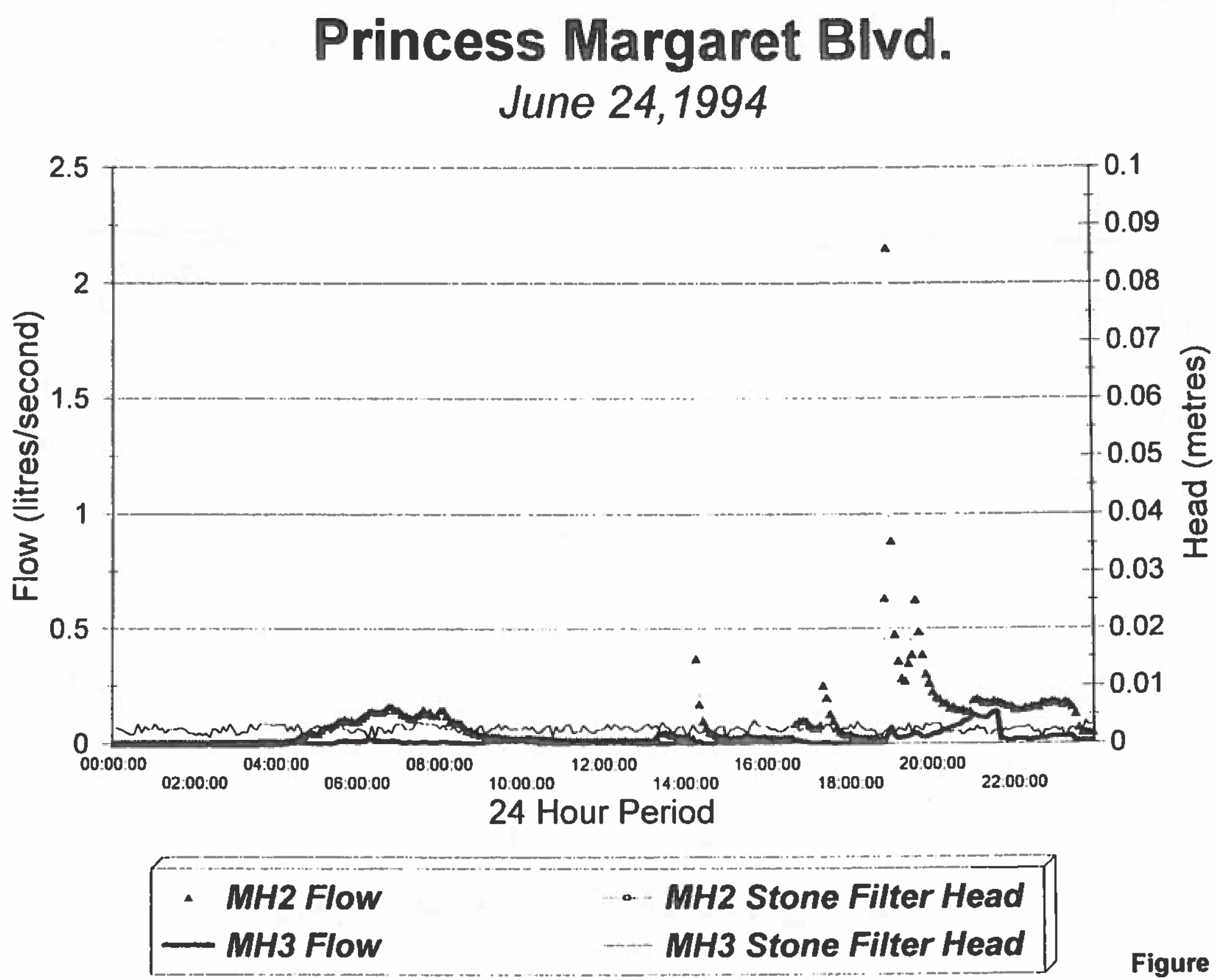

Princess Margaret Blvd.
June 24,1994
Flow (litres/second)
2.5
2
1.5
1
0.5
0
Head (metres)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
00:00:00
02:00:00
04:00:00
06:00:00
08:00:00
10:00:00
12:00:00
14:00:00
16:00:00
18:00:00
20:00:00
22:00:00
24 Hour Period
MH2 Flow
MH3 Flow
MH2 Stone Filter Head
MH3 Stone Filter Head

Figure 7.10

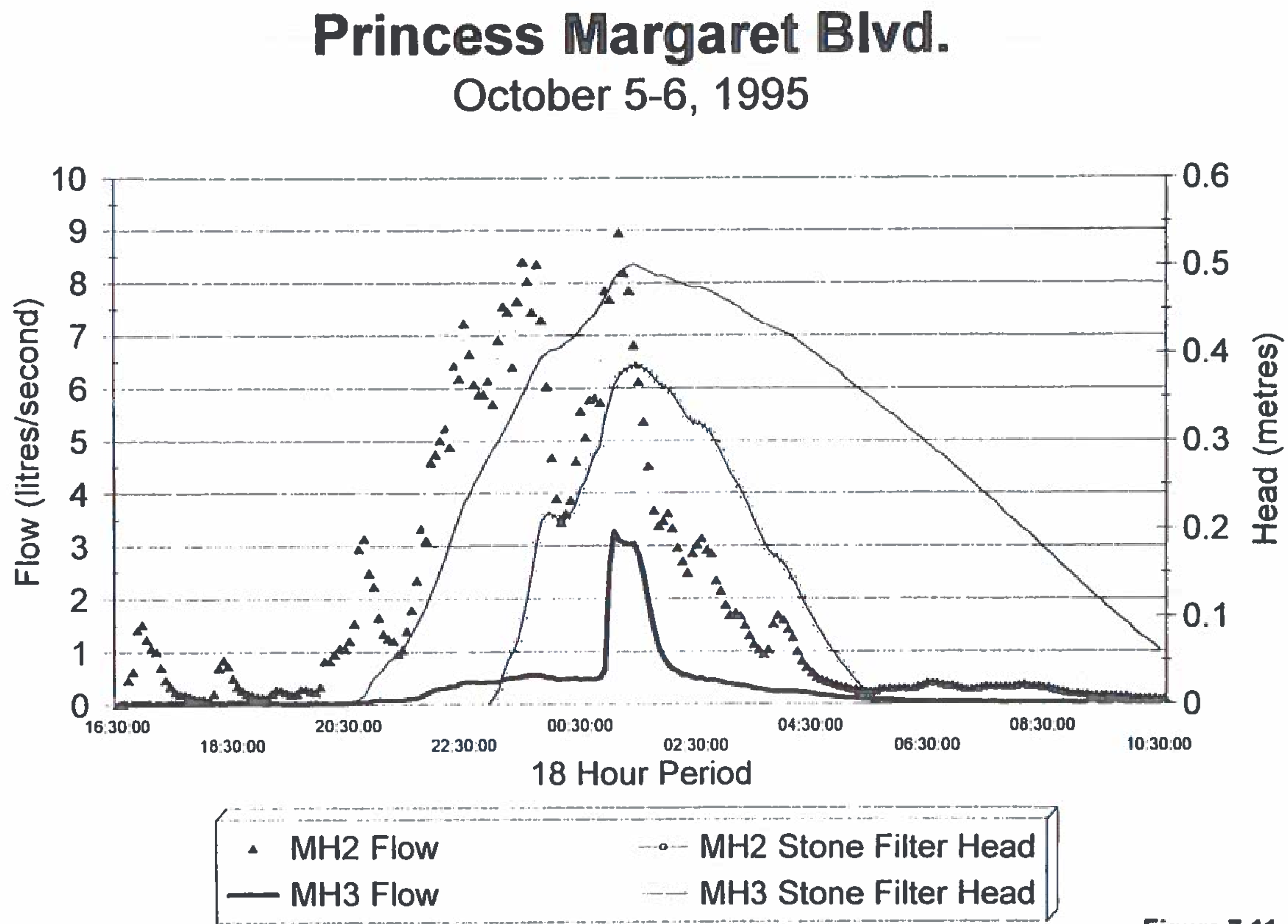

Princess Margaret Blvd.
October 5-6, 1995
Flow (litres/second)
Head (metres)
10
9
8
7
6
5
4
3
2
1
0
0.6
0.5
0.4
0.3
0.2
0.1
0
16:30:00
18:30:00
20:30:00
22:30:00
00:30:00
02:30:00
04:30:00
06:30:00
08:30:00
10:30:00
18 Hour Period
MH2 Flow
MH3 Flow
MH2 Stone Filter Head
MH3 Stone Filter Head

Figure 7.11

During the rainfall event there was a minor increase in the head in the stone filter of approximately 65 mm, as measured at the downstream MH3 which indicated that the stone trench was not full. At MH2 there was no increase in head within the stone trench. The stone trench, perforated pipes and storm sewer were constructed at a grade of 0.65% between MH2 and MH3. Over the 98 m length there is a grade difference of 0.637 m, therefore a static head of 0.637 m must occur in the trench at the downstream MH3 prior to any static head being measured at the upstream MH2. In some cases there could be a dynamic head in the stone trench at MH2 as water is exfiltrated from the perforated pipe. Based on the typical trench cross section the stone trench will be full and overflow will occur to the storm sewer when the depth is about 65 mm at the upstream MH2 and a total head of 1.287 m at MH3 at the invert of the perforated pipe. Accounting for the 300 mm trench below the perforated pipe, the head will be 1.587 m at the downstream trench invert.

The above scenario is valid for rainfall events where the resulting peak flow can be accessed by the upstream perforated pipes in MH2. In cases where the incoming peak flow exceeds the inlet capacity of the perforated pipes, overflows may occur in MH2 prior to the stone trench being full.

A minor flow of approximately 0.3 l/s was observed through the storm sewer during the peak rainfall event with a peak flow of 9.7 l/s which entered the system. This minor flow can be attributed to two sources:

- Minor leakage through the three catchbasins between MH2 and MH3 which were sealed as part of the monitoring exercise.

- Water entering through an abandoned culvert connection to a catchbasin located downstream of MH2 (note that this culvert connection was not plugged).

With the exception of these minor flows, it is evident that this 28 mm rainfall event was substantially infiltrated in the stone trench since there was no net outflow from the system.

A subsequent rainfall event on May 31, 1994 produced 11.1 mm of rainfall over a 0.5 hour period. Although there was less cumulative rainfall than the previous rainfall event of May 26, 1994, this event was more intense and resulted in a peak flow of 8.1 l/s entering the system as indicated in Figure 7.9. At MH3 a minor flow of 1.5 l/s was recorded. Similar to the storm of May 26, 1994 this flow was attributed to infiltration/inflow downstream of MH2 rather than overflows due to the system being full. There was no noticeable change in head in the stone filter at MH2, with a minor change of approximately 5 mm in the stone filter downstream at MH3.

The next significant rainfall event occurred on June 24, 1994 at which time 24.1 mm of rainfall fell over a 24 hr. period. The majority of this rainfall (15.5 mm) occurred in the last 6 hours. The peak flow to the system during that event was 2.2 l/s as indicated in Figure 7.10. As with the previous events, some minor infiltration/inflow occurred in the system between MH2 and MH3 as indicated by the peak flow of 0.1 l/s.

The change of head in the stone trench at MH3 was minor with an average depth of 3 mm. As previously discussed the typical stone trench has a depth of about 650 mm, with a static depth of 1.287 m having to occur at the downstream invert of the perforated pipe (MH3) prior to the system overflowing at MH2.

The recorded data indicated that for this 24.1 mm rainfall event, total infiltration occured in the system.

A review of rainfall records for the remainder of 1994 indicated that there were no storms that exceeded the 28.3 mm cumulative rainfall of May 26, 1994. Therefore, no further rainfall events were analysed in 1994.

Based on the review of the 1995 rainfall data no significant events exceeding the 1994 data occurred until August. As discussed in Section 7.3, monitoring commenced in mid August 1995. During the monitoring period of October 5-6 1995, the rainfall event produced 63 mm over an

18 hour period. As indicated in Figure 7.11 the resulting inflow to the system at MH2 peaked at 10 l/s with flows ranging from 6 l/s to 10 l/s over a 3.5 hour period. Although the cumulative rainfall from this event was approximately double that of May 26, 1994, the peak flows from both events were similar.

During this event the head in the stone trench increased and was recorded at both MH2 and MH3. The maximum recorded depths were 0.38 m at MH2 and 0.5 m at MH3. These depths would indicate that the filter stone was filled. It appears that during the rainfall event the inflow to the system was both being stored in the stone and infiltrated into the soil.

The inflow to the system generally subsided at about 4:30 a.m. on October 6, 1995 while the flow in the stone filter of the downstream manhle (MH3) continued beyond 10:30 a.m. ending at 11:30 a.m.. This response represented the movement of water stored in the stone trench being infiltrated into the soil.

The cumulative rainfall from this event exceeds the original design criteria of 15 mm by a factor of 4. Furthermore, the entire runoff was exfiltrated within 8 hours after the end of the rainfall event which satisfies the original design criteria that the system should exfiltrate all the captured runoff within a 2 day period.

A peak flow of about 3.4 l/s was recorded at MH3. This flow as with the other events was due to inflow/infiltration, since the head in the stone trench did not exceed the overflow depth at MH2.

Based on the monitoring results the system performed beyond the original design criteria. Storm events up to 63 mm, 4 times the original design criteria, have been accommodated. The maximum recorded depth in the downstream stone filter (MH3) was 0.5 m, and 0.38 m at the MH2 stone trench. For overflows to occur at MH2 the water depth would have to be about 0.65 m.

Although the maximum recorded peak inflow to the system was about 10.0 l/s (events of May 26, 1994 and October 5, 1995), the cumulative rainfall from the October 1995 event was double that of the May 26, 1994 event. It would therefore appear that the design criteria and system performance are affected by the distribution of the rainfall event as well as the cumulative rainfall.

7.3.2.1.1 Discussion of Monitory Results

Based on the observed results, it would appear that the system is capable of accommodating runoff from a storm which exceeds the original design criteria of 15 mm by a factor of 4. The results indicated that the actual runoff is less than the design runoff as calculated based on the Rational Method approach as discussed in Section 5.0.

Further flow testing/calibration was undertaken in the system (see Section 8.0) to further evaluate and observe the system performance.

7.3.2.2 Queen Mary's Drive

The monitoring of Queen Mary's Drive was delayed until the Fall of 1994 until construction. In 1994, there was only 1 rainfall event on September 25 that exceeded 10 mm as previously listed in Table 7.6. The monitoring results for this 1994 event and 1995 event (Oct. 5-6) are plotted in Figures 7.12 and 7.13 and presented in Table 7.9.

The rainfall event of September 25, 1994 resulted in a total cumulative rainfall of 19.1 mm over a duration of 6 hours. The resulting peak inflow at the upstream end of the system (MH14) was approximately 52 l/s; the water depths in the stone trench were approximately 220 mm at the upstream end (MH14) and 10 mm at the downstream end (MH15) respectively. These depths are less than the 650 mm stone trench capacity (over the 650 mm capacity an overflow will occur). The results indicated that the runoff from the 19 mm rainfall event was accommodated by the system and exfiltrated. The results indicate that less than 50% of the available trench depth was

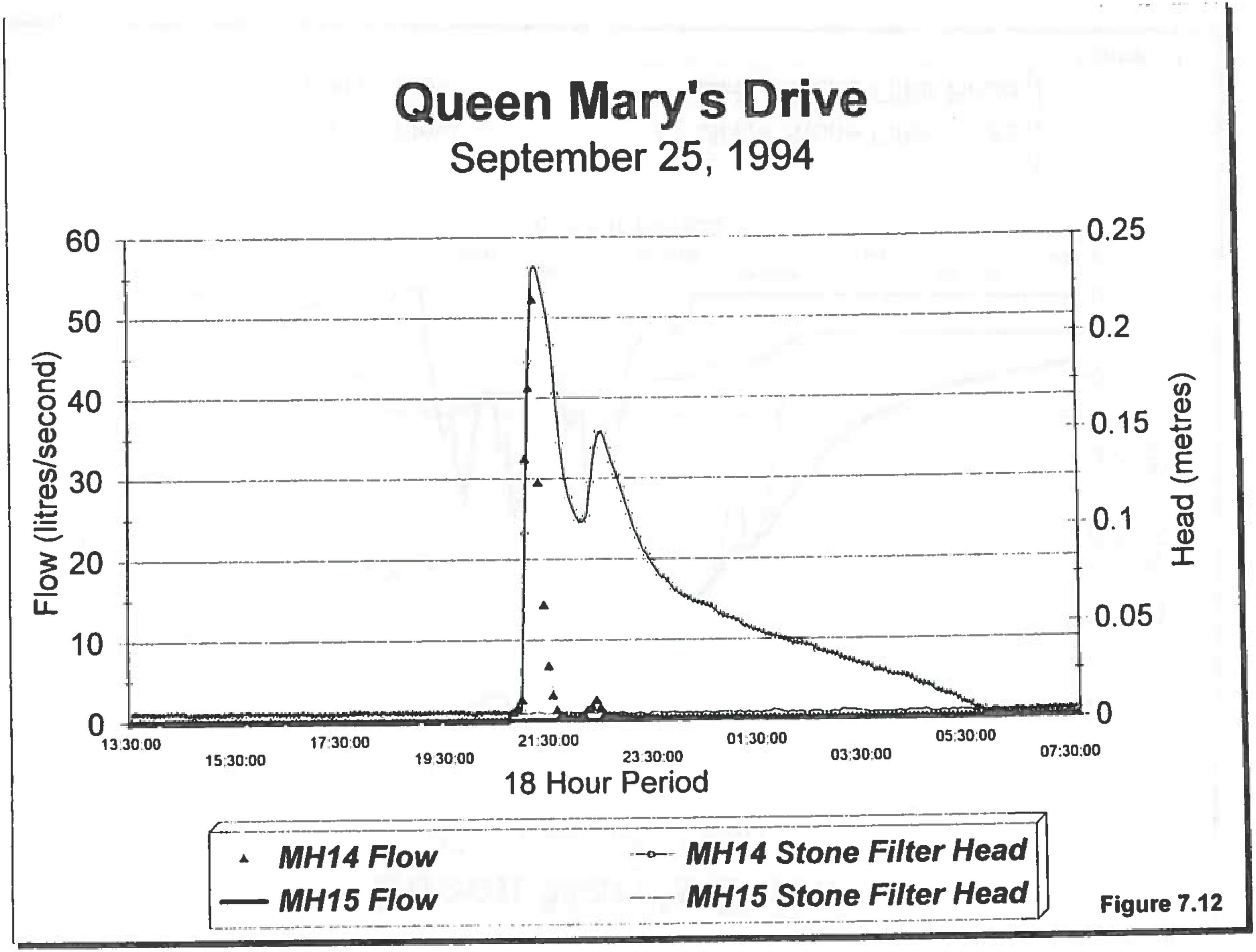
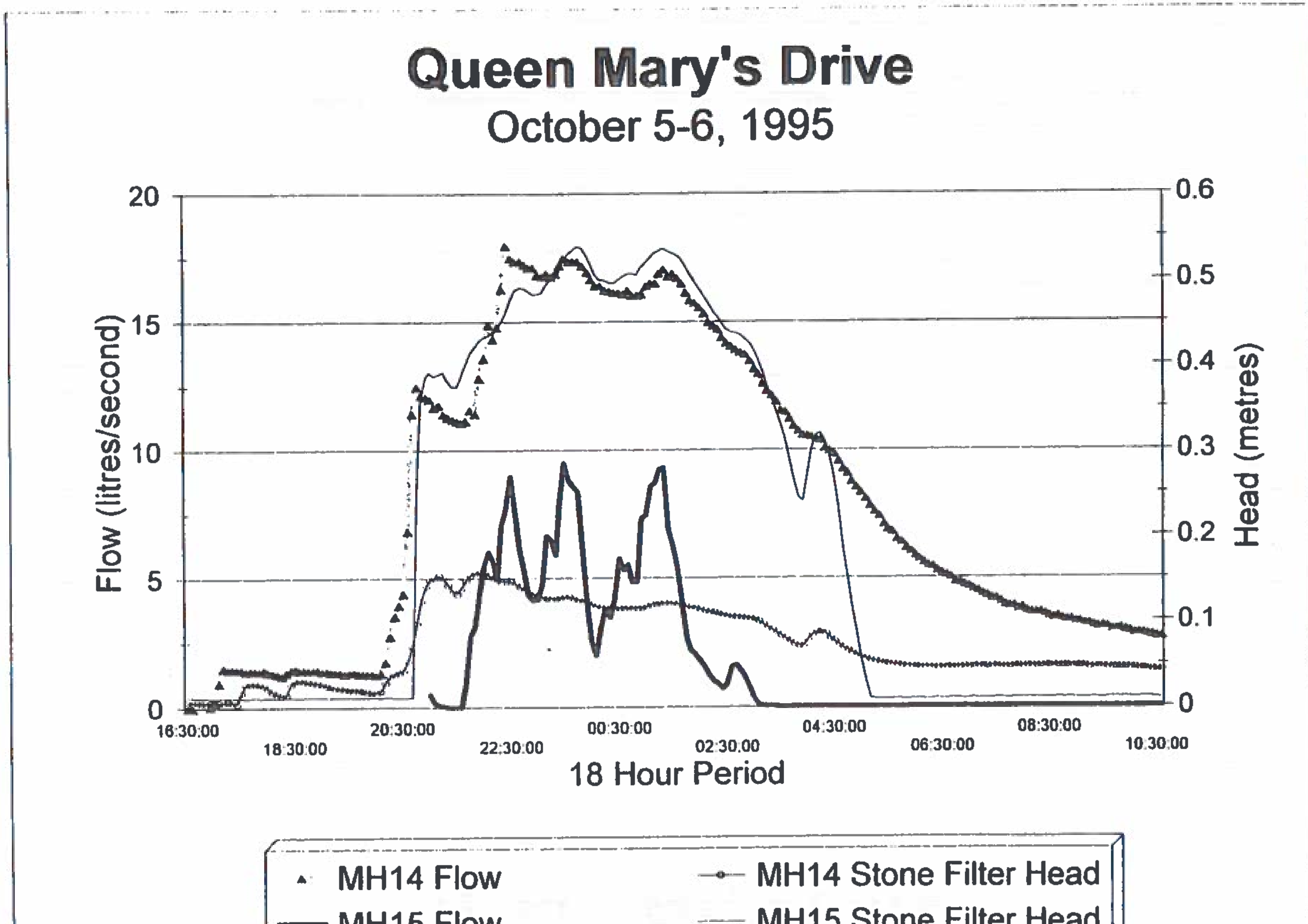

Queen Mary's Drive
September 25, 1994
Flow (litres/second)
60
50
40
30
20
10
0
Head (metres)
0.25
0.2
0.15
0.1
0.05
0
13:30:00
15:30:00
17:30:00
19:30:00
21:30:00
23:30:00
01:30:00
03:30:00
05:30:00
07:30:00
18 Hour Period
MH14 Flow
MH15 Flow
MH14 Stone Filter Head
MH15 Stone Filter Head

Figure 7.12



Queen Mary's Drive
October 5-6, 1995
Flow (litres/second)
20
15
10
5
0
Head (metres)
0.6
0.5
0.4
0.3
0.2
0.1
0
16:30:00
18:30:00
20:30:00
22:30:00
00:30:00
02:30:00
04:30:00
06:30:00
08:30:00
10:30:00
18 Hour Period
MH14 Flow
MH15 Flow
MH14 Stone Filter Head
MH15 Stone Filter Head

Figure 7.13

utilized at a rainfall greater than the 15 mm design criteria; therefore it is likely that the original design analysis, overestimated the runoff, underestimated the exfiltration rate, or a combination of both. In Section 8.2, where the system modelling was undertaken, these scenarios are further discussed.

A minor flow of 6.5 l/s was recorded in the storm sewer at the downstream MH15. This flow was due to inflow/infiltration from the catchbasins between MH14 and MH15 which had been sealed during the monitoring program. Also roof areas in this road section are connected to the storm sewer, and possibly contributes runoff to the minor flow.

The rainfall event of October 5-6, 1995 resulted in a cumulative rainfall of 63 mm over 18 hours. The peak flow into the system was approximately 17.5 l/s at MH14. Depths in the filter trench ranged from 150 mm upstream at MH14 to 550 mm downstream at MH15.

For this event the peak flows downstream at MH15 were approximately 10 l/s which is significant relative to the peak inflow of 17 l/s. However, the maximum depth in the stone trench was 150 mm, hence an overflow would not have occurred, therefore the relatively high flows at MH15 are likely due to the roof areas connected to the sewer system.

In reviewing Figures 7.12, 7.13 and summary Table 7.9, it has been noted that the September 25, 1994 storm was significantly higher in intensity, shorter in duration and contributed less rainfall depth (19.1 mm) than the October 5-6 storm (63.0 mm). The October event produced an outflow volume of about 92,000 litres in comparison to the 2.0 litres produced during the September event. This outflow is attributed to contributions from downspouts and foundation drains which are directly connected to the storm sewer in this area. It is suggested that for shorter duration events, the downspout flow is retained within the foundation drain stone trench. Conversly for longer duration events, the storage capacity in the weeping tile/stone trench becomes saturated and the excess runoff discharges directly to the storm sewer.

In Figure 7.13, the hydraulic head measured in the stone trench at MH15 dropped abruptly at approximately 4:30 a.m., indicating either a monitoring equipment problem or a high rate of infiltration.

7.3.2.3 Braecrest Avenue

The results of the monitoring for the Braecrest Avenue system are presented in Figures 7.14 to 7.17 and summarized in Table 7.10.

In Table 7.10 the results indicate that no overflows occurred into the storm sewer except for the storm event of May 26, 1994. Thus overflow was likely caused by a blockage at the lower outlet pipe in the catchbasin. This blockage hence resulted in the flows discharging via the upper outlet pipe directly to the storm sewer.

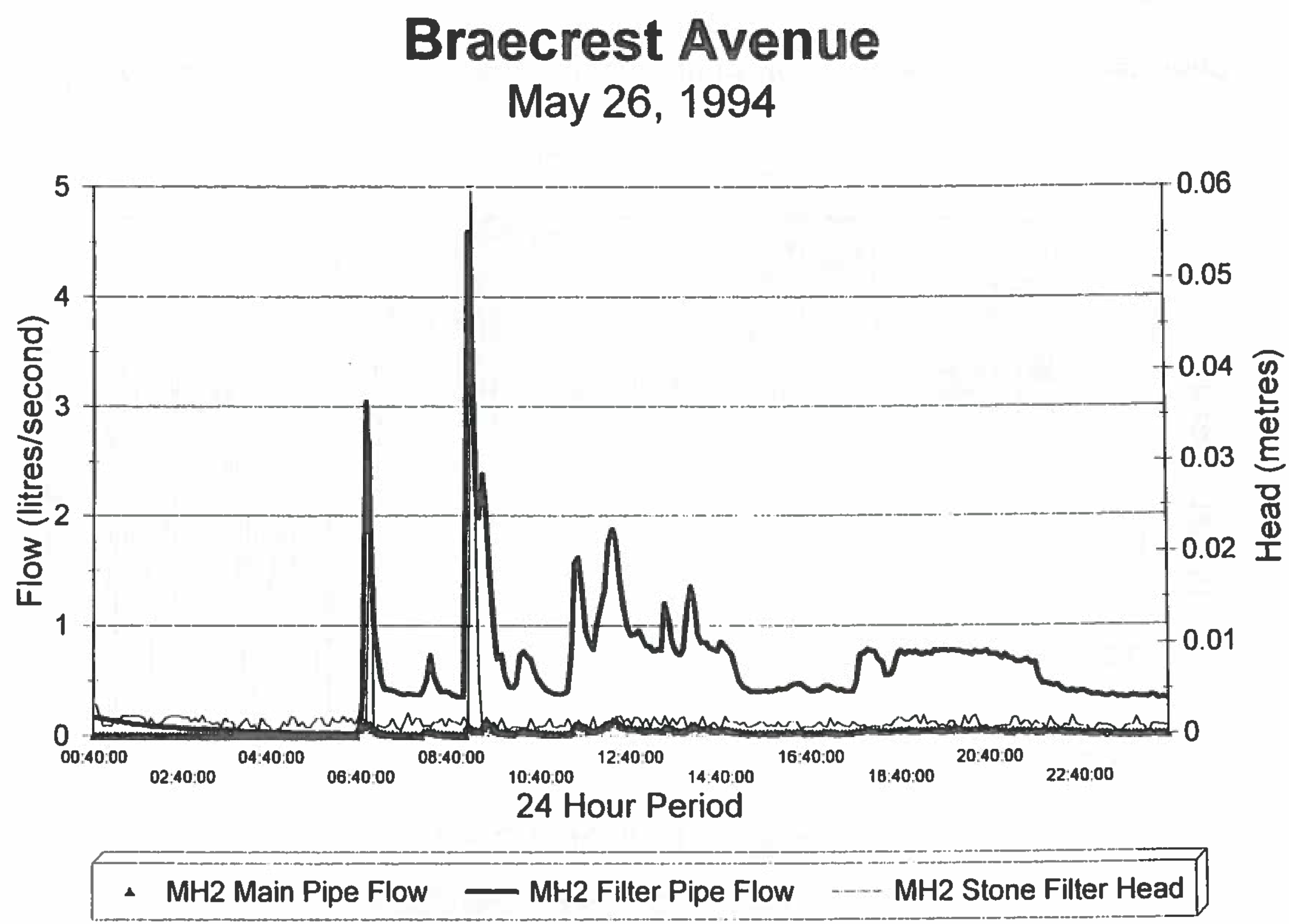

Braecrest Avenue
May 26, 1994
Flow (litres/second)
5
4
3
2
1
0
Head (metres)
0.06
0.05
0.04
0.03
0.02
0.01
0
00:40:00
02:40:00
04:40:00
06:40:00
08:40:00
10:40:00
12:40:00
14:40:00
16:40:00
18:40:00
20:40:00
22:40:00
24 Hour Period
MH2 Main Pipe Flow
MH2 Filter Pipe Flow
MH2 Stone Filter Head

Figure 7.14

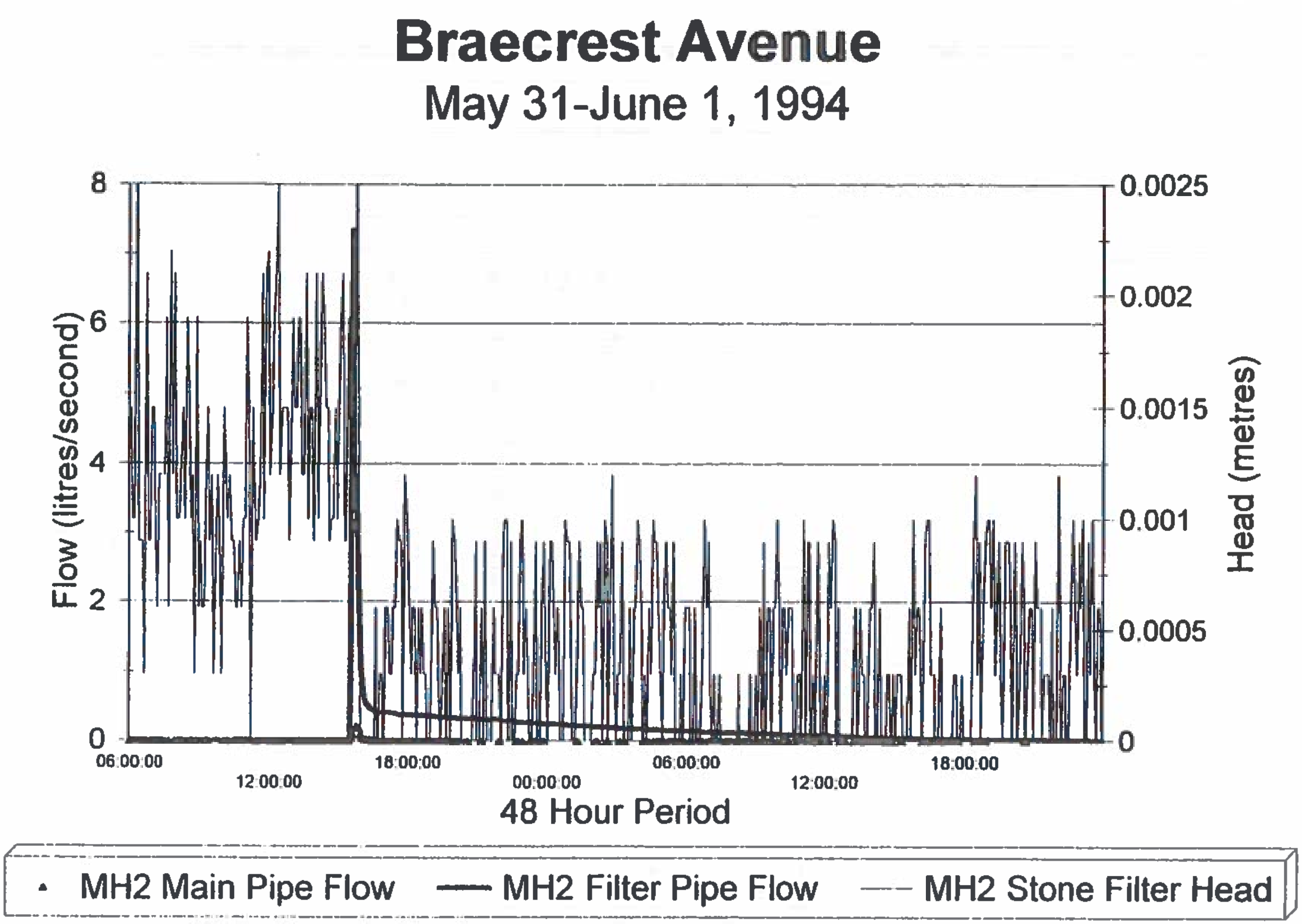

Braecrest Avenue
May 31-June 1, 1994
Flow (litres/second)
8
6
4
2
0
Head (metres)
0.0025
0.002
0.0015
0.001
0.0005
0
06:00:00
12:00:00
18:00:00
00:00:00
06:00:00
12:00:00
18:00:00
48 Hour Period
MH2 Main Pipe Flow
MH2 Filter Pipe Flow
MH2 Stone Filter Head

Figure 7.15

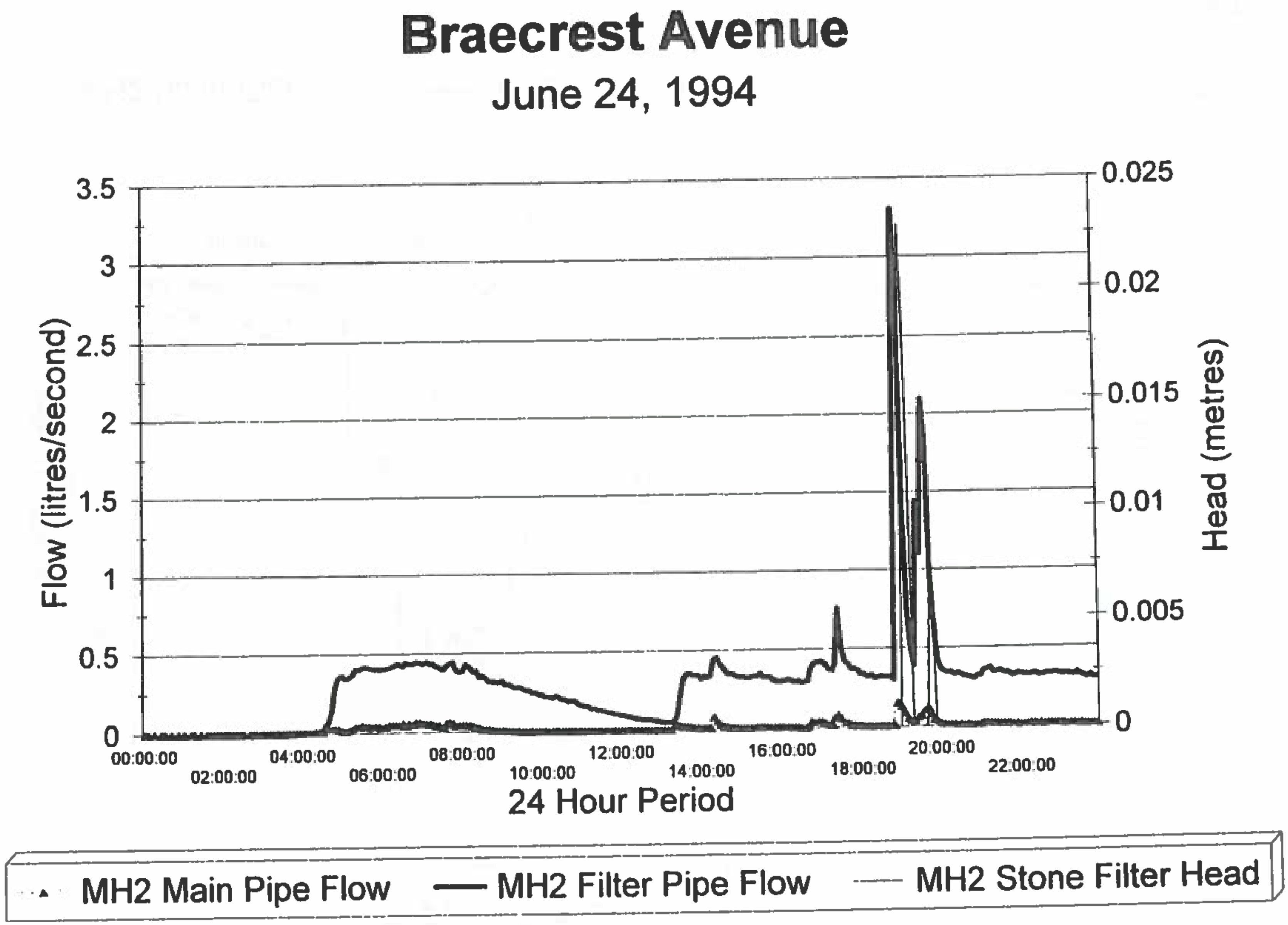

Braecrest Avenue
June 24, 1994
Flow (litres/second)
3.5
3
2.5
2
1.5
1
0.5
0
Head (metres)
0.025
0.02
0.015
0.01
0.005
0
00:00:00
02:00:00
04:00:00
06:00:00
08:00:00
10:00:00
12:00:00
14:00:00
16:00:00
18:00:00
20:00:00
22:00:00
24 Hour Period
MH2 Main Pipe Flow
MH2 Filter Pipe Flow
MH2 Stone Filter Head

Figure 7.16

Braecrest Avenue

October 5-6, 1995

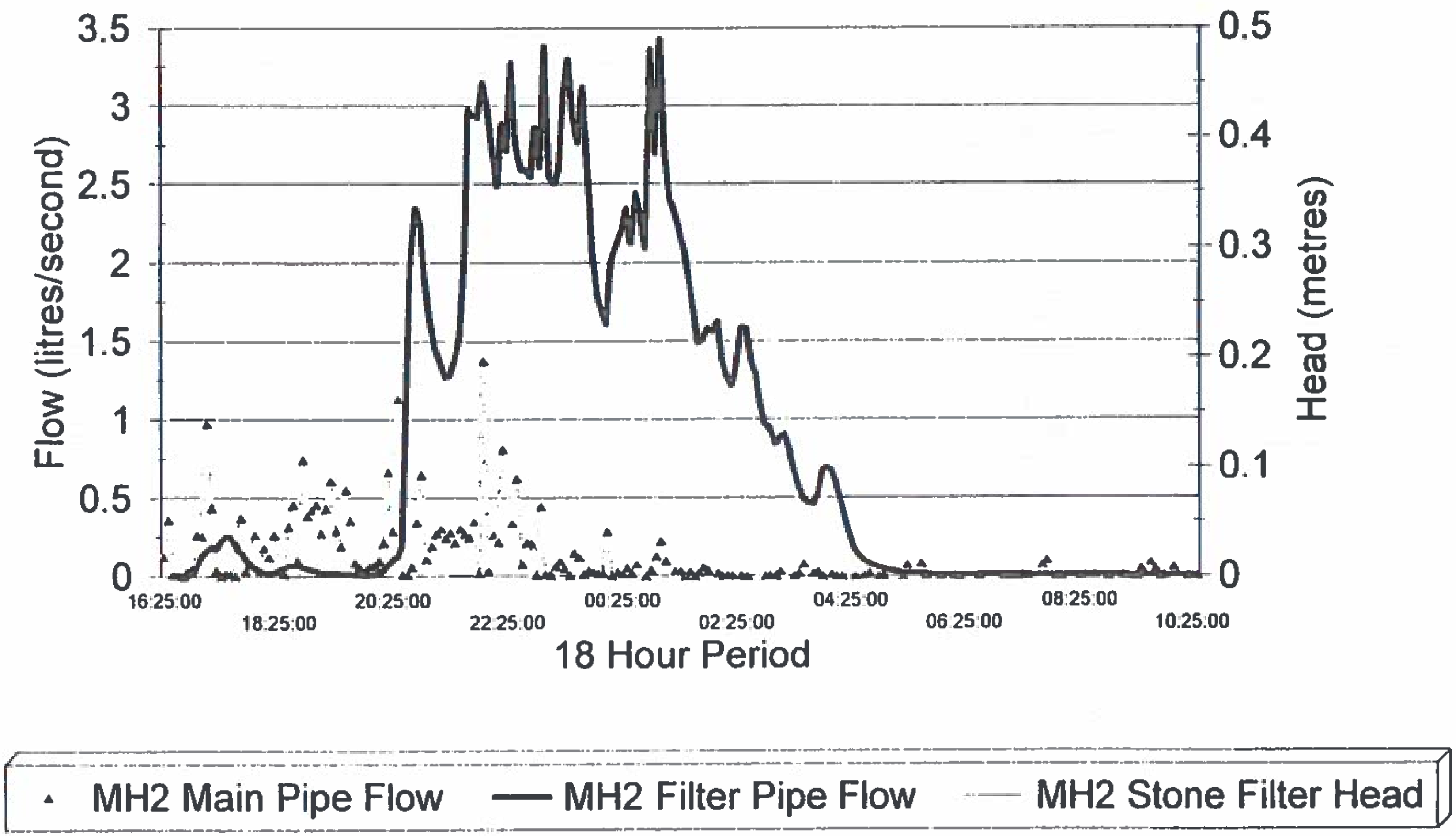


Figure 7.17

Table 7.1: Precipitation Summary

Period: May 1, 1994 to May 31, 1994

RAINFALL (mm)				
DATE	AIRPORT	LAMBTON	EUGENE	DOROTHY
1	1.2	1.8		0.5
2				
3				
4				
5	6.2	3.8		1.6
6		6.2		3.2
7	6.2	1.1		0.8
8	0.2	3.0		2.1
9	5.6	5.3		2.5
10				
11	6.0	5.6		5.9
12				
13				
14	0.2			
15	15.6	13.9		9.2
16	0.2	0.5		0.2
17			0.8	
18				
19				
20				
21				
22				
23				
24	2.4	1.8	1.4	1.1
25	5.4	0.1	1.0	10.0
26	27.2	34.2	28.4	22.0
27				
28	0.8	0.5	0.3	0.1
29		0.1	0.3	0.2
30				
31	13.2	14.3	11.2	10.2
TOTALS	90.4	92.2	43.4	69.6

LEGEND:
- AIRPORT — LESTER B. PEARSON WEATHER STATION
- LAMBTON — LAMBTON KINGSWAY JUNIOR MIDDLE SCHOOL
- EUGENE — SAINT EUGENE CATHOLIC SCHOOL
- DOROTHY — ST. DOROTHY CATHOLIC SCHOOL

READINGS COMMENCED MAY 17, 1994 FOR EUGENE

Table 7.2: Precipitation Summary

Period: June 1, 1994 to June 30, 1994

RAINFALL (mm)				
DATE	**AIRPORT**	**LAMBTON**	**EUGENE**	**DOROTHY**
1	0.2			
2				
3				
4				
5				
6	0.4	0.4	0.2	0.8
7				
8				
9				
10				
11	0.8	0.5	0.4	0.9
12	1.0	5.3	3.9	10.7
13	1.6	0.2	1.4	1.6
14				
15				
16				
17				
18				
19				
20				
21				
22				
23	1.0	0.5	0.4	0.3
24	27.2	41.6	24.1	21.3
25		3.3	2.5	3.5
26	2.8	0.1		
27		2.7	3.2	2.5
28				
29	19.2	2.6	9.3	11.2
30	0.2	4.6	0.8	1.9
TOTALS	54.4	61.8	46.2	54.7

LEGEND:

AIRPORT	LESTER B. PEARSON WEATHER STATION
LAMBTON	LAMBTON KINGSWAY JUNIOR MIDDLE SCHOOL
EUGENE	SAINT EUGENE CATHOLIC SCHOOL
DOROTHY	ST. DOROTHY CATHOLIC SCHOOL

Table 7.3: Precipitation Summary

Period: July 1, 1994 to July 31, 1994

RAINFALL (mm)				
DATE	AIRPORT	LAMBTON	EUGENE	DOROTHY
1				
2				
3				
4				
5	1.8		3.2	0.4
6	8.2	7.5	10.8	5.3
7	5.6	3.9	2.4	4.9
8	2.2	6.4	3.5	6.0
9	1.0	2.7	1.7	0.6
10				
11				
12				
13				
14				
15				0.3
16				
17				
18				
19				
20	1.6	1.0	0.5	0.6
21	6.4	2.0	1.8	5.3
22	33.6	18.7	23.1	23.9
23		0.8		
24		0.3		
25	4.4	1.4	1.8	1.7
26	2.8	4.2	1.2	0.9
27				
28				0.3
29				
30	15.4	15.1	17.9	22.8
31		0.1		
TOTALS	83.0	64.1	67.9	73.0

LEGEND:
AIRPORT LESTER B. PEARSON WEATHER STATION
LAMBTON LAMBTON KINGSWAY JUNIOR MIDDLE SCHOOL
EUGENE SAINT EUGENE CATHOLIC SCHOOL
DOROTHY ST. DOROTHY CATHOLIC SCHOOL

Table 7.4: Precipitation Summary

Period: August 1, 1994 to August 31,1994

RAINFALL (mm)				
DATE	AIRPORT	LAMBTON	EUGENE	DOROTHY
1	9.4	5.3	3.5	3.1
2		1.0	2.8	4.4
3				
4	28.8	20.0	25.9	44.1
5				
6				
7				
8	1.4	0.5	1.1	0.2
9	3.4	5.0	3.8	4.0
10				
11				
12				
13	8.0	7.3	8.4	
14	1.4	3.8	0.6	
15				
16				
17				
18				
19		0.2	0.1	
20	0.4	0.5	0.4	
21	0.4	0.7	0.8	
22				
23				
24				
25				
26				
27				
28	0.2			
29				
30	0.6			
31	5.8		5.2	
TOTALS	59.8	44.3	52.6	55.8

LEGEND:
AIRPORT LESTER B. PEARSON WEATHER STATION
LAMBTON LAMBTON KINGSWAY JUNIOR MIDDLE SCHOOL
EUGENE SAINT EUGENE CATHOLIC SCHOOL
DOROTHY ST. DOROTHY CATHOLIC SCHOOL

Table 7.5: Precipitation Summary

Period: September 1, 1994 to September 30, 1994

	RAINFALL (mm)			
DATE	AIRPORT	LAMBTON	EUGENE	DOROTHY
1			0.3	
2				
3				
4				
5				
6	3.0		2.8	
7			0.3	
8	6.4		5.8	
9		1.5		
10				
11				
12				
13	11.8	3.7	6.9	
14	11.4	19.1	17.4	
15	1.0	0.5	0.3	
16				
17				
18				
19				
20				
21				
22				
23				
24				
25	10.0	16.6	10.3	
26	0.6	0.6	3.7	
27	2.2	3.6	4.6	
28	5.0	4.3	4.2	
29		0.2	0.2	
30			0.2	
TOTALS	51.4	50.1	57.0	0.0

LEGEND:

AIRPORT	LESTER B. PEARSON WEATHER STATION
LAMBTON	LAMBTON KINGSWAY JUNIOR MIDDLE SCHOOL
EUGENE	SAINT EUGENE CATHOLIC SCHOOL
DOROTHY	ST. DOROTHY CATHOLIC SCHOOL

Table 7.6: 1994 Precipitation Summary

EUGENE (1)			LAMBTON (2)		
DATE	DURATION (hours)	DEPTH (mm)	DATE	DURATION (hours)	DEPTH (mm)
MAY 15/94	N/A	N/A	MAY 15/94	18.25	13.8
MAY 26/94	22.5	28.3	MAY 26/94	22.5	34.1
MAY 31/94	0.5	11.1	MAY 31/94	1.5	14.2
JUNE 24/94	24.0	24.1	JUNE 24/94	23.5	41.6
JULY 22/94	N/A	N/A	JULY 22/94	6.75	18.5
JULY 30/94	N/A	N/A	JULY 30/94	6.25	15.0
AUG. 4/94	N/A	N/A	AUG. 4/94	7.75	19.9
SEPT. 14/94	N/A	N/A	SEPT. 14/94	6.0	19.1
SEPT. 25/94	N/A	N/A	SEPT. 25/94	1.5	16.5

Note: Only storms having a cummulative rainfall of 10 mm or greater are shown.
N/A Rainfall information is not available at this time.
(1) Rainfall Data for Princess Margaret Boulevard and Braecrest Avenue.
(2) Rainfall Data for Queen Mary's Drive.

Table 7.7: 1995 Precipitation Summary

LESTER B PEARSON INTERNATIONAL AIRPORT		
DATE	DURATION (hours)	DEPTH (mm)
APRIL 21/95	16.5	31.1
APRIL 26/95	11.75	13.4
MAY 10/95	6.5	12.9
MAY 28/95	15.5	12.2
MAY 29/95	6.5	17.7
AUGUST 1/95	6.0	12.8
AUGUST 3-4/95	18.5	14.16
AUGUST 4-5/95	23.75	78.4
AUGUST 14/95	10.5	20.1
OCTOBER 5-6/95	18.0	63.0

Note: Only storms having a cumulative rainfall of 10 mm or greater are shown.

Table 7.8: Princess Margaret Blvd. Exfiltration System Summary of Monitoring Results

Date	Storm Duration (hr)	Rainfall Depth (mm)	Peak Inflow (MH2) (l/s)	Total Inflow Volume (l)	Maximum Filter Head Upstream MH2 (mm)	Maximum Filter Head Downstream MH3 (mm)	Peak Outflow (MH3) (l/s)	Total Outflow Volume (l)	Comments
May 26 1994 (See Fig. 7.8)	22.5	28.3	9.7	73,668	Nil	65	0.3 (1)	4,486	Stone trench not full No overflow at MH2
May 31 1994 (See Fig. 7.9)	0.5	11.1	8.1	28,340	Nil	5	1.5 (1)	2,003	Stone trench not full No overflow at MH2
June 24 1994 (See Fig.7.10)	24.0	24.1	2.2	7,587	Nil	3	0.1 (1)	1,131	Stone trench not full No overflow at MH2
Oct. 5-6 1995 (See Fig. 7.11)	18.0	63	10.0	130,015	380	500	3.0 (1)	18,895	Stone trench full No overflow at MH2
July 12 1994 (See Fig. 8.2)		Flow Testing	13.3		430	430	8.3 (1)		Overflow occurs after 45 minutes of inflow at MH2, with the 13.3 l/s peak inflow occurring for a 10 minute period

(1) The observed flows at MH3 were due to an abandoned culvert that was connected to the sealed catchbasin downstream of MH2.

(2) The overflow in MH2 occurs prior to the theoretical static head of 650 being achieved. Overflows occured due to the inflow at MH2 exceeding the inlet capacity of the perforated pipes.

Table 7.9: Queen Mary Exfiltration System: Summary of Monitoring Results

Date	Storm Duration (hr)	Rainfall Depth (mm)	Peak Inflow (MH14) (l/s)	Total Inflow Volume (l)	Maximum Filter Head Upstream MH14 (mm)	Maximum Filter Head Downstream MH15 (mm)	Peak Outflow (MH15) (l/s)	Total Outflow Volume (l)	Comments
Sept 25/94 (See Fig. 7.12)	1.5	19.1	52.0	69,891	220	180	6.5	1.89 (1)	No overflow at MH14 Flows at MH15 due to downspouts
Oct 5-6/95 (See Fig. 7.13)	18.0	63.0	17.5	536,961	150	550	10.0	92,215 (1)	No overflow at MH14 Flows at MH15 due to downspouts

(1) Discharge from downspouts.

Table 7.10: Braecrest Infiltration System: Summary of Monitoring Results

Date	Storm Duration (hr)	Rainfall Depth (mm)	Outflow MH2 Main Pipe (Storm Sewer)	Filter Pipe Flow (MH2) (l/s)	Stone Filter Head (m)	Comments
May 26 1994 (See Fig. 7.14)	22.5	28.3	Nil	4.5	0.06	No overflow to storm sewer
May 31 1994 (See Fig. 7.15)	0.5	11.1	Nil	7.3	0.05	No overflow to storm sewer
June 24 1994 (See Fig. 7.16)	24.0	24.1	Nil	3.3	0.023	No overflow to storm sewer
Oct 5-6 1994 (See Fig. 7.17)	18.0	63.0	Nil	3.5	0.0025	No overflow to storm sewer

8.0 PERFORMANCE EVALUATION OF EFS & EES

8.1 Flow Testing

Flow testing was conducted in July 1994 at the Braecrest Avenue and Princess Margaret Boulevard Systems. The flow testing was undertaken to permit calibration of the monitoring devices as well as to observe the performance of the systems.

The monitoring results up to that time had not indicated any overflows or system capacity being exceeded (in particular the Princess Margaret system). However, rainfall events up to twice the original design criteria of 15 mm rainfall had been recorded.

The flow testing procedure involved introducing water into the systems through a fire hose connected to a fire hydrant at the catchbasin locations. The fire hose was equipped with a flow meter to measure the rate of water delivery into the system. Both heads and flows in the system were monitored throughout the flow testing period.

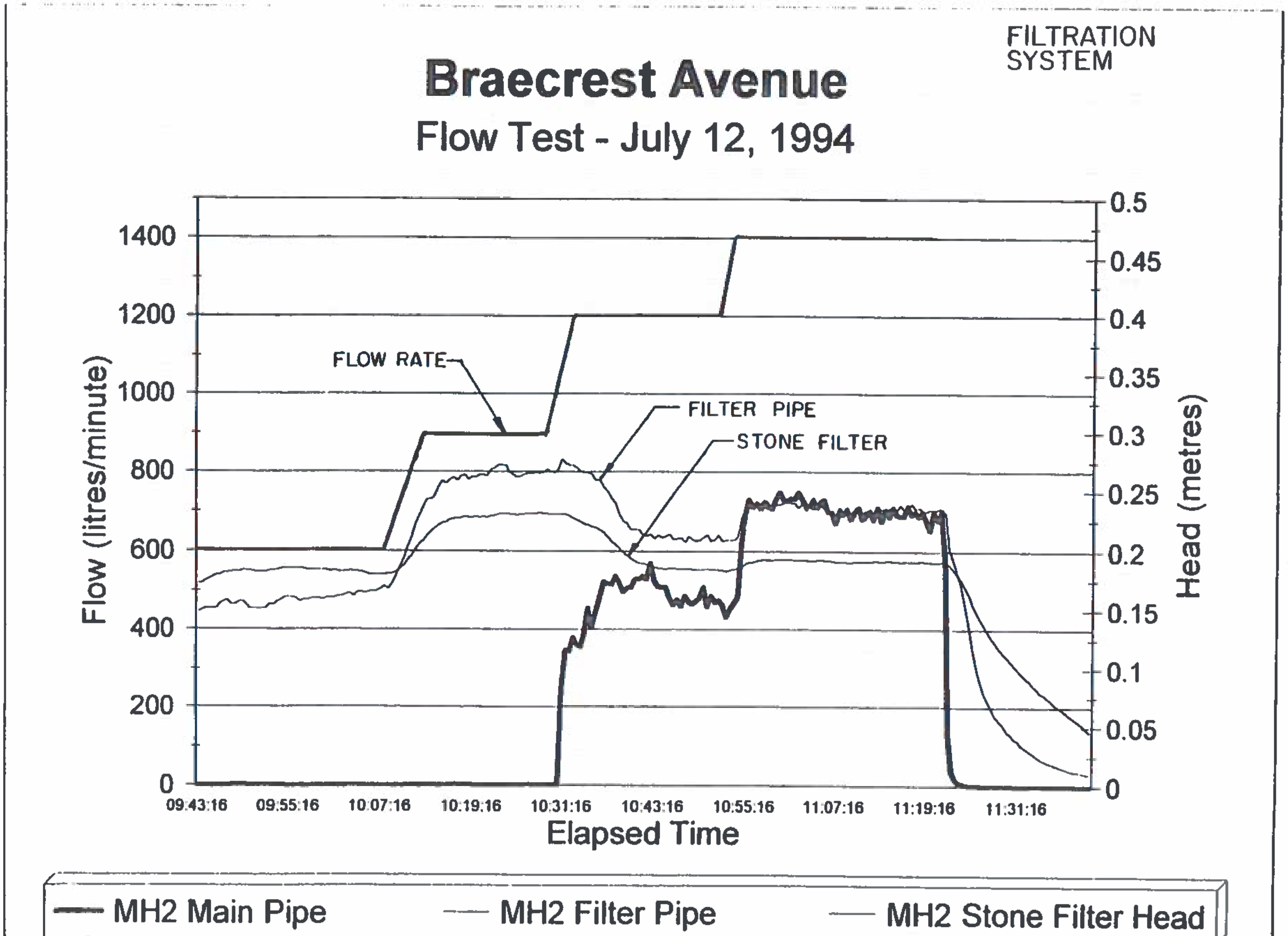
Descriptions of the flow testing procedure and results are described in the following sections.

8.1.1 Braecrest Avenue System Testing

The system consists of the following components:

- The input to the system at the catchbasin location (labelled as "flow rate" on Figure 8.1). The discharge through the perforated filter pipe at the base of the system (labelled as "filter pipe" on Figure 8.1).

- The head or water level in the stone material surrounding the filter pipe (labelled as "stone filter" on Figure 8.1).


FILTRATION
SYSTEM
Braecrest Avenue
Flow Test - July 12, 1994
FLOW RATE
FILTER PIPE
STONE FILTER
Flow (litres/minute)
1400
1200
1000
800
600
400
200
0
Head (metres)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
09:43:16
09:55:16
10:07:16
10:19:16
10:31:16
10:43:16
10:55:16
11:07:16
11:19:16
11:31:16
Elapsed Time
MH2 Main Pipe
MH2 Filter Pipe
MH2 Stone Filter Head
Figure 8.1

- The flow or discharge through the non-perforated portion of the sewer (main sewer pipe) which comprises those flows which do not enter the filtration pipe (labelled as "main pipe" on Figure 8.1).

The results of the flow testing indicated that:

- Flows of up to approximately 900 l/min are accommodated exclusively in the filter pipe. Up to this flow rate there is no discharge through the conventional storm sewer. There is a small increase in head in the stone filter of approximately 25 mm.

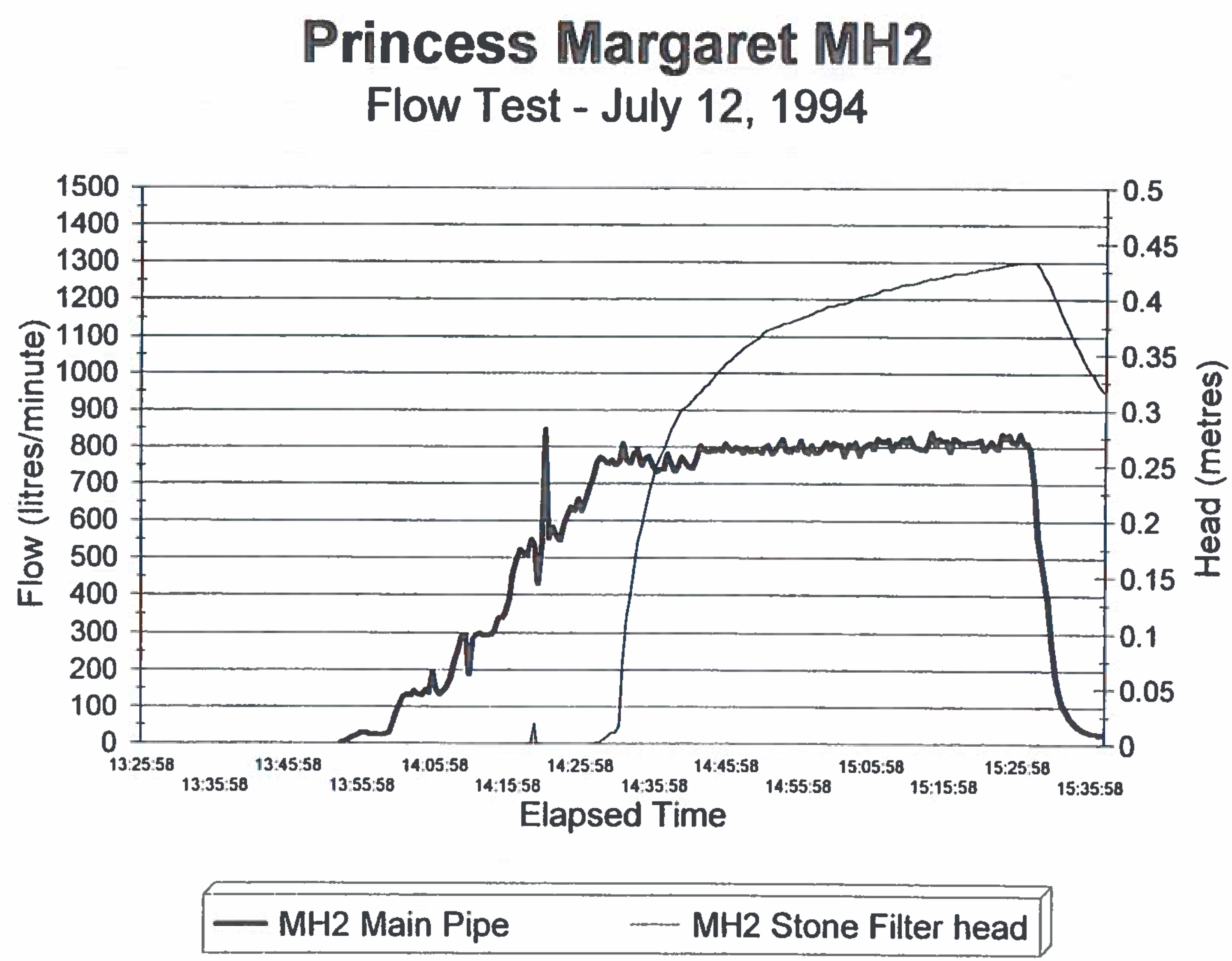
- Flows greater than 900 l/min (15 l/s) will exceed the capacity of the filter pipe and overflow into the conventional storm sewer. As flows enter the main pipe, there is a corresponding small reduction in the flow or maximum capacity seen exiting the filter pipe system. As a result, there is also a small decrease in head in the stone filter. The head in the stone filter decays rapidly after termination of the flow. The flow rate of 15.0 l/s conveyed by the filter pipe, exceeds the peak flow rates measured during the monitoring period.

8.1.2 Princess Margaret Boulevard System Testing

The results of the Princess Margaret Boulevard System Testing are presented in Figures 8.2, 8.3 and 8.4.

In summary, monitoring was conducted at MH2 and MH3. The flows in MH2 represent the inflow to the system and MH3 represent the overflows when the system capacity is exceeded. The depth of water (head) in the stone trench upstream and downstream was also measured.

As indicated in Figures 8.2 and 8.3 an inflow occurred into the system for a period of approximately 45 minutes and reached a peak flow of 800 l/m (13.3 l/s), before any flow was



Princess Margaret MH2
Flow Test - July 12, 1994
Flow (litres/minute)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Head (metres)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
13:25:58
13:35:58
13:45:58
13:55:58
14:05:58
14:15:58
14:25:58
14:35:58
14:45:58
14:55:58
15:05:58
15:15:58
15:25:58
15:35:58
Elapsed Time
MH2 Main Pipe
MH2 Stone Filter head

Figure 8.2

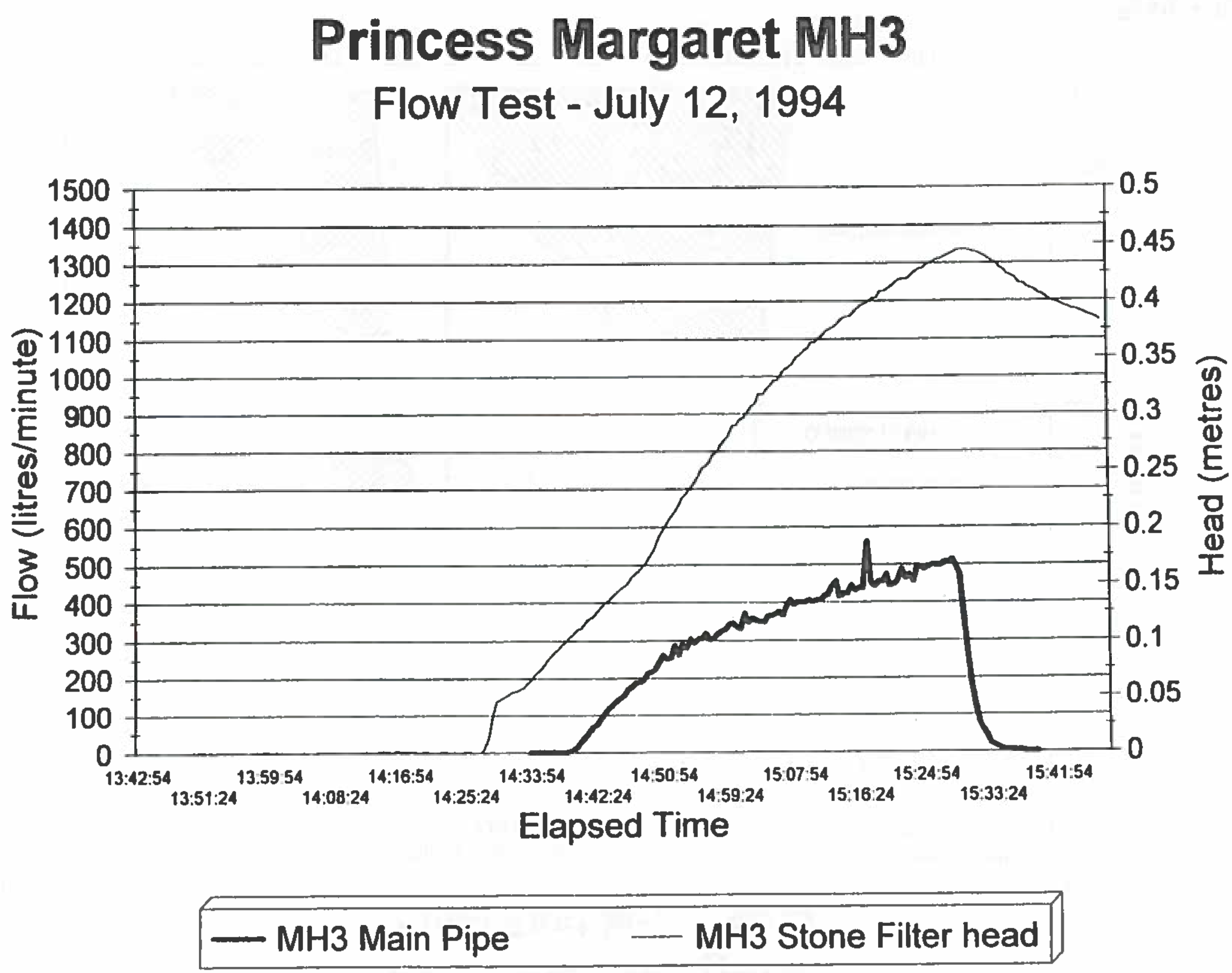

Princess Margaret MH3
Flow Test - July 12, 1994
Flow (litres/minute)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Head (metres)
13:42:54
13:51:24
13:59:54
14:08:24
14:16:54
14:25:24
14:33:54
14:42:24
14:50:54
14:59:24
15:07:54
15:16:24
15:24:54
15:33:24
15:41:54
Elapsed Time
MH3 Main Pipe
MH3 Stone Filter head

Figure 8.3

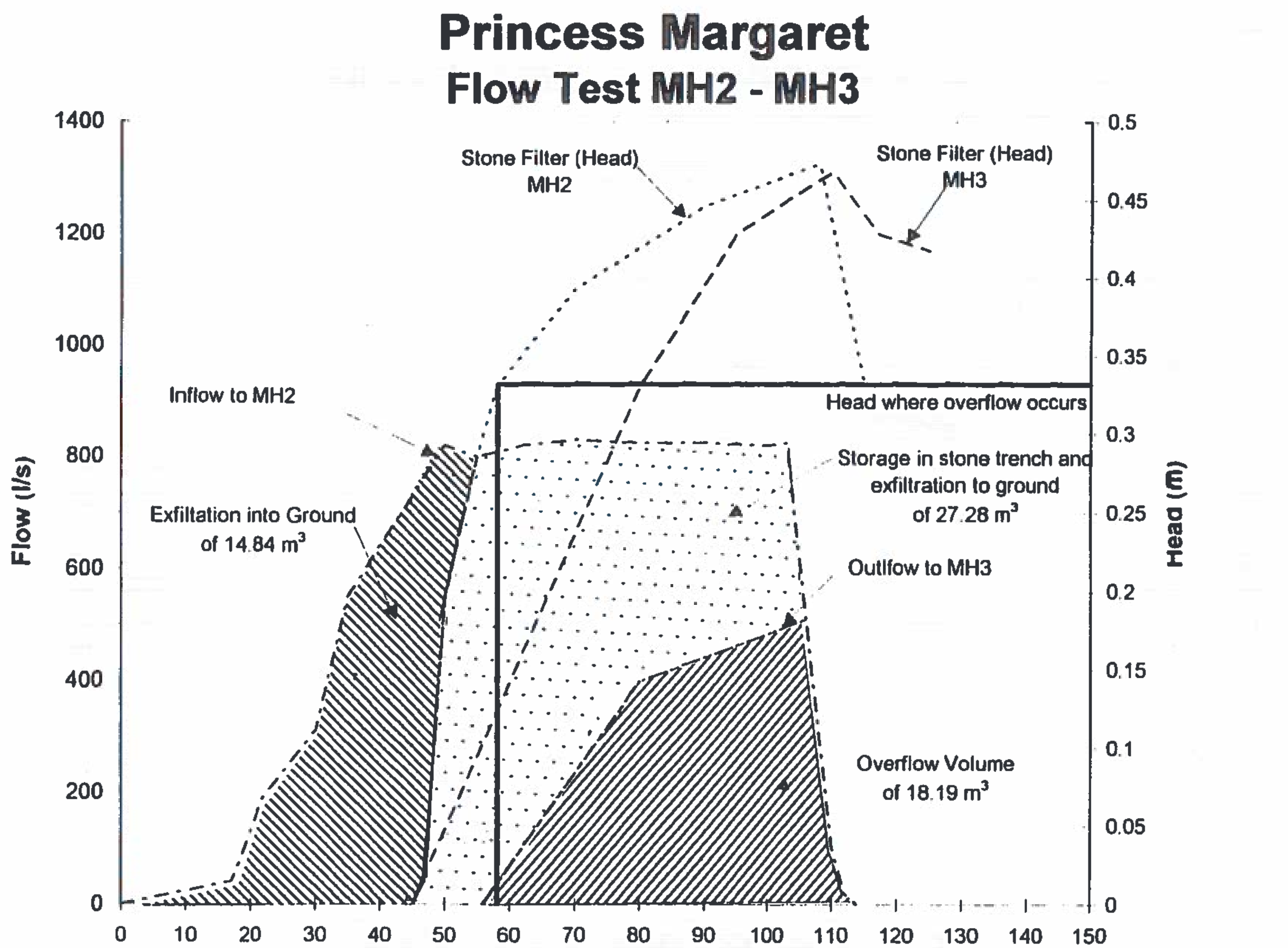

Princess Margaret
Flow Test MH2 - MH3
Flow (l/s)
Head (m)
Stone Filter (Head) MH2
Stone Filter (Head) MH3
Inflow to MH2
Head where overflow occurs
Exfiltation into Ground of 14.84 m³
Storage in stone trench and exfiltration to ground of 27.28 m³
Outflow to MH3
Overflow Volume of 18.19 m³
0
200
400
600
800
1000
1200
1400
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

Figure 8.4

noted in the outlet of the main pipe at MH3. During this period, some water infiltrated into the soil beneath the system while the remainder of water was stored in the voids of the granular material. This is evidenced by the increase in head in the stone filter, which began to occur after approximately 40 minutes. The increase was uniform across the base of the stone filter accumulating to a maximum depth of about 0.45 m. The peak inflow at MH2 of 13.3 l/s exceeded the peak flow recorded for any storm recorded during the monitoring period. This substantiated the findings during the monitoring period that no overflow occurred during the rainfall events.

It was anticipated that once the storage volume of the stone trench had been filled, overflow would occur at MH2 storm sewer and the flow would be recorded at MH3. The rate of overflow increased steadily throughout the testing period. However, at the completion of the flow tests after approximately 110 minutes, the overflow peak was about 500 l/min (8.3 l/s) while the peak inflow was about 800 l/min (13.3 l/s). Thus at that point, approximately 300 l/min (5 l/s) was infiltrating into the base of the system.

It can be expected that the capacity of an infiltration system will steadily decrease with time. Initially, the capacity was high as a result of storage in the stone filter (as noted above), capillary action, and infiltration of water into the native soil around the base of the trench. Once the soil is saturated, the flow will be governed by the permeability and hydraulic gradient prevailing around the base of the trench. This will result in considerably lower infiltration rates than are noted under unsaturated conditions.

As indicated in Figure 8.4, the total runoff volume removed from the system was approximately 42 m^3 of which 14.8 m^3 is exfiltrated. The resulting net storage volume of 27.3 m^3 volume was approximately equal to the theoretical available storage in the stone trench based on a 40% void ratio.

Although flows caused by an overflow condition were recorded at MH3, the recorded depth (0.45 m) in the stone trench did not exceed the design depth of 0.65 m. This would indicate that overflows may have occurred due to either the inlet or conveyance capacities of the perforated pipes being exceeded. These results suggest that the rate of inflow (and consequently, the rainfall intensity) are important design factors that will affect system performance.

8.2 Improvement of Design Algorithm

During this study, three observed storm runoff were input to the design spreadsheet in order to compare the spreadsheet results with the observed results. This exercise could assist in improving the design algorithm of the trench system.

The exfiltration system section on Princess Margaret Blvd. between MH2 and MH3 was chosen. Dimension of the system was measured from design drawings. Field measured hydraulic conductivity was also used.

The spreadsheet results are summarized as follows:

Date	Rainfall Volume (m^3)	Rainfall Duration (hr)	Flow Peak (l/s)	Flow Volume (m^3)	Available Volume (m^3)	Required Volume (m^3)
May 26/94	249	22.5	9.7	73.7	70.6	72.7
May 31/ 94	99	0.5	8.1	28.3	70.6	27.9
October 5/95	554	18	10	130	70.6	129.1

According to the flow monitoring results, the available storage in this section was able to accommodate all the above runoff but the spreadsheet results indicated that more storage was required for the May 26, 1994 and October 5, 1995 runoff. Therefore the design algorithm tends to oversize the system.

The current design algorithm of the trench system is based on solving the water budget equation and an equation governing the outflow of the system. This algorithm considers the trench system as one whole unit that ignores the interaction among different components within the system. While this algorithm may be adequate for design purpose, improvement must be made if prediction of system performance is essential in the future.

The most critical section in the algorithm need to be improved is the equation governing the outflow of the system. The current equation, Darcy's law, was derived for homogeneous permeable media under saturated condition. It was observed in this project that the outflow could be much larger under unsaturated condition. Therefore better simulation result can be achieved by developing an improved equation.

9.0 OPERATION AND MAINTENANCE

9.1 Regular Maintenance and Observation Program

During the monitoring of the three demonstration systems, a regular maintenance and observation program was undertaken. The purpose was to qualitatively describe the ongoing working conditions of the system, and to repair and clean minor deficiencies that occurred.

Observations included; the general condition of the manholes, catchbasins, perforated pipes and conventional storm sewers. The observation program involved lifting the manhole lids and assessing the performance. General features noted were:

- Visual evidence of an overflow as manifested by the presence of water staining and sediment accumulation in the conventional storm sewer.

- The water level in the manhole was a critical indicator. If the water level was higher than the invert of the perforated pipes, this would suggest that the perforated pipe was or is currently at capacity, or that it required maintenance. If the water level was below the invert of the perforated pipes, this indicated that the system was performing adequately.

The perforated pipes are plugged at the downstream end of the sewers. A concern is the potential for pressure build-up in the perforated pipes, causing the plugs to be pushed out of the perforated pipes, and creating a short circuit of flow for that length of pipe. This will have to be monitored, and if a problem persists, another method of blocking the flow will have to be implemented.

Another regular maintenance concern was ensuring that the catchbasins were free of debris, and were working properly. If debris such as sticks or leaves were able to enter the system, they could plug either the inlet lead or the main sewer where the lead from the catchbasin is connected.

9.2 Structural Integrity of Roads

During the site visits, the general condition of each of the streets was noted. In general, no obvious signs of distress (i.e. settlement) was noted in the road surface.

9.3 Long Term Maintenance

The long term maintenance of the system depends on several factors that could contribute to the deterioration of the exfiltration and filtration capabilities. There is the concern of sediment buildup in the perforated pipes and the surrounding filter cloth. Over time, sediment will eventually plug the perforations in the pipe and filter cloth, causing the system to short circuit. The water will no longer filter through the stone, but will back up through the system, overflow the perforated pipes, and be discharged into the conventional storm sewer. To prevent this from occurring, the system must be regularly monitored as described above. Hence, it is recommended that the system be video inspected every five years to identify lengths of pipe that have sufficient debris and sediment accumulation that require removal.

9.4 Impacts of Winter Sanding and Salting

Winter salting and sanding operations by municipalities on existing roadways will result in additional pollutant and sediment loadings to the EES and EFS. Records of these operations should be available from municipalities. Depending on the de-icing or traction requirements for a specific location, the annual loadings will vary. In areas where salting operations are primarily undertaken, the sedimentation or plugging of the perforated pipes would not be a concern, as it would in areas where sanding is undertaken. Furthermore with cleaning and sweeping of roadways being a common springtime maintenance operation in most municipalities, the actual sediment loadings reaching the perforated pipes could be further reduced. In addition to surface cleaning, frequent maintenance of the catchbasins would reduce any grit and sand in the catchbasin sumps which would be conveyed into the perforated pipe.

To assess the impacts of sanding operations on the EES, data from the City of Etobicoke Works Department was reviewed for the 1993/1994 winter season.

For the Braecrest Avenue site the total sanding for the winter season was 992.25 kg. Based on a density of 1900 kg/m^3 an annual volume of 0.52 m^3 of sand is estimated. Assuming that this entire sand volume was conveyed to the perforated filtration pipe, it would take approximately 20 to 25 years to fill the perforated pipes. However plugging of the perforations and filter cloth could reduce the performance prior to the entire pipe becoming plugged. By undertaking a regularly scheduled maintenance program including power flushing this situation would not occur.

9.5 Power Flushing

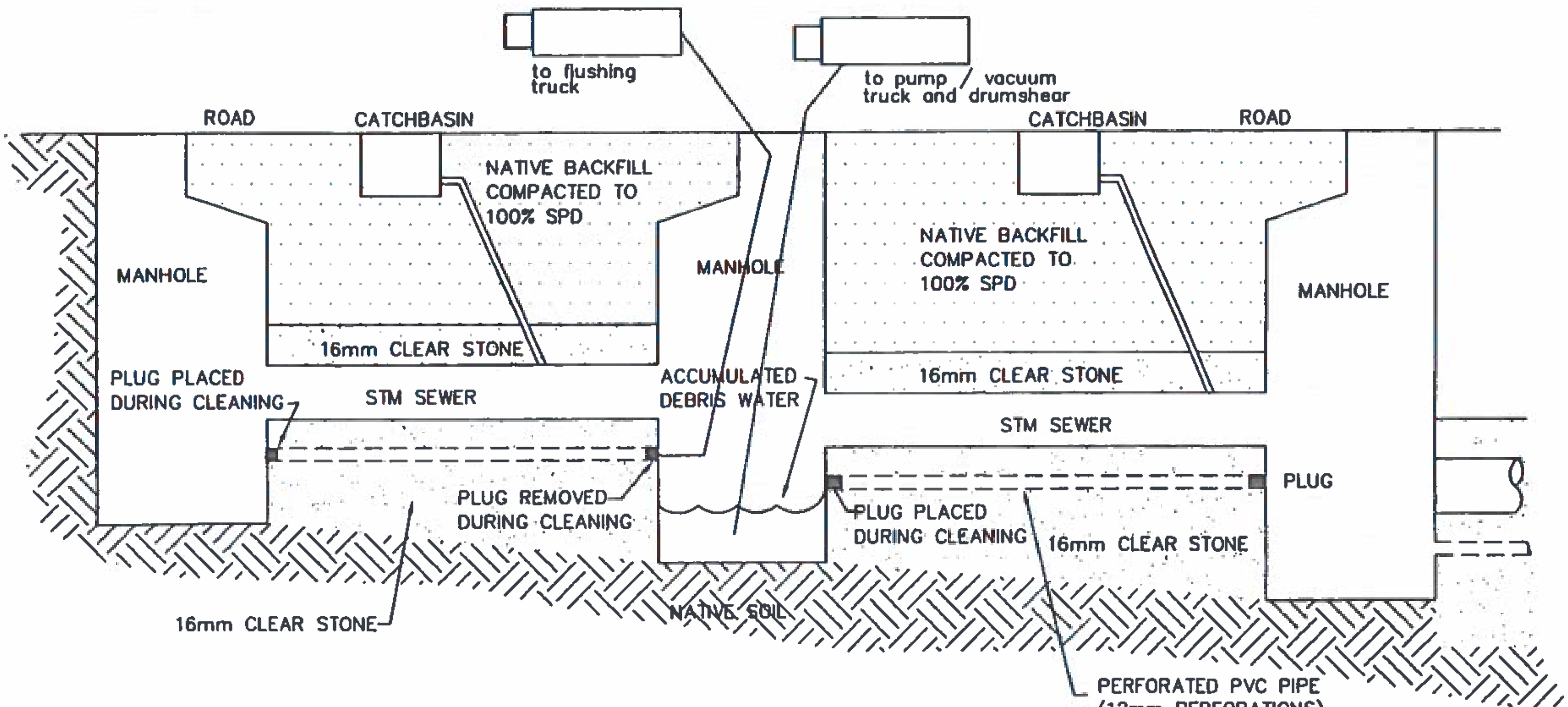
If certain lengths require cleaning, power flushing using a high pressurized water flusher can be applied. The flusher discharges continuous pressurized jets of water that scours the walls of the pipes and pushes the sediment along the pipe length until the sediment is ultimately discharged at the downstream manhole (Figures 9.1 and 9.2). Prior to flushing, the downstream plugs must be removed to allow the sediment and water from the pipes to be discharged into the downstream manholes. These plugs are to be inserted into the upstream pipes of the same manholes that the sediment is flowing to, to allow trapping of sediment to prevent its conveyance downstream.

The debris from the cleaning has to be removed from the manholes. This can be achieved with a vacuum truck which removes all debris and water from the bottom of the catchbasin. There are two options for dealing with the debris and water. The vacuum truck can remove the entire load off-site. Alternatively the accumulated debris and water can be treated on site, using a 'shear drum separator', that will separate the sediment and debris from the water. The water can then be put back into the system. The remaining debris will have to be disposed of off site.

The cost associated with the regular maintenance schedule of the EES/EFS will not increase the existing municipal budget. However, the cost for long term observation and maintenance is an

PRINCESS ANNE CRESCENT,
PRINCESS MARGARET BLVD.
& QUEEN MARY'S DRIVE

EXFILTRATION SYSTEM



SYSTEM FLUSHING

SCALE: N.T.S.

a.m.candaras associates inc.

FIGURE 9.1

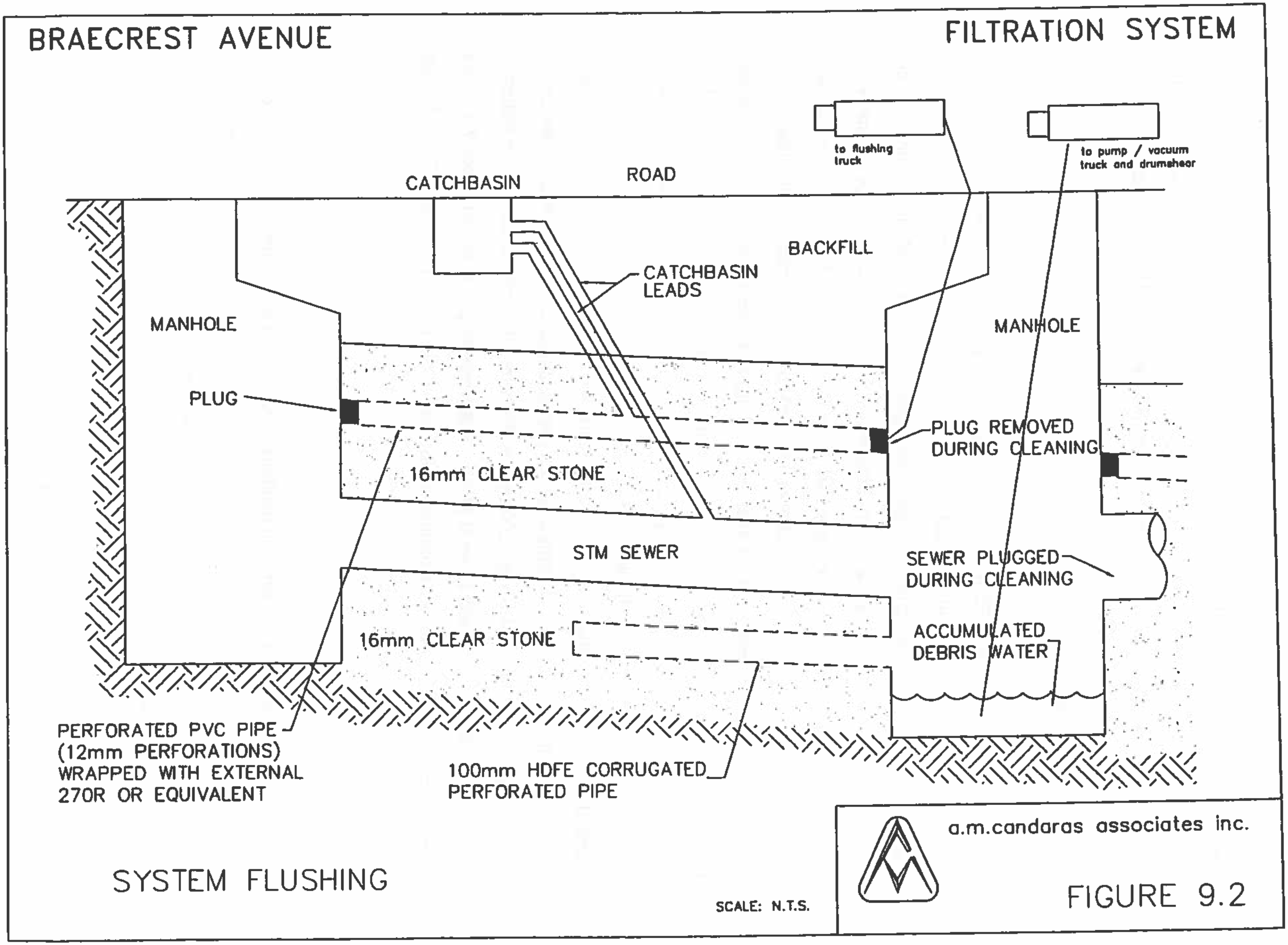

BRAECREST AVENUE
FILTRATION SYSTEM
to flushing truck
to pump / vacuum truck and drumsheor
CATCHBASIN
ROAD
BACKFILL
CATCHBASIN LEADS
MANHOLE
MANHOLE
PLUG
PLUG REMOVED DURING CLEANING
16mm CLEAR STONE
STM SEWER
SEWER PLUGGED DURING CLEANING
16mm CLEAR STONE
ACCUMULATED DEBRIS WATER
PERFORATED PVC PIPE (12mm PERFORATIONS) WRAPPED WITH EXTERNAL 270R OR EQUIVALENT
100mm HDFE CORRUGATED PERFORATED PIPE
SYSTEM FLUSHING
SCALE: N.T.S.
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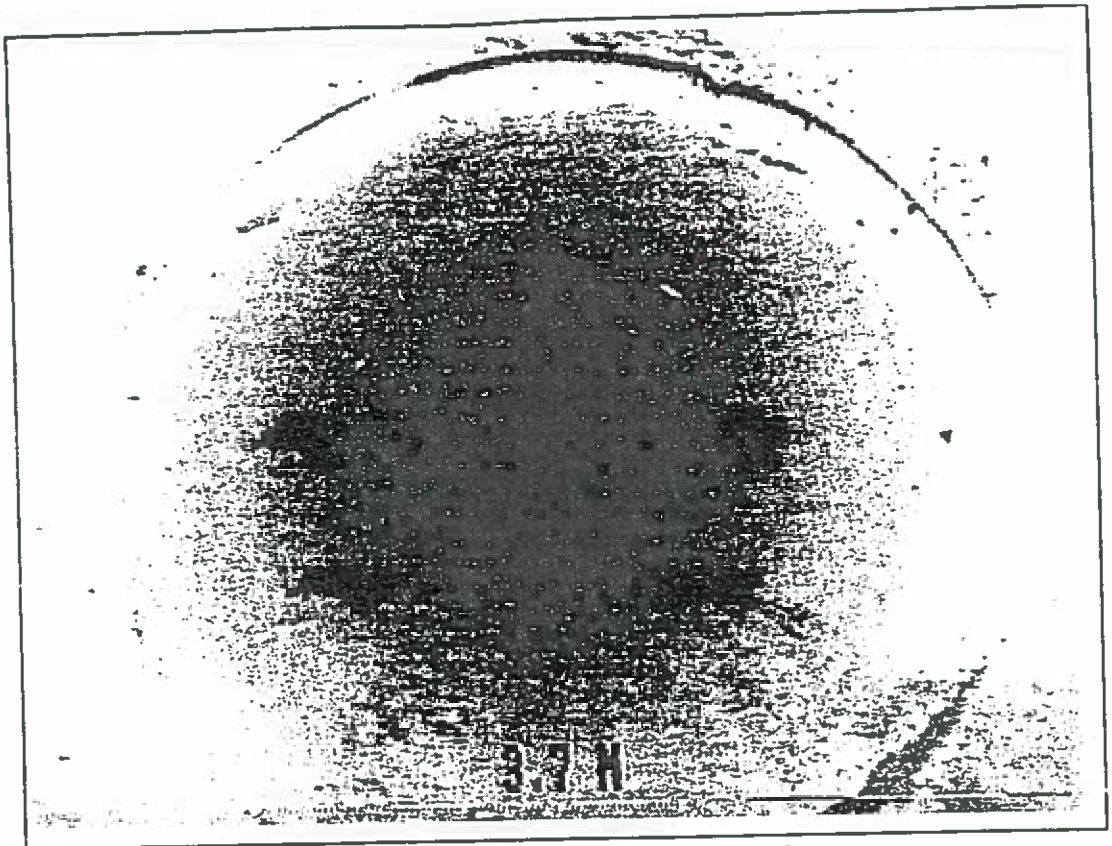
FIGURE 9.2

additional cost. Large municipalities have their own flushers and vacuums. However, the cost to hire a flusher and vacuum contractor, based on 1995 prices, is approximately $1.50 - $2.00/metre. The video inspection of the sewer is approximately $1.25 -$1.50/metre.

9.6 Video Inspection

Video inspection of the EES and EFS was carried out in July 1994 and December 1995 to observe the extent of any sediment accumulation and any damage to the two perforated pipes. In July 1994, almost a year after construction, the perforated pipes between manholes 2 and 3, at the Princess Margaret Boulevard. site, showed very little sedimentation buildup (Photos 9.1 and 9.2). As expected, most of the sediments settled near MH 3, the lowest point. The video camera reached the manhole during this inspection. On December 13, 1995, the City carried out additional video inspections to determine the extent of the sediment buildup after the storm of October (rainfall accumulation of 63 mm). Photo 9.3 shows the buildup of organic material on the obvert of the pipes. This may be due to the floating organic material being subjected to a large hydrostatic pressure during the rain event of October 1995. When the level of the water in the perforated pipes receded, this material adhered to the obvert. Photo 9.4 is about 20 m upstream of manhole 3 and where the video inspection was terminated due the accumulation of sediment. Considering that the pipe shown on Photo 9.4 is only 200 mm in diameter, it is estimated that the sediment buildup is no more than 25 mm with more at MH 3. It is interesting to note that Photo 9.3 which was taken 3.5 m from MH 2 shows a buildup at the top of the pipe. Photo 9.4 (70 m further down) also shows a build up along the top of the pipe and the accumulation of sediment at the invert.

The section of 450 mm storm sewer between manhole 2 and 3 was video inspected for damage and water marks (Photo 9.5 to 9.10). In this instance, the camera was facing upstream and the reduction of the water mark is quite noticeable. Once the camera passed the last catchbasin connection, the watermark completely disappears confirming monitoring data that the system did not overflow. Table 9.1 summarizes the video observations with accompanying photos.



Phote 9.1: Princess Margaret Blvd., July 25, 1994 - Perforated Pipe
Looking downstream from Manhole 2

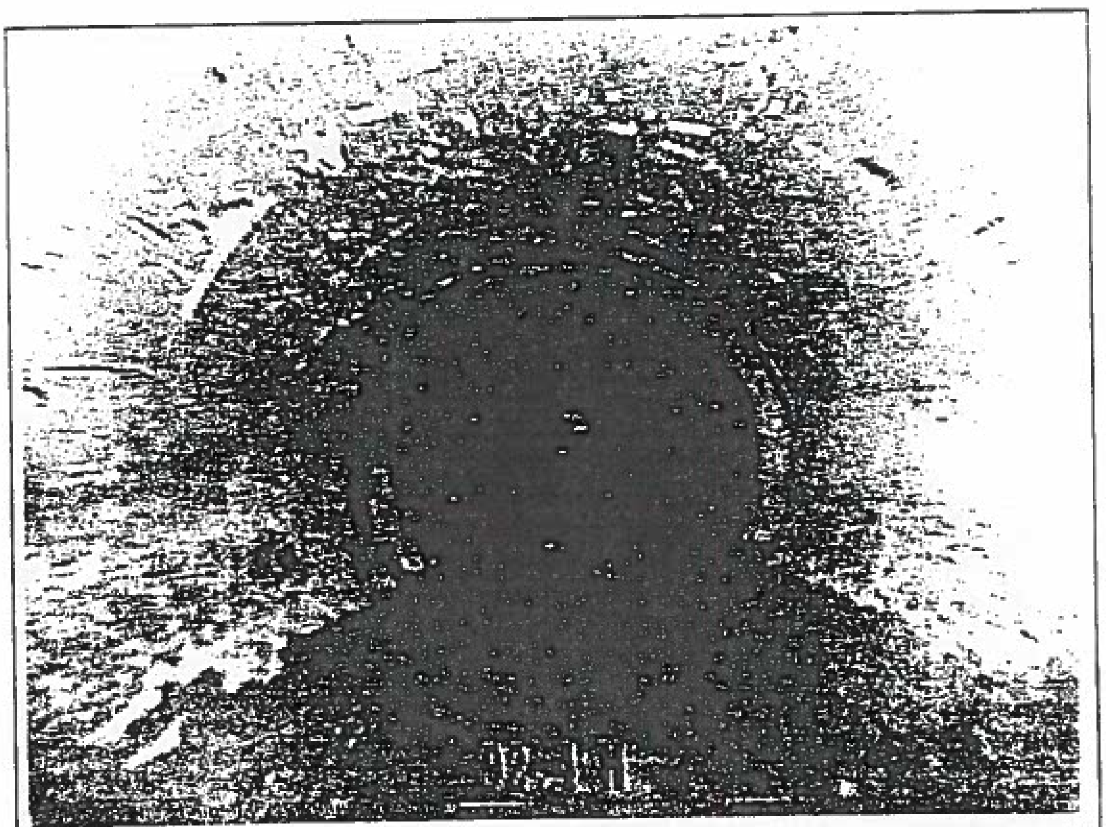


Photo 9.2. Princess Margaret Blvd., July 21, 1994 - Perforated Pipe
Looking downstream near Manhole 3

Phote 9.3   Princess Margaret Blvd., December 13, 1995 - Perforated Pipe Downstream of Manhole 2

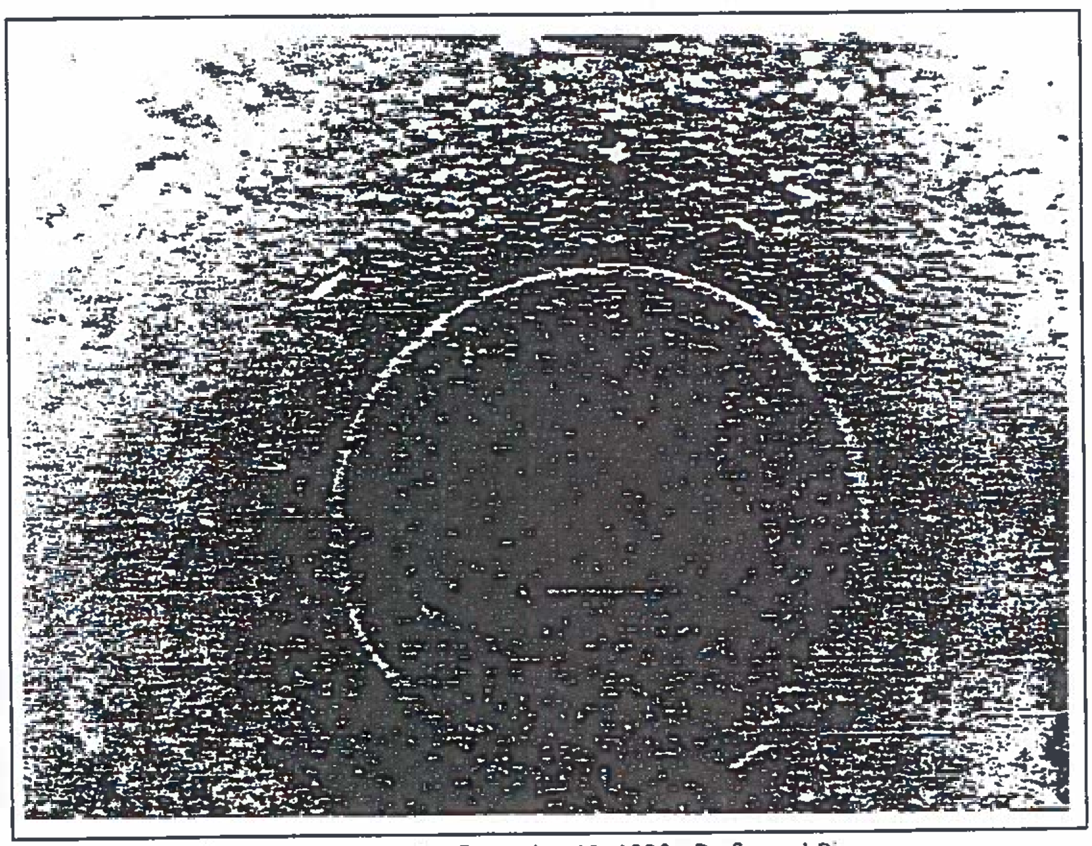


Photo 9.4:   Princess Margaret Blvd., December 13, 1995 - Perforated Pipe Downstream from Manhole 3 (Beginning of sediment)

Phote 9.5: Princess Margaret Blvd., December 13, 1995 - Concrete Pipe Downstream of Manhole 3 {Water mark near springline}

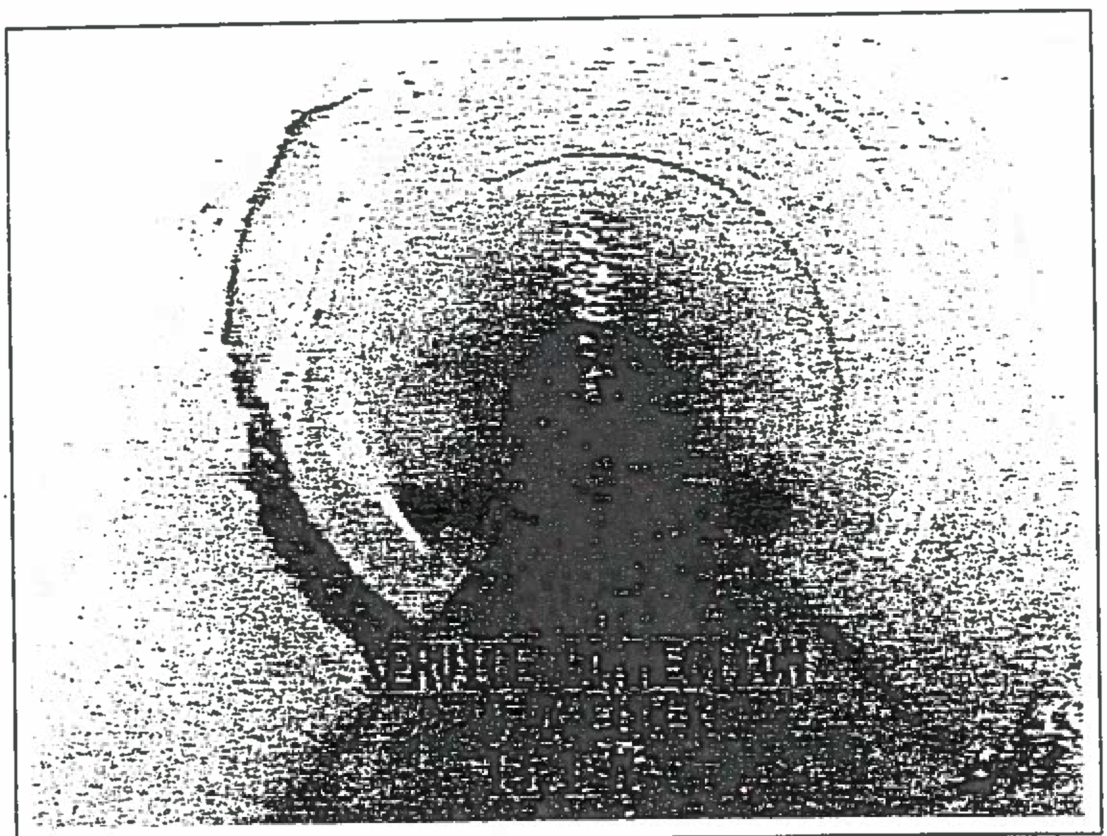
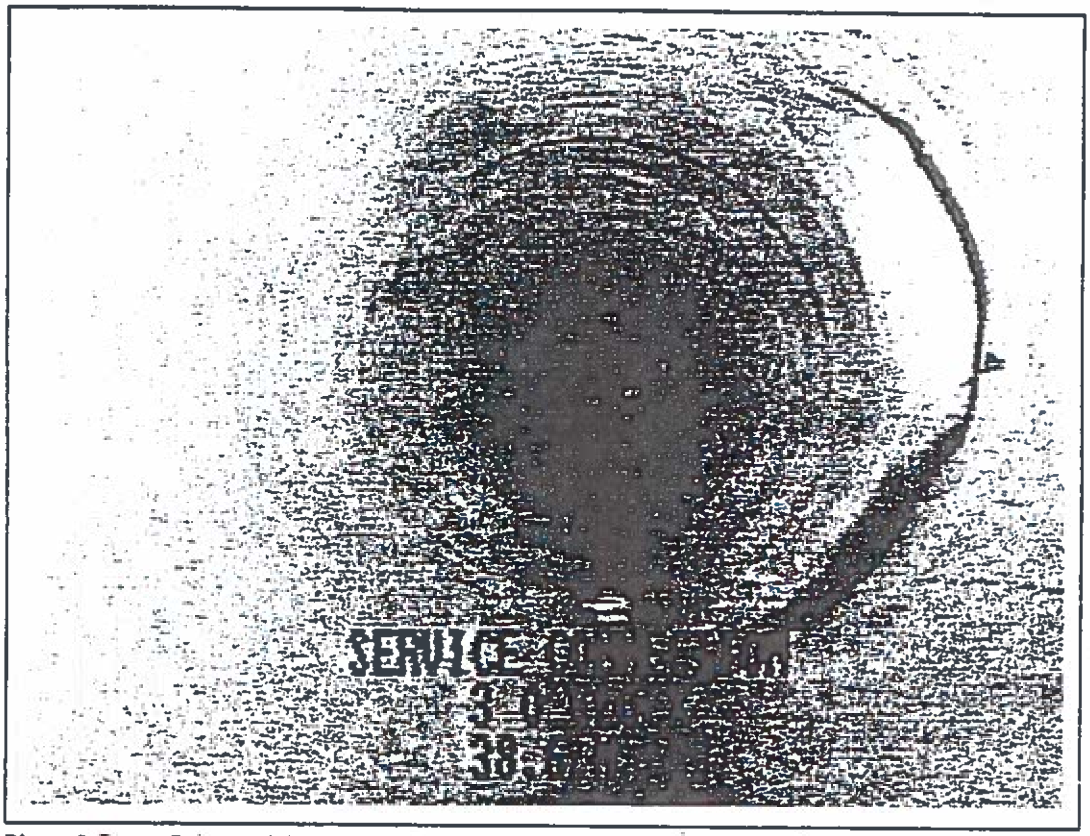


Photo 9.6: Princess Margaret Blvd., December 13, 1995 - Concrete Pipe Downstream of Manhole 3 {Water ponding and lower water mark from downstream weir}



Phote 9.7: Princess Margaret Blvd., December 13, 1995 -Concrete Pipe Downstream of Manhole 3 (Water mark over invert)

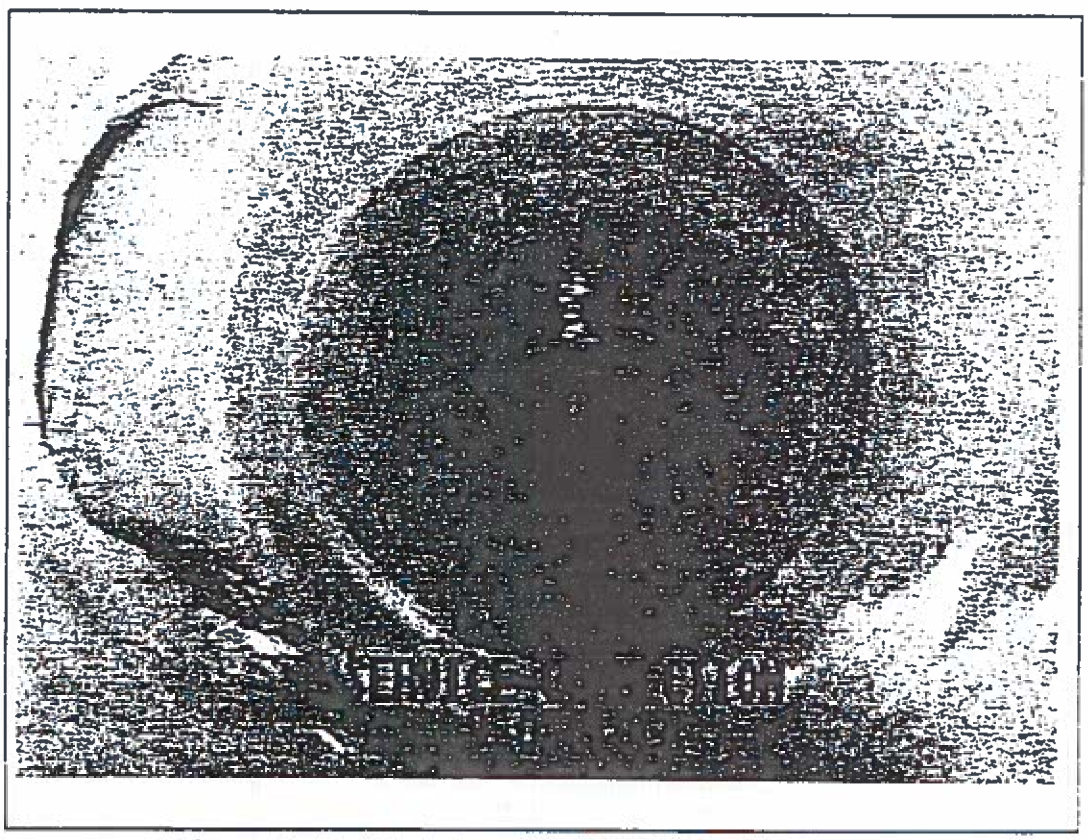
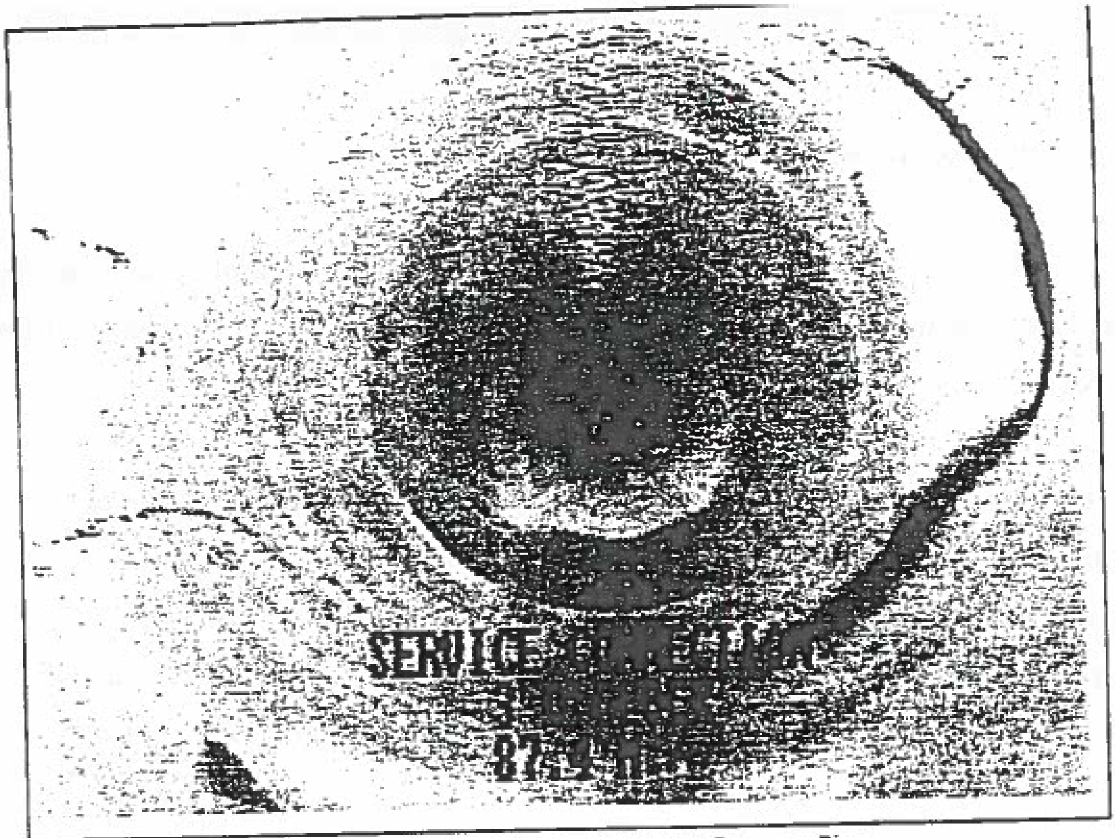


Photo 9.8: Princess Margaret Blvd., December 13, 1995 - Concrete Pipe Downstream of Manhole 3 (Water mark over invert)



Phote 9.9: Princess Margaret Blvd., December 13, 1995 -Concrete Pipe Downstream of Manhole 3 (Minimum water marks and cracks on left side)

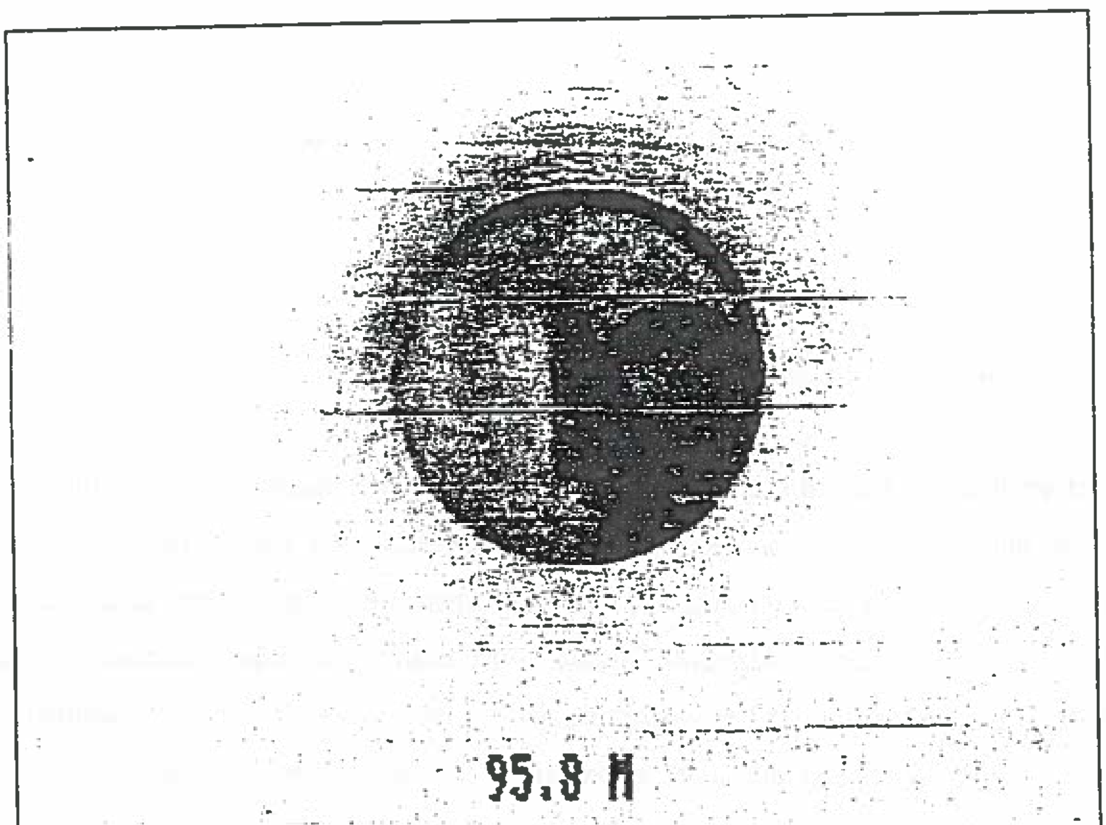


Photo 9.10: Princess Margaret Blvd., December 13, 1995 - Concrete Pipe Downstream of Manhole 3 (No water marks, monitoring equipment in the background)

9.7 Analysis of Accumulated Sediment

On April 17, 1996, sediment samples were collected from the perforated pipes at MH 3 on Princess Margaret Boulevard. These samples were forwarded to AGRA Earth & Environmental for particle size distribution and sediment quality analysis on April 18, 1996.

Since the Etobicoke Exfiltration System on Princess Margaret Boulevard did not experience any overflow since its construction in 1993, it can be concluded that the system provides for 100% removal of suspended solids. The particle size distribution of the sediment that has accumulated in the perforated pipes provides an insight about which particles have migrated through the filter cloth to the surrounding clear stone bedding and which particles have been retained.

The quality of the sediment was analysed to determine the most appropriate disposal method. In addition, the sediment quality analysis will provide an indication as to the ability of the Etobicoke Exfiltration System to contain the pollutants and prevent them from migrating to the ground water table.

Groundwater contamination was not investigated in this study. It should be recognized that these systems do pose a potential source of contamination to shallow aquifers as identified by the U.S. EPA (1994).

9.7.1 Particle Size Distribution

The performance of a Best Management Practice (BMP) is often measured by its ability to remove suspended solids. A common practice is to compare the inflow concentration to the outflow concentration which can lead to erroneous conclusions because of the dynamic character and high variability of the suspended solids concentration. Furthermore, the inflow concentration can vary seasonally (i.e. winter sanding) and geographically (clay soil vs. silty loam). Another practice is to carry out a particle size distribution analysis of the captured sediment and to compare it to literature data. The difference is then the percentage not captured. A more accurate indicator of performance would be the comparison of the particle size distribution at the inlet and the outlet. The difference between the two plots would then show which class of size of particulates has been removed and the corresponding extent of removal.

In the case of the Etobicoke Exfiltration System at Princess Margaret Boulevard, F_{out} is equal to zero for storms up to 63 mm and since no concentration of outflow has been measured because there has not been any outflow, the above equation results in Pe = 100% in most cases.

While it has been established that all sediments carried by runoff to the storm sewers on Princess Margaret Boulevard are prevented from discharging to Silver Creek (the receiving water), the particle size distribution of the sediment found in the perforated pipes is not necessarily characteristic of sediment found in storm water. Clay particles (less than 4 micron) may have escaped through the filter cloth surrounding the perforated pipes and this may explain the low percentage of clay shown on the following Table 9.2.

Table 9.2 shows the comparison between the particle size distribution found in the Etobicoke Exfiltration System and other recent studies. Mr. J. Marsalek of the National Water Research Institute has published his findings in 1995 (Stormwater Pond Sediments: Characteristic, Removal and disposal, 1995) which are based on the sampling of bottom sediment from Colonel Sam Smith Pond, City of Etobicoke, Tapiscott Pond, City of Scarborough, Heritage Estates pond, Town of Richmond Hill and the Unionville Pond in the Town of Markham. The Bluffer's Park Particle Size Distribution is based on the laboratory results of sampling taken at the future site of the Scarborough's Dunker's Flow Balancing System. One sample was taken at five different locations and the average psd is shown on Table 9.2. The Ministry 's Laboratory has a different sizing for Sand (parameter 297- 62-999 micron), Silt (parameter 296 - 2.63 - 62 micron) and Clay (parameter 295 - 0.17 - 2.63 micron), therefore it was found necessary to analyse the unpublished laboratory results (personal communication) to make them compatible with Marsalek's findings

(1995). In Table 9.2, MOEE 94 represents the Particle Size Distribution identified in the MOEE's Stormwater Management Practices Planning and Design Manual, June 1994 (pp 89- Table 3.3) and MOEE 87 represents the particle size distribution found in the 1987 Ontario Urban Drainage Design Guidelines (pp a-97 - Table A-8.4 - Appendix A).

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The sediment collected in the perforated pipes was not construction activities (as outlined in Section 6.2) since mechanical plugs were installed at the upstream manhole to prevent any sedimentation from entering the perforated pipes during the construction period. These plugs were not removed until the road was paved.

9.7.2 Sediment Quality

In addition to the particle size distribution analysis, the sediment samples obtained on April 17, 1996 were also tested for pollutant concentrations for 21 major general chemical and metal parameters. The results are included in Table 9.3, along with sediment quality found in the four previously mentioned ponds and Bluffer's Park.

Section 3.1.3 - Background Stormwater Quality and Table 3.5 have established the existing stormwater quality for Queen Mary's Drive, that because of its land use, is not different from Princess Margaret Boulevard. Both drainage flows are from low residential areas with ditch roads before construction. After construction, Queen Mary's Drive remains a ditch road while Princess Margaret Boulevard is now a curb and gutter. Since there was no monitoring or sampling available before construction, the benefits of road side ditches regarding storm water quality will not be quantified in this report.

Pre-construction stormwater runoff quality of both Queen Mary's Drive and Princess Margaret Boulevard is comparable to residential runoff quality found in Table 9.3 (source: MOEE's Wet Weather Outfall Study 1992).

Marsalek's findings (1995) are based on four ponds of which two are residential ponds, Heritage and Unionville. They represent the (geometric) mean concentrations measured in 80 samples. Bluffer's Park data were provided by laboratory results supplied by MOEE and consist of one sample taken at each of five locations within the embayment. Land use of the drainage area is mostly urban residential with some commercial along Kingston Road. Because the embayment is subject to Combined Sewer Overflow discharging sanitary flow, it is expected that the quality of sediment shows characteristics associated with this fact. In preparing Table 9.3, only the parameters found at station 1(#3105) is shown. Station 1 is the nearest to the outfall.

Of the seven parameters tested by Marsalek, only one (Nickel) shows similar level of concentration as found in the Princess Margaret Boulevard sediment. Of the remaining concentration, the Etobicoke Exfiltration sediment exceeds Marsalek's (1995). The exceedance varies from 20% (Manganese) to 297% (Zinc).

At Bluffer's Parks, 17 comparable parameters were tested and 11 were found to have concentration. Of these, only two parameters (Aluminum and Barium) were found to have greater concentration than Princess Margaret Boulevard sediment. Of the remaining parameters, the exceedance by the Princess Margaret Boulevard sediment varies from 42.85 % (Nickel) to 670% for Zinc.

In general, the sediment at Bluffer's Park contains lower concentration than found by Marsalek (1995). Of the seven comparable parameters, none were found exceeding the geometric mean concentration found in the four ponds evaluated by Marsalek.

The SEL refers to the Severe Effect Level of the Ministry of Environment and Energy's 1992 Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. In these guidelines, three levels of contaminated sediment effects are defined:

- No Effect Level (NEL)

  At this level, no chemical transfer into the food chain is expected. There is practically no restriction on the disposal of such sediment.

- Low Effect Level (LEL)

  No effect on the majority on sediment dwelling organisms. The sediment is considered marginally polluted. Some restrictions on the disposal of such sediment exist.

- Severe Effect level (SEL)

  The sediment is considered too heavily polluted and likely to affect the health of sediment dwelling organisms. Special management plans may be required for the disposal of such sediment, or it may be required to be removed.

For all parameters, the sediment of the Etobicoke Exfiltration System was found to exceed the Low Effect Level and copper and zinc also exceed the Severe Effect Level. In comparison, Marsalek (1995) found no exceedances of the SEL for samples collected from the two residential ponds.

In Table 9.3, MOEE (1997) represents limits drawn from MOEE's Guidelines for Use at Contaminated Sites in Ontario (1997). The Guidelines call for the testing of 21 parameters of which 12 were comparable with the parameters tested on the Princess Margaret Boulevard sediment. Additional parameters need to be tested before disposal. Criteria of the guidelines have two Land Use categories. Within each category, there are criteria for medium & fine textured soil and for coarse textured soil. The two categories of Proposed Land Use are:

- Agriculture/ Residential and Parkland
- Commercial/ Industrial

As shown in Table 9.2, the sediments of Princess Margaret Boulevard consist of less than 70% sand, and under these guidelines, are considered as a medium and fine textured soil.

For Agriculture/ Residential/ Parkland land use, the sediment exceeds many criteria including copper cadmium. The sediment is more suitable for disposal in Commercial/ Industrial Land Use (shown on Table 9.3) except zinc concentration exceeds the zinc criteria. Depending on other parameters to be tested, this sediment may be best disposed at land fill.

In concluding , it is noted that sediment particle size distribution show less clay than found in the sediment from other similar residential areas.

Despite of the fact that it has always been assumed that a higher contaminant concentration can be found in the smaller size particles, the sediment in the Etobicoke Exfiltration System, while coarser, was found to have a higher concentration of contaminants than in Stormwater Management wet ponds and areas subject to Combined Sewer Overflow.

Finally, this section also raises many questions for future monitoring. Some of these are:

- Which particle size fraction contains the highest contaminant concentrations?
- What is the fate of clay particles?
- What is the fate of contaminants as they travel through the ground and their potential for groundwater contamination?
- Should the sediment be removed more frequently than the three year cycle proposed to reduce contaminant concentrations?

9.8 Evaluation of Placing Internal Filter Sock

The feasibility of placing the filter sock on the inside perimeter of the 200 mm perforated pipe was evaluated. At a similar exfiltration type installation, in another municipality, various alternatives were considered.

The difficulty arose in developing a method that provided internal support for the filter cloth along the inside perimeter of the perforated pipe, while being flexible enough to allow for removal. Furthermore when the internal filter cloth becomes laden with sediments, the weight of the accumulated sediments would result in it being torn when removed. Based on the above factors it was concluded that placing an internal filter cloth was not feasible.

Table 9.1: Video Observations (450mm conventional storm sewer)

Photo No	Location	Distance from MH3 (m)	Observations
5	at Manhole 3	0.0	Watermark ½ between Springline & Invert
6	1st connection	13.1	ponding, watermark the same
7	2nd connection	38.6	watermark lower and not as wide but distinct
8	3rd connection	73.6	2-3 in. wide at invert
9	4th connection	87.4	same
10		95.8	no watermark

Table 9.2: Particle Size Distribution
(units in percent)

	Present Study	Marsalek (1995)	Bluffer's	MOEE 94	MOEE 87
SAND (d>0.064mm)	35	20	25	60	94
SILT (0.004<d<0.0064mm)	57	33	53	40	6
CLAY (d<0.004mm)	8	47	22	N/A	N/A

Table 9.3: Sediment Quality

Parameters	Unit	Candaras	Marsalek	Bluffer's	LEL	SEL	MOEE (1997)
Aluminum	ug/g	11,400.0	n/t	15,000.0			
Barium	ug/g	82.0	n/t	89.0			2,000.0
Bismuth	ug/g	9.5	n/t	n/t			
Beryllium	ug/g	0.1	n/t	n/t			10.0
Cadmium	ug/g	4.4	1.2	0.7	0.6	10.0	8.0
Calcium	ug/g	63,200.0	n/t	n/t			
Cobalt	ug/g	8.0	n/t	n/t			100.0
Chromium	ug/g	88.0	48.0	30.0	26.0	110.0	1,000.0
Copper	ug/g	263.0	71.6	28.0	16.0	110.0	300.0
Iron	ug/g	40,200.0	n/t	21,000.0	2%	4%	
Lead	ug/g	214.0	76.4	20.0	31.0	250.0	1,000.0
Magnesium	ug/g	33,700.0	n/t	n/t			
Manganese	ug/g	807.0	667.0	510.0	460.0	1,100.0	
Molybdenum	ug/g	5.0	n/t	n/t			40.0
Nickel	ug/g	30.0	30.4	21.0	16.0	75.0	200.0
Phosphorus	ug/g	1,410.0	n/t	780.0			
Potassium	ug/g	2,420.0	n/t	n/t			
Silver	ug/g	5.0	n/t	n/t			50.0
Sodium	ug/g	2,070.0	n/t	n/t			
Vanadium	ug/g	56.0	n/t	n/t			250.0
Zinc	ug/g	1,001.0	252.0	80.0	120.0	820.0	800.0

10.0 CONCLUSIONS AND RECOMMENDATIONS

The Etobicoke Exfiltration and Filtration Systems were constructed in 1993. The performance of these systems was evaluated using monitoring data collected between May 1994 and October 1995. The following summarizes the major statements derived from this study:

System Performance

- The exfiltration/filtration capacity of the systems exceeded the design runoff from a 15 mm (AES - 1 hour) rainfall event. The systems successfully exfiltrated/filtrated stormwater for events which exceeded the design runoff volume.

- The data suggest that because of the high exfiltration rate of the system, efficiencies can be derived through an optimization of the design which could include a reduction in the sizing of the storm sewer and a reduction in the trench cross section used in the system.

- The design methodology used provides a conservative system design and should continue to be used until an alternate approach is developed and tested against monitoring data collected.

- Stormwater runoff contaminant loadings to surface waters, for catchments serviced by these systems, were virtually eliminated during the period of study. Additional study is required however, to assess the potential impact of these systems on groundwater sources.

Exfiltration System Implementation Constraints

- The system is best suited for low density residential areas where there is a minimum risk of hazardous spills. Goss traps in catchbasins, where the system is implemented, should be used to capture minor spills.

- The system should not be considered for sites close to a water supply aquifer.

- The groundwater table must be below the invert elevation of the stone trench.

- The subsurface soil should have reasonably good hydraulic conductivity (exfiltration potential). The system performed satisfactorily in areas where the hydraulic conductivity of underlying soils measured as low as 1×10^{-7} cm/s. While the filtration system would be better suited for low conductivity soils, a modified exfiltration system (the exfiltration system with the perforated pipe plugs placed further upstream of the downstream manhole) was proposed for these cases because construction of the infiltration system was found to be complicated by the number of pipes used.

Precautions During Construction

- Mechanical plugs should be placed on the upstream side of the perforated pipes during construction of the Exfiltration System to prevent sediments from entering the system. The plugs should be relocated at the downstream end of the perforated pipes when the construction is complete and the site is stabilized.

- All catchbasins should be covered with a heavy metal plate and filter cloth to prevent sediment laden stormwater from entering the system during construction. The plates should be removed when the construction is complete and the site stabilized.

Maintenance

- Maintenance was not required on the system over the two year post-construction operating period of this study.

- Long term system operation will be affected by the buildup of sediments collected within the perforated pipes. Video inspection of the system, after operating for the two year period, showed some sediment accumulation and suggests that video inspection should be conducted on a five year cycle.

- Standard sewer system power flushing procedures were found to be effective in cleaning the perforated pipes of the trapped debris and sediments. This approach is recommended when system cleaning is required. Power flushing should be conducted between maintenance holes. The mechanical plugs should be repositioned to the upstream end of the perforated pipes to ensure that the flushed material is trapped within the downstream maintenance hole and the material removed by vacuum truck.

- There were no visible signs of structural deterioration on road surfaces (e.g. settlement) where the systems were constructed.

Perforated Pipe Sediment

- Particle size analysis on a representative sediment sample collected from a perforated pipe showed it to be coarser (less clay size particles) than stormwater retention pond sediments. This may be attributed to the fact that the capture of smaller particles is limited by the filter cloth mesh size.

- Analysis of a limited set of samples indicated that heavy metal concentrations were generally higher than those of stormwater retention pond sediments. Most parameters exceeded the MOEE's sediment quality guidelines for lowest effect levels, while copper and magnesium concentrations exceeded the severe effect levels. Zinc concentrations also exceeded the MOEE's Guideline for Use at Contaminated Sites (Industrial). These relatively high metal concentrations would suggest that special consideration may be necessary for the disposal of sediment collected.

Future Study Needs

- A monitoring program should be established to assess the overall system performance for the exfiltration system on a longer term basis.

- The longer term maintenance and operation requirements should be assessed. Additional analysis of material trapped within the perforated pipes is warranted and disposal options identified.

- A full cost-benefit analysis should be completed and compared to a conventional system with an end-of-pipe treatment facility.

- An assessment of the potential ground water impact should be conducted.

- A detailed design brief should be developed to include an evaluation of the design parameters and using available performance data, provide an optimization for the design of the exfiltration system.

11.0 REFERENCES

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APPENDIX A

SURVEY OF LOCAL ENVIRONMENTAL PRACTICES

A.0 LOCAL ENVIRONMENTAL PRACTICES

A.1 Survey of Environmental Related Household Activities and Interests

As part of the evaluation of the Etobicoke Exfiltration System, component was undertaken to define potential pollution problems introduced by the system. A survey of residents' habits was undertaken to identify a potential source of pollutants which may find their way into groundwater through the Exfiltration System.

Environment-Related Household Activities and Interest questionnaires were distributed to homeowners who participated in the Rain Barrel Pilot Project in July of 1994. While the profile of respondents may show them to be more aware of environmental issues than the average Metro resident, selecting these recipients of the Rain Barrel Pilot projects provided a greater diversity geographically, ethically, and in age and income.

Out of 100 questionnaires distributed, 65 were returned to the City of Etobicoke. Of these, only 58 were considered completed.

The survey was designed with 20 main questions, which attempted to cover the range of household activities which can be indicators of potential environmental pollution through storm water runoff. Table A.1 shows the responses and percent participation in each activity.

The information provided by homeowners were gathered in strict confidence and cannot be traced back to any individual homeowners. The survey was strictly carried to assist in understanding the source of pollution as related to storm water runoff, to develop an environmental profile of the residents of the City of Etobicoke and to determine the acceptance by the public of the Etobicoke Exfiltration System.

Because the survey was carried together with the Rain Barrel Pilot project, only single dwelling homeowners were targeted and results do not reflect environmental awareness of households in apartments or rental housings, both single and multiple.

Where results are recorded as a percentage, this was rounded to the nearest whole number for ease of presentation and use by the readers.

Survey Results

1. Family Members

It was found that 41 families (71%) have adult only compositions while only 17 (29%) have children. It was originally anticipated that the presence of children will have a positive influence in the household participation in various conservation and environmental initiatives such as recycling and composting. Many environmental programs, such as the Etobicoke Paint-a-Fish, targets children as one means to influence adults toward greater environmental awareness. As the results of this survey will show, the presence of children may not be a major influencing factor.

2. Pets

A total of 16 (27 %) households reported having a dog, 29 (50 %) have a cat and 1 (2%) household even reported having a rabbit. The remainder 12 (21 %) homeowners reported having no pet. It was anticipated that animal faeces form domestic pets may be the major contributor of fecal pollution in the storm water runoff. However, homeowners tended to indicated that their pets were not allowed to run at large and that they took care to dispose of pet waste (Stoop and Scoop) in a proper manner, either through the trash or composting. In other words, there was nothing to be washed down the storm sewers, at least as far as this homeowner sample was concerned.

3. Use of Lawn and Garden Products

This question was designed to gather information on the use of yard chemicals and application rates. Only 2 respondents did not answer this question. Only 7 (12 %) households do use pesticides to control insect pests and 16 (28%) use herbicides. Of the 58 household surveyed, 62% use chemical fertilizers and 21 % use natural fertilizer such as compost. The remainder do not use any chemicals.

The reported application rate for all products follows a distribution pattern skewed toward low-to-moderate use by households involved:

Less than annually (every other year)	3 %
Annually	28 %
Twice annually	66 %
Three times a year	17 %
Four or more times per year	9 %

4. Lawn Watering

This question was designed to gauge the water conservation habit of respondents. A surprisingly large percentage (45 %) of respondents indicated that they water their lawn less than once a week or never. Another 46 % water once or twice a week, and 9 % do it 3-5 or more times a week.

5. Lawn Mowing

Lawn mowing and watering are two activities which are closely related and it was found that 85 % of respondents mow their lawn weekly. Considering that the application rate of fertilizers is only twice a year for the majority, and that 45 % water their lawn less than once a week, this high rate of mowing may indicate the presence of a good topsoil over sandy soil, allowing the grass to grow well without watering. The remaining 15 % of households mow their grass twice a week. The possible use of mulching mowers and lot grades which allow maximum infiltration of precipitation may be additional factors which influence lawn management practices. In addition, landscaping which emphasizes treatments other than grass will have an influence.

6. Grass Cutting Disposal

Three types of disposal were available to respondents. These were mulching, composting and bagging for pickup by municipal collection. Mulching was found to be the most popular (52%), followed closely by composting (50%). Only 19 % of respondents indicated that they bag lawn cutting for composting by municipal services. It is obvious from the results that many respondents use all three methods, resulting in some overlap. It is evident that residents of the City of Etobicoke are optimizing the reuse of this readily available nutrient source for their gardens and lawns, which helps to explain the high lawn growth rate with minimum inputs of water and nutrients described in item 5 above.

7. Lawn Care Company

Only 5 out 58 (9 %) of households surveyed indicated they use a professional service to maintain their lawn. This is an indication that professional services need not be regulated as they may not be the major source of fertilizer and pesticide found in stormwater runoff.

8. Car Care

It is a belief that a major source of phosphate is found in the soap used in domestic car washing. The survey found that 85 % of respondents do wash their own car. On the other hand, 83 % of respondents have their oil changed exclusively at a service station.

The other 17 % who do their own oil change dispose of their oil waste at a waste oil disposal centre such as a Metro Transfer Station.

This bodes well for the Etobicoke Exfiltration System as it reduces the concern of the designers of the system that phosphate and hydrocarbon may contaminate groundwater which will eventually find its way to rivers and lakes.

9. Swimming Pools

It was expected that swimming pool backwash may be a problem, however the survey found only 7 % of respondents have a swimming pool. Of these, 50 % empty their pool to the street and will find its way to the Exfiltration System if located under the road. Another 25% discharge to the basement drain (sanitary sewer) and 25% to yard. The results of this question should be viewed with discretion as the response (7%) is by no means representative of the numbers of pools in Etobicoke.

10. Snow Removal

A total of 67 % of respondents reported using deicing material to supplement shovelling, and 33 % said that shovelling was the only treatment used. Of interest is the distribution of chemicals and materials used:

Salt	31 %
Sand & Salt	2 %
Salt free deicer	5 %
Fertilizer Pellets	3 %
Sand only	19 %
Cat Litter	5 %
Bird Seed	2 %
Total	67 %

It can be concluded that only 33 % of respondents still use salt for deicing and that the majority (67 %) have deliberately found alternatives to salt. This would suggest a fairly well informed public about the effect of salt on the environment.

11. Composter Use

This is a very good indicator of environmental awareness. With 85 % of respondents reporting owning and using a composter, a high level of the 3R's awareness (Reduce, Reuse, Recycle) exists among respondents.

12. Home Heating System

Clearly, Gas Heating is the preferred system with the majority of respondents (79 %). A further breakdown shows that 29 % own and operate a high efficiency gas heating . system, 45 % a have a mid efficiency gas furnace system and 3 % supplement their mid efficiency gas furnace with electric baseboard heaters. Oil is the secondary system with 11 % of respondents still owning an oil furnace. Electric Heating and Heat Pump account for 5 % and 2% respectively. Only 3 % did not answer the question.

Furnace Oil is of concern, despite the fact that only 11 % of respondents still own an oil furnace. Spill studies (Tran et al, 1996) show that furnace oil in existing areas may account for the second highest volume of spill after diesel fuel. This reinforces the decision of the City of Etobicoke to use catchbasins fitted with Goss traps, to capture oil, in conjunction with the Exfiltration System. This may not be a requirement for new developments since most new homes will have a gas furnace.

13. Fireplace Use

There was a 50-50 split for home with a fireplace and those without. Wood burners were predominant with 38 % of homes burning wood only, 2 % combined gas and wood and 7 % of homes reported owning a wood burning fireplace but not using it.

Only 3 % reported owning a gas fireplace. Of those using wood, 90 % reported composting the ash or spreading it on the garden. Again this shows a very high level of environmental awareness in recycling waste ash as garden nutrient.

14. Use of Blue Box

If the response to this part of the survey is an indicator of the public awareness of environmental issues at all, then it can be said that the City of Etobicoke is a recycling community. A total of 98 % of homes reported using the Blue Box programme.

15. Toxic Waste Disposal

Four choices of waste indicators were used in this question. These were paint cans, plastic, chemical containers and used oil. A total of 90 % of respondents answered the question while the remainder either did not answer or said that they did not have this type of waste. For those answering, five mechanisms for disposal were identified. Figure A.1 shows the break down on the use of Disco Road Transfer Station, Toxic Taxi, Environment Day Depot, Blue Box and Garbage. This is the type of question where respondents may have more than one choice. For example a respondent may use the Toxic Waste Taxi, but will also use the waste collection held on Environmental Day by the local Metro Councillor.

The volume of disposal through municipal garbage collection is high, however many respondents stress that this is only done with paint can which have been emptied and cleaned, and non recyclable plastic. Further breakdown by indicators is shown on the following Table A.1.

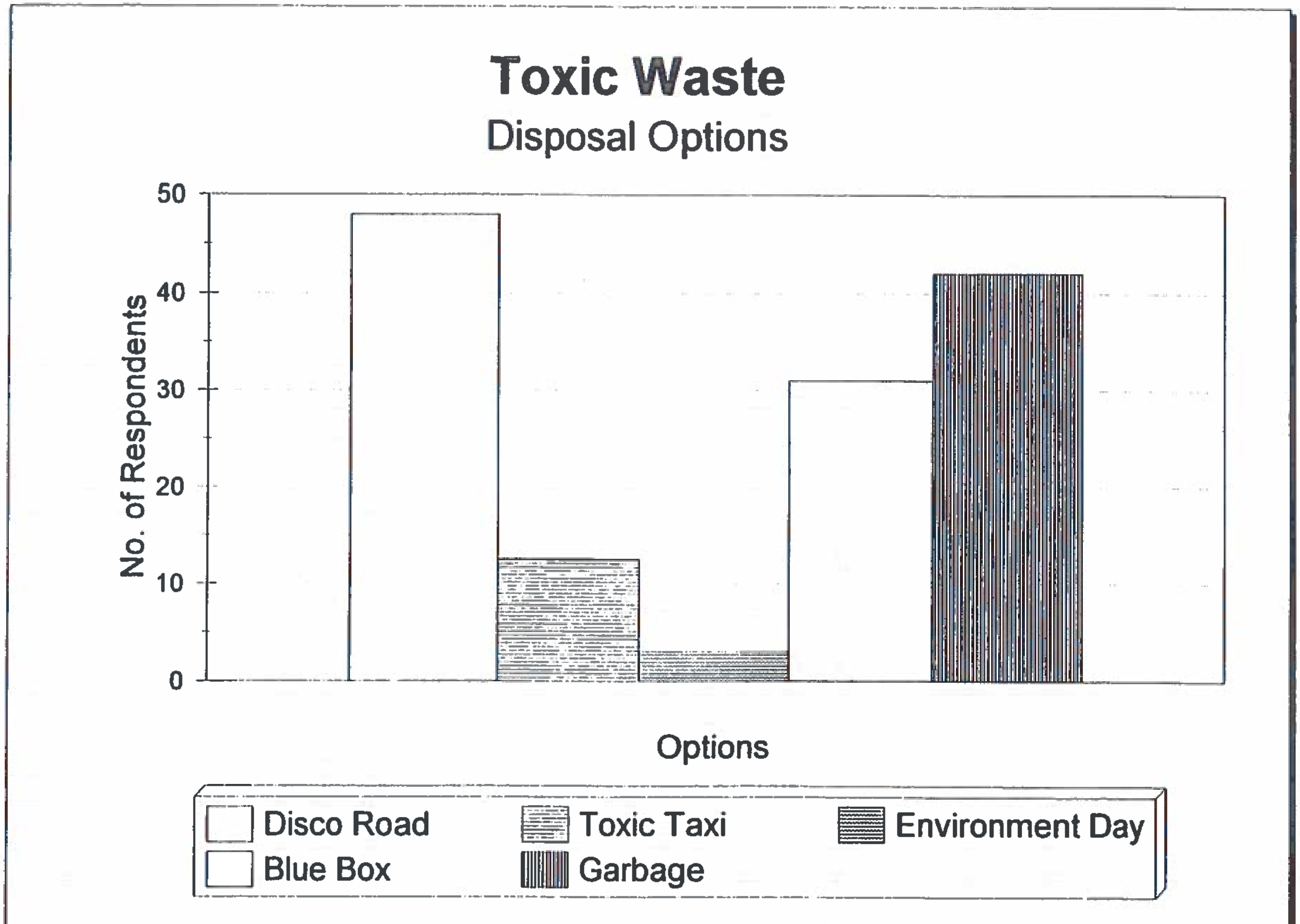
Toxic Waste
Disposal Options
No. of Respondents
0
10
20
30
40
50
Options
Disco Road
Toxic Taxi
Environment Day
Blue Box
Garbage

Figure A.1

These findings clearly indicate that the majority of respondents prefer either to recycle waste or not to generate it at all. When combined with previous findings, it appears that this is an environmentally friendly community with marginal potential to contaminate storm water. Further there is no reason to belief that any illicit dumping of paint or oil into storm catchbasin occurs, given the number of disposal options being used. A review of spills in the City of Etobicoke, as reported to the Spill Action Centre indicates that only three paint spills occurred in 1993 and 1994. None of these were caused by private residents. (Personal communication).

16. Natural Pesticide Awareness

A total of 69 % of respondents were aware of natural alternatives to chemical pesticides. The remainders did know they exist but will look into it. Since only 12 % of respondents use pesticide (see question 3 above), it can be expected that none of respondents will use chemical pesticide in the near future.

17. Natural Pesticide Use

33 % of respondents reported having use natural pesticide. Again this is consistent with the low use of pesticide in the community.

18. Want to attract birds/butterflies

This question was designed to assess the sensitivity of the respondents to other organism than fish and vegetation. Not surprising, most (92 %) responded yes to this question.

19. Remedial Action Plan Awareness

In many way, the City of Etobicoke has carried out many projects in support of the Remedial Action Plan. These include Paint-a-Fish, the Rain Barrel, the naturalization of Berry Creek, the Etobicoke Exfiltration System, the Etobicoke Flow Balancing System, to name only a few. These projects were carried with municipal tax payer's monies. Unfortunately 85 % of respondents were not aware of the Metro Toronto Remedial Action Plan. This does not bode well for public support and future municipal funding support of this important federal/provincial initiative. After all, it has been established through the findings of this survey that his group of respondents is probably above average in environmental awareness, and yet only 12 percent know about the Metro RAP.

20. Additional Information

A total of 78 % of respondents requested further information on a variety of issues, including RAP. These have been provided by the City as a public service.

In conclusion, there is no doubt that the public is receptive to "at Source" initiatives which are within their control. While the number of survey recipients is too low to be representative of the population of the City of Etobicoke, it is anticipated that, if presented as an holistic approach to stormwater management, the Etobicoke Exfiltration System will be well received by the public at large. Further the information and options selected by respondents in this survey could be used in support of the installation of the Exfiltration in other areas and other municipalities by showing how potential sources of pollutant can be eradicated by the effort of local residents.

Table A.1: Toxic Waste Disposal

	Recycle	Garbage	None
Paint Cans	67 %	25 %	8 %
Plastic	62 %	35 %	3 %
Chemical	36 %	21 %	42 %
Used Oil	18 %	2 %	80 %

APPENDIX B

SAMPLE SPREADSHEET OF DESIGN ALGORITHM

For subcatchment: SAMPLE (TWO PIPES SYSTEM)

Given Data:		
Pipes diameter (m) =	0.1	
Length of pipes (m) =	102	
Distance between perfo. pipes / main & perfo. pipe(m) =	0.6	0.3
Thickness of gravel pack under pipe (m) =	0.3	
Thickness of gravel pack beside one side of pipe (m) =	0.45	
Distance from groundwater table to bottom of trench (m) =	10	
Hydraulic conductivity of soil (cm/sec) =	0.001	
Safety factor =	2	
Initial water storage in trench (m^3) =	0	
Soil void ratio =	0.4	
Time step (min) =	5	

Calculated data:	
Exfiltration rate is evaluated by Darcy's law	
Gradient or head loss (m) =	1.07
Area of exfiltration (m^2) =	316.2
Exfiltration rate (cms) =	0.00169
Pipe volume (m^3) =	1.60221
Storage capacity of trench (m^3) =	47.9111
Total volume available (m^3) =	49.5133

Check water balance:	
Total volume of inflow (m^3) =	47.916
Total volume of outflow (m^3) =	47.916
Storage required (m^3) =	32.8402

Time (min)	Inflow (cms)	(I1+I2)/2 (cms)	Outflow (cms)	(O1+O2)/2 (cms)	S2 (m^3)
0	0	0	0	0	0
5	0.00747	0.00374	0.00169	0.0008458	0.86675
10	0.0143	0.01089	0.00169	0.0016917	3.62475
15	0.02139	0.01785	0.00169	0.0016917	8.47075
20	0.02159	0.02149	0.00169	0.0016917	14.4102
25	0.01193	0.01676	0.00169	0.0016917	18.9307
30	0.00632	0.00913	0.00169	0.0016917	21.1607
35	0.00359	0.00496	0.00169	0.0016917	22.1397
40	0.00317	0.00338	0.00169	0.0016917	22.6462
45	0.00352	0.00335	0.00169	0.0016917	23.1422
50	0.004	0.00376	0.00169	0.0016917	23.7627
55	0.0045	0.00425	0.00169	0.0016917	24.5302
60	0.00464	0.00457	0.00169	0.0016917	25.3937
65	0.00507	0.00486	0.00169	0.0016917	26.3427
70	0.00534	0.00521	0.00169	0.0016917	27.3967

75	0.00496	0.00515	0.00169	0.0016917	28.4342
80	0.00449	0.00473	0.00169	0.0016917	29.3442
85	0.00407	0.00428	0.00169	0.0016917	30.1207
90	0.00369	0.00388	0.00169	0.0016917	30.7772
95	0.00334	0.00352	0.00169	0.0016917	31.3242
100	0.00303	0.00319	0.00169	0.0016917	31.7722
105	0.00274	0.00289	0.00169	0.0016917	32.1302
110	0.00248	0.00261	0.00169	0.0016917	32.4057
115	0.00225	0.00237	0.00169	0.0016917	32.6077
120	0.00204	0.00215	0.00169	0.0016917	32.7437
125	0.00185	0.00195	0.00169	0.0016917	32.8197
130	0.00167	0.00176	0.00169	0.0016917	32.8402
135	0.00152	0.0016	0.00169	0.0016917	32.8112
140	0.00137	0.00145	0.00169	0.0016917	32.7372
145	0.00124	0.00131	0.00169	0.0016917	32.6212
150	0.00113	0.00119	0.00169	0.0016917	32.4692
155	0.00102	0.00108	0.00169	0.0016917	32.2842
160	0	0.00051	0.00169	0.0016917	31.9297
165	0	0	0.00169	0.0016917	31.4222
170	0	0	0.00169	0.0016917	30.9147
175	0	0	0.00169	0.0016917	30.4072
180	0	0	0.00169	0.0016917	29.8997
185	0	0	0.00169	0.0016917	29.3922
190	0	0	0.00169	0.0016917	28.8847
195	0	0	0.00169	0.0016917	28.3772
200	0	0	0.00169	0.0016917	27.8697
205	0	0	0.00169	0.0016917	27.3622
210	0	0	0.00169	0.0016917	26.8547
215	0	0	0.00169	0.0016917	26.3472
220	0	0	0.00169	0.0016917	25.8397
225	0	0	0.00169	0.0016917	25.3322
230	0	0	0.00169	0.0016917	24.8247
235	0	0	0.00169	0.0016917	24.3172
240	0	0	0.00169	0.0016917	23.8097
245	0	0	0.00169	0.0016917	23.3022
250	0	0	0.00169	0.0016917	22.7947
255	0	0	0.00169	0.0016917	22.2872
260	0	0	0.00169	0.0016917	21.7797
265	0	0	0.00169	0.0016917	21.2722
270	0	0	0.00169	0.0016917	20.7647
275	0	0	0.00169	0.0016917	20.2572
280	0	0	0.00169	0.0016917	19.7497
285	0	0	0.00169	0.0016917	19.2422
290	0	0	0.00169	0.0016917	18.7347
295	0	0	0.00169	0.0016917	18.2272
300	0	0	0.00169	0.0016917	17.7197
305	0	0	0.00169	0.0016917	17.2122

310	0	0	0.00169	0.0016917	16.7047
315	0	0	0.00169	0.0016917	16.1972
320	0	0	0.00169	0.0016917	15.6897
325	0	0	0.00169	0.0016917	15.1822
330	0	0	0.00169	0.0016917	14.6747
335	0	0	0.00169	0.0016917	14.1672
340	0	0	0.00169	0.0016917	13.6597
345	0	0	0.00169	0.0016917	13.1522
350	0	0	0.00169	0.0016917	12.6447
355	0	0	0.00169	0.0016917	12.1372
360	0	0	0.00169	0.0016917	11.6297
365	0	0	0.00169	0.0016917	11.1222
370	0	0	0.00169	0.0016917	10.6147
375	0	0	0.00169	0.0016917	10.1072
380	0	0	0.00169	0.0016917	9.59967
385	0	0	0.00169	0.0016917	9.09217
390	0	0	0.00169	0.0016917	8.58467
395	0	0	0.00169	0.0016917	8.07717
400	0	0	0.00169	0.0016917	7.56967
405	0	0	0.00169	0.0016917	7.06217
410	0	0	0.00169	0.0016917	6.55467
415	0	0	0.00169	0.0016917	6.04717
420	0	0	0.00169	0.0016917	5.53967
425	0	0	0.00169	0.0016917	5.03217
430	0	0	0.00169	0.0016917	4.52466
435	0	0	0.00169	0.0016917	4.01716
440	0	0	0.00169	0.0016917	3.50966
445	0	0	0.00169	0.0016917	3.00216
450	0	0	0.00169	0.0016917	2.49466
455	0	0	0.00169	0.0016917	1.98716
460	0	0	0.00169	0.0016917	1.47966
465	0	0	0.00169	0.0016917	0.97216
470	0	0	0.00169	0.0016917	0.46466
475	0	0	0.00169	0.0015489	0