20 YEAR PERFORMANCE EVALUATION OF GRASS SWALE AND PERFORATED PIPE DRAINAGE SYSTEMS

Project No. 524 (02)

Submitted to:
Infrastructure Management Division
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Prepared by:
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July 2008 Edition

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Infrastructure and Management Division
City of Ottawa

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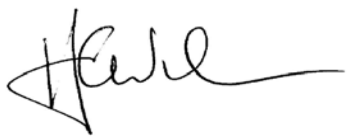

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NOTICE

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PUBLICATION INFORMATION

The *20 Year Performance Evaluation of Grass Swale and Perforated Pipe Drainage Systems* report is available from the City of Ottawa website:

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20 Year Performance Evaluation of
Grass Swale and Perforated Pipe Drainage Systems
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PREFACE

Stormwater management in Canada and other developed countries no longer focusses solely on flood control. Increasingly water quality and erosion control, as well as groundwater recharge, are taken into account. One particular drainage system which has been found to address all of these needs is the combined use of grass swales and perforated pipes (GSPP).

A research study, conducted by J.F.Sabourin in 1991/92, demonstrated that design peak flows from GSPP drainage systems can be as much as 6 to 8 times lower than those measured from a conventional curb and gutter system. In addition, runoff volumes from the perforated pipe drainage systems were found to be similar to runoff volumes from pre-development conditions. A comparison of stormwater pollutant concentrations and pollutant loadings between the conventional drainage system and the grass swale perforated pipe systems indicated that the GSPP systems could provide significant benefits to the local receiving streams

In 1998 a follow-up study to the 1991/92 assessment was undertaken by JFSA. By going back to the same sites it was possible to identify how the performance of perforated pipe and grass swale drainage systems may have been affected with time. The results of the 1998 research demonstrated that the performance of the perforated pipe/grass swale systems had not diminished. At that time the GSPP systems were between 6 and 13 years old.

Although these encouraging and favourable results have been noted, questions remain regarding the longevity and future performance of these systems. The purpose of this 20 Year Performance Evaluation of Grass Swale and Perforated Pipe Drainage Systems is to address those questions about the long-term performance. At the time of this study, in 2006, the investigated systems had been in operation for 14 to 21 years.

JULY 2008 Edition

This July 2008 edition is an update of the 20 Year Performannce Evaluation report published in June 2007. A section reporting on the 2008 winter and spring monitoring of GSPP systems has been included in this edition.

ACKNOWLEDGEMENTS

The 20 Year Performance Evaluation of Grass Swale and Perforated Pipe Drainage Systems was accomplished with the assistance of a number of people and agencies. JFSA would like to thank those individuals and organizations for their time, effort, information and/or loan of equipment.

These individuals and organizations include:

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- Carleton Lodge - Leo Armstrong

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- Avensys Solutions - Peter Seto, Dan Tavares and sales staff

1. INTRODUCTION

This report summarises the work and findings of the 2006 performance evaluation of three City of Ottawa sewersheds. The evaluation was conducted from early August to late November, 2006. The three sewersheds, which are described in Section 2, consist of two serviced by GSPP drainage systems and one serviced by a conventional curb and gutter drainage system. These are the same systems that were evaluated in the 1991/92 and 1998 field studies. A typical GSPP drainage system is shown in Figure 1 below. The locations of the drainage systems studied are shown in Figure 2.

As with past evaluations, the 2006 evaluation included precipitation monitoring, continuous flow monitoring, water quality analyses, video inspections, surface infiltration tests, a system exfiltration test, and surface and vegetation analyses. The monitoring and tests collectively assessed the functioning of the beneficial features of the GSPP drainage systems.

For the precipitation monitoring, two rain gauges were installed close to the monitored sewersheds to continuously record rainfall intensities. The methodology and results of the precipitation monitoring are outlined in Section 3. For the flow monitoring, which is reported on in Section 4, dedicated flow monitors were installed within the pipe systems and remained there for duration of the evaluation.

The water quality of discharge samples collected from each of the three systems was analysed. The methodology and results from the water quality analyses are described in Section 5.

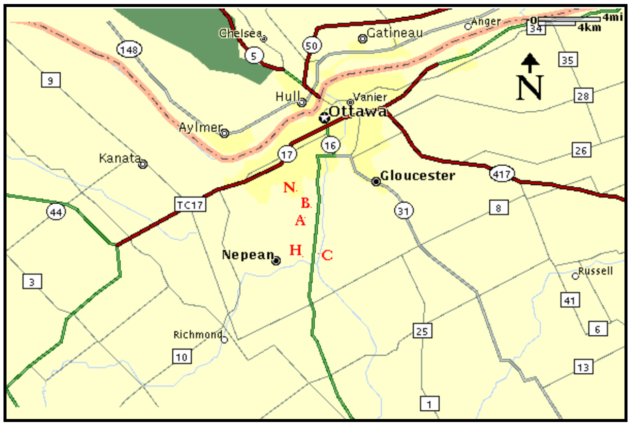
Video inspections of sections of the GSPP systems were conducted in order to assess the general conditions of the pipes and to quantify any deterioration. The methods and findings of these inspections are described in Section 6.

The infiltration tests, described in Section 7, were performed in conventional ditches and in the grass swales of the GSPP drainage systems. The exfiltration test, described in Section 8, was performed in trenches of one of the GSPP systems. This exfiltration test measured the rate at which water in the granular trench below the pipe was exfiltrated to the surrounding native soil.

Soil and grass samples were collected in the grassed swales and analysed for nutrients and metals. The methods and findings of the soil and vegetation sampling and analyses are described in Sections 9 and 10, respectively.

An overview of all the findings and the conclusions drawn from the 2006 evaluation results are included in Section 11.

Figure 1: Streetscape of a typical grass swale and perforated pipe drainage system



General Location of Monitored Areas and Raingauge locations

Monitored Areas

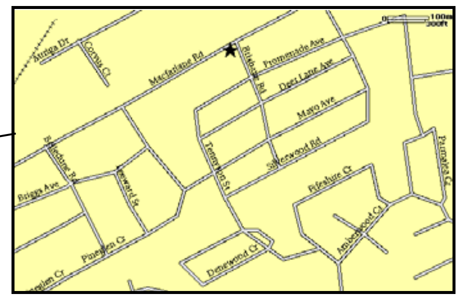
A. Amberwood Conventional System
B. Brisbane Perforated Pipe System
(McFarlane-Pine Glen sub-division)
H. Heart's Desire Perforated Pipe System

Raingauge Locations

N. Nepean Hydro
C. Carleton Lodge

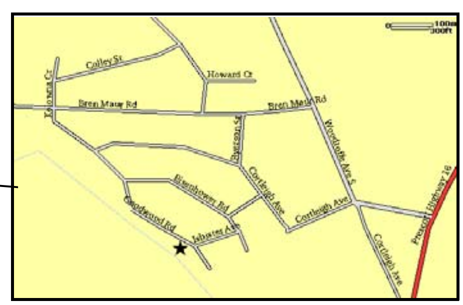
★ Indicates Flow Monitoring Location

Relative location of Monitored Areas and Raingauge locations



McFarlane-Pine Glen Sewershed (perforated pipes/grassed swales)

Amberwood Sewershed (conventional system)



Heart's Desire (perforated pipes/grassed swales)

Figure 2: Locations of Monitored Areas

2. THE SEWERSHEDS

In total three sewersheds, two serviced by grass swale and perforated pipe systems, and one conventional system were monitored and evaluated. The conventional system was included for comparison purposes. The locations of the three sewersheds are shown in Figure 2. The sewershed characteristics are listed in Table 1. Maps showing the sewershed boundary and outflow locations are included in **Appendix A**.

How Grass-Swales and Perforated Pipe Systems Work

Typically, grassed swales are shallow longitudinal depressions, located slightly off the side of the road (see Figure 1). Below the swale, a continuous section of perforated pipes is enclosed within an exfiltration trench of clear stone. Small "T" type catchbasins are installed along the grass swale between each driveway to capture the surface runoff (see Figure 3). The catchbasins are connected to the perforated pipes such that the perforated pipes are left intact and pass through the catchbasins.

Surface runoff from the road and adjacent properties drains to a grass swale where the water is infiltrated or slowly conveyed towards a catchbasin. Water which enters the pipe is exfiltrated to the gravel trench and to the surrounding native soils. When the gravel trench is saturated, and the inflow rate exceeds the exfiltration rate, the perforated pipe works like a conventional storm sewer.

A filter sock surrounds the pipe and prevents sediments from entering the pipe. A geotextile encases the trench to prevent the migration of fines from the surrounding soils into the gravels.

Table 1: Characteristics of the Monitored Sewersheds

Characteristic	Grass Swale / Perforated Pipe Systems		Concrete Stom Sewer System
	Heart's Desire	MacFarlane-Pine Glen	Amberwood Phase 1
Land Use	Residential	Res/Comm	Residential
Sewershed Area	13.64 ha	10.02 ha	12.08 ha
Total Imperviousness	25%	25%	35%
Directly connected Impervious Area	15%	17%	25%
Number of Lots	70	39	82
Average Lot Size[1]	0.20 ha	0.26 ha	0.13 ha
Total Pipe Length	3045 m	2685 m	1204 m
Relative Pipe Length in Sewershed Area	223 m/ha	268 m/ha	100 m/ha
Type of Underlying Soils	Silty Till	Sand/Silty Till	n.d.
Current Age of Subdivision[2]	47-50 yrs	51 yrs	34 yrs
Current Age of Perforated Pipe System[2]	15-21 yrs	14-20 yrs	n.a.

1) Includes Right of Way
2) Based on 2006 as reference year

n.a. = not applicable
n.d. = not determined

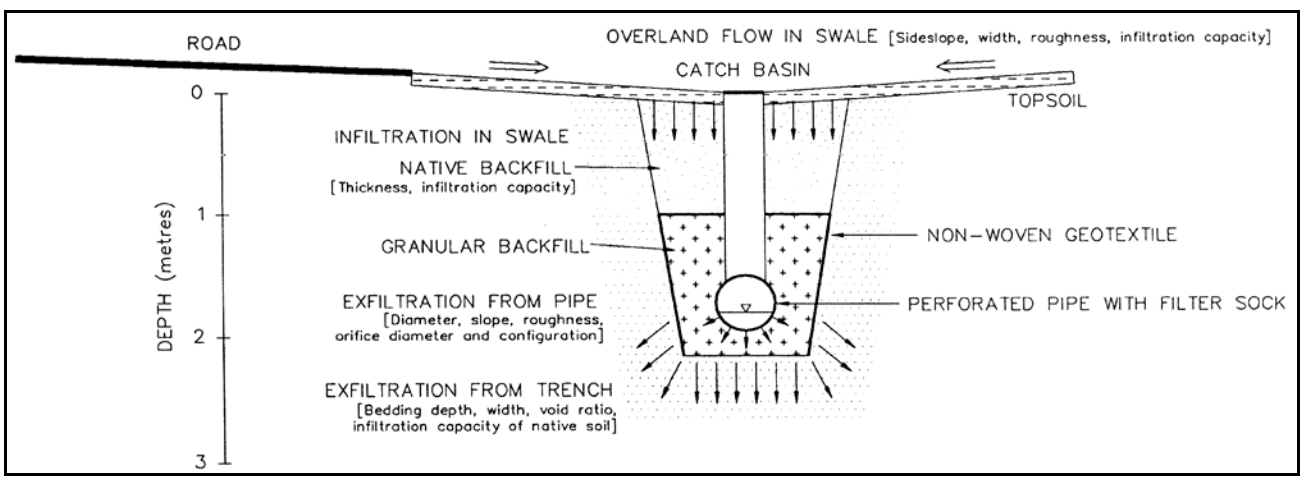


Figure 3: Typical cross section of a grass swale / perforated pipe system

3. PRECIPITATION

Two “Tipping-Bucket” type rain gauges were installed close to the monitored sewersheds (Figure 2). The rainfall was monitored in order to correlate measured flows to actual precipitation. From this correlation, runoff coefficients were determined. A statistical analysis was performed on four significant events, and Intensity-Duration-Frequency (IDF) return periods (RTP) were calculated based on the historical record for the Ottawa International Airport (see Table 2). The most intense of those events have been plotted on an IDF curve, shown in Figure 4. The daily rainfall hyetographs are shown in Figures 5 and 6 and the precipitation totals are included in Table 3.

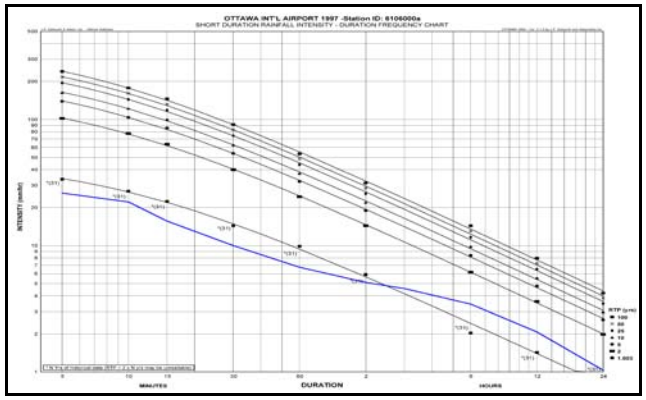


Figure 4: September 18 Event plotted on IDF curves for Ottawa Intl Airport

Table 2: IDF Return Periods (Ottawa Intl Airport) of Significant Events measured at Hydro Ottawa Location

Duration	09/18/06 Event (24.8 mm)		09/23/06 Event (11.8 mm)		10/11/06 Event (21.1 mm)		10/20/06 Event (16.1 mm)	
	Max Int. (mm/hr)	RTP (yrs)	Max Int. (mm/hr)	RTP (yrs)	Max Int. (mm/hr)	RTP (yrs)	Max Int. (mm/hr)	RTP (yrs)
15 min	15.7	<1	14.8	<1	11.3	<1	6.1	<1
30 min	10.0	<1	10.9	<1	8.7	<1	6.1	<1
60 min	6.7	<1	6.3	<1	6.5	<1	5.4	<1
2 hour	5.1	<1	3.4	<1	5.9	<1	4.9	<1
6 hour	3.4	1.1	1.7	<1	3.0	1	2.7	1
12 hour	2.1	1	1.0	<1	1.6	1	1.3	<1

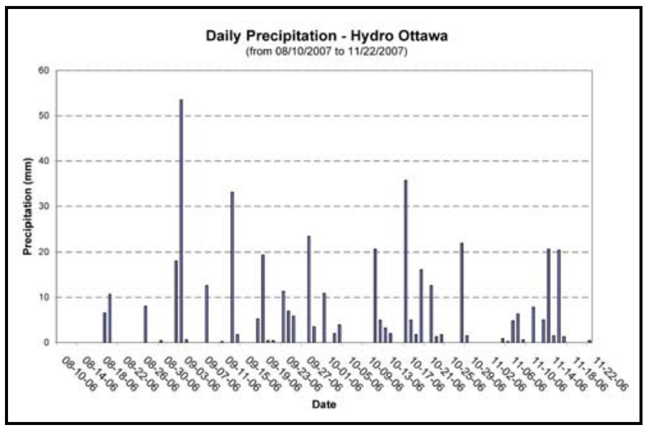


Figure 5: Total Daily Precipitation (Hydro Ottawa)

Table 3: Cumulative precipitation from Aug. 1 to Nov. 31

Station	2006	Normal*
Hydro Ottawa	446.8	N/A
Carleton Lodge	419.5	N/A
Ottawa CDA	476.9	311.1
Ottawa Int.'l Airport	451.9	307.1

* Normals computed as mean of data from 1971 to 2000 (Env. Canada)

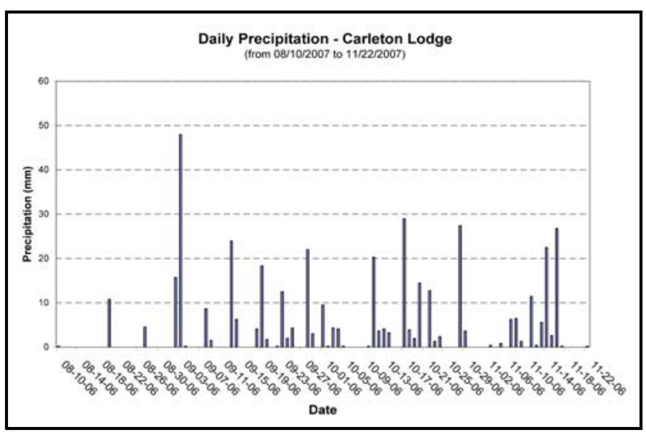


Figure 6: Total Daily Precipitation (Carleton Lodge)

Summary

The two rain gauges recorded approximately the same precipitation events. However, certain events were less intense at Carleton Lodge, and as a result, the total precipitation measured at that site was lower. Nearly 50% more precipitation than the computed normal was received during the monitored period (August 9 to November 22, 2006). A full record of the methods, data and analyses of the rainfall monitoring is included in **Appendix B**.

4. FLOW MONITORING

Continuous flow monitoring was performed at all three locations.* The purpose of the flow monitoring was to compare each system's response to precipitation. As shown in Table 1, the sewersheds have different amounts of contributing impervious area. In order to "standardize" the flow monitoring results, the flow results (in L/s) were divided by the amount of contributing impervious area (in ha). The result of this standardization was a compatible unit of measurement for comparison purposes: L/s/ha of impervious area.

Plotted side by side, the standardized results show that much less water reaches the outlet of the grass swale and perforated pipe systems, than of the conventional systems. Table 4 summarizes the results for four significant events for MacFarlane and Amberwood sewersheds.

Table 4: Comparison of flow monitoring results

Event	Sept. 18 24.8 mm	Sept. 23 11.8 mm	Oct. 11 21.1 mm	Oct. 20 16.1 mm
Total Recorded Volume (L/impervious hectare)				
Conventional	56140	32881	66603	74468
Perforated Pipe	11315	4457	12401	19979
Peak Flow (L/s/impervious hectare)				
Conventional	8.3	8.1	5.7	4.3
Perforated Pipe	1.5	1.1	1.8	2.3
Computed Volumetric Runoff Coefficient				
Conventional	0.08	0.10	0.11	0.16
Perforated Pipe	0.01	0.01	0.02	0.03
Rational Method "C-value" for peak flow computations				
Conventional	0.10	0.09	0.08	0.09
Perforated Pipe	0.02	0.01	0.03	0.05

Note: The Amberwood and McFarlane-Pine Glen sites are approximately 1km from each other and were assumed to be subjected to the same rainfall.

Summary

Peak flows (in L/s/impervious hectare) from the outlet of the perforated pipe / grass swale system were 14 to 53 % of those of the conventional system. Total runoff volumes (in L/impervious hectare) were only 14 to 27% of those for conventional systems.

More information on the flow monitoring sites, methods, data and analyses are included in **Appendix C**.

* The flow monitors were designed, manufactured, installed and operated by Geotivity Inc..

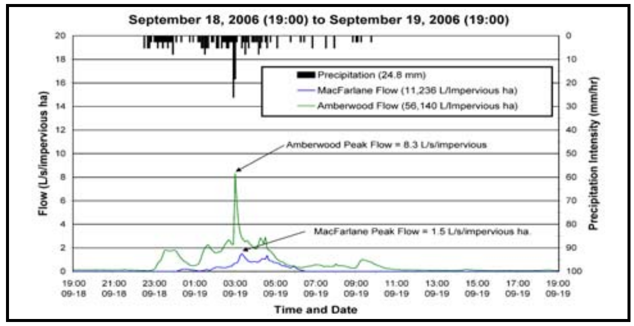


Figure 7: Flow Monitoring Comparison, 24.8 mm event

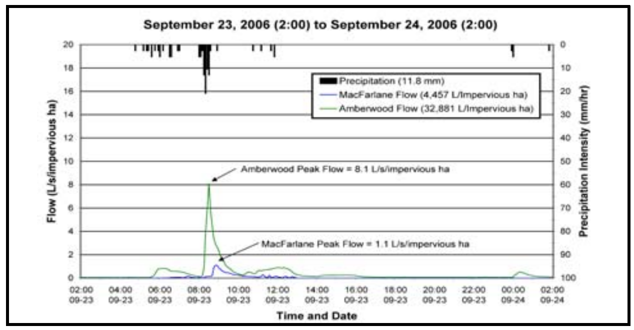


Figure 8: Flow Monitoring Comparison, 11.8 mm event

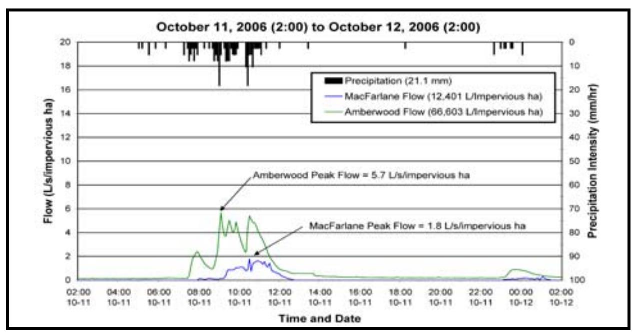


Figure 9: Flow Monitoring Comparison, 21.1 mm event

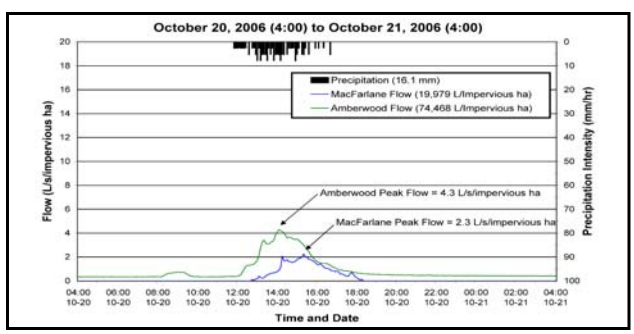


Figure 10: Flow Monitoring Comparison, 16.1 mm event

5. WATER QUALITY

Water quality samplers were installed at all three monitored sewersheds. The samplers were set to take grab samples of the runoff at 20 minute intervals. Samplers were triggered at the beginning of rainfall events, so as to capture "the first flush" of sediments and nutrients. Immediately after the captured event, composite samples were made to represent the first hour, second hour and third hour of the event.

The composite samples were appropriately labelled, kept on ice, and promptly delivered to the Accutest laboratories for analysis.

The purpose for water quality analysis was to compare the concentrations and loadings of the following parameters: Total Suspended Solids, E. Coli, TKN, chloride, TP, COD and metals. A summary of results are listed below in Table 5.

Table 5: Summary of Water Quality Results
Average concentrations of first three hours

Element	Units	AMBER	MCF	HD	PWQO
TP	mg/L	0.25	0.1	0.15	0.03
TKN	mg/L	0.69	0.42	0.38	N/A
Cl	mg/L	32	234	323	250*
TSS	mg/L	24	10	8	80**
pH	pH	7.57	8.11	8.24	6.5-8.5
E.Coli	ct/100ml	1243	13181	1760	100
COD	mg/L	29	13	8	N/A
Al	mg/L	0.11	0.19	0.15	0.075
Cd	mg/L	<0.0001	<0.0001	<0.0001	0
Cr	mg/L	0.002	0.005	0.005	0.009
Co	mg/L	0.0003	0.0003	0.0003	0.0009
Cu	mg/L	0.005	0.004	0.003	0.005
Fe	mg/L	0.55	0.18	0.12	0.3
Pb	mg/L	0.002	0.001	0.001	0.005
Mo	mg/L	<0.005	<0.005	<0.005	0.04
Ni	mg/L	<0.005	<0.005	<0.005	0.025
V	mg/L	0.002	0.003	0.002	0.006
Zn	mg/L	0.02	0.04	0.01	0.02
Hg	mg/L	<0.0001	<0.0001	<0.0001	0.0002

AMBER = Amberwood Conventional System
MCF = McFarlane-Pine Glen Perforated Pipe System
HD = Heart's Desire Perforated Pipe System
PWQO = Provincial Water Quality Objectives (Ontario, 1994)
* = Max. Allowable Conc. for drinking water (CWQG)
** = MNR, Carleton Place (1992)

Comparative pollutant loadings were calculated by multiplying the average concentrations (mg/L) by the expected flow volume (L) for a six month period (May 1 to October 31). The expected flow volume, was computed by multiplying the "normal" rainfall depth (465 mm, from AES statistics), with the sewershed area and then by the runoff coefficients as calculated from flow monitoring and precipitation data. The results are summarized in Table 6 below.

Table 6: Summary of Water Quality Results
Comparative Loadings (kg/ha/6 months)

Parameter	AMBER	MCF	HD	Other Studies
R.C.	0.23	0.11	0.031	--
Area (ha)	12.08	10.02	13.64	--
Volume (m^3)	12983	5129	1980	--
TP	0.27	0.05	0.02	0.45*
TKN	0.74	0.21	0.05	0.448-133*
Cl	34	120	47	65-190***
TSS	26	5	1	240**
COD	31	7	1	135*
Cu	0.0056	0.0019	0	0.045*
Pb	0.0019	0	0	0.25**
Zn	0.02	0.02	0.002	0.20**

Notes: Loadings for this study based on normal precipitation of 465 mm from May 1 to Oct 31 (AES)
R.C. Runoff Coefficient (Seasonal average)
* Shaeffer, Wright, Taggart and Wright, 1982
** NURP Data (half year)
*** General Urban values

Summary

With the exception of chloride, chromium and *e. coli.*, the water quality testing showed that overall the pollutant concentrations measured in the perforated pipe discharge were the same or lower than those measured in the discharge from the conventional system. When a loading comparison was made, the perforated pipes were shown to release significantly less pollutants than the conventional system. This includes significantly less Total Suspended Solids (TSS). Based on the difference in the relative TSS concentrations between the discharge from the conventional systems and the GSPP systems, the reduction represents a potential 81 to 95% sediment removal by the GSPP systems. This is equivalent to MOE guideline's "enhanced" level of TSS removal.

The water quality data, laboratory reports and additional analyses are included in **Appendix D**.

6. VIDEO INSPECTIONS

A Closed Circuit TV (CCTV) video inspection was done of the approximately 1000 metres of the perforated pipes in the McFarlane sewershed and 500 metres of perforated pipes in the Heart's Desire sewershed. The purpose of the CCTV inspection was to assess the general conditions of the pipes and to quantify any deterioration. The pipes were not cleaned before they were videoed.

The video inspection found no indications of collapse or signs of tree-root intrusion. There were only a few anomalous incidences of dents, debris and pipe intrusions in the almost 1.5 kilometres of pipe inspected. Overall, the pipes were generally clean, with very little sediment build up (see Figures 10, 11 and 12). City of Ottawa staff verified that the MacFarlane perforated pipe system has never been flushed since its installation over 20 years ago.

As observed in the 1998 study, discarded wash water was found in the drainage systems, potentially through the residential sump pumps as the sump pumps in these systems are connected to the perforated pipes. These connections were detected in both the MacFarlane and Heart's Desire sewersheds through the CCTV inspection, as large quantities of foamy water were recorded (Figure 13.) The wash water may contribute phosphorus and/or nitrogen to the drainage systems discharge. Unlike the 1998 study, no evidence was found of racoons inhabiting the pipes.

Information on the video inspections sites and additional photos are included in **Appendix E**.

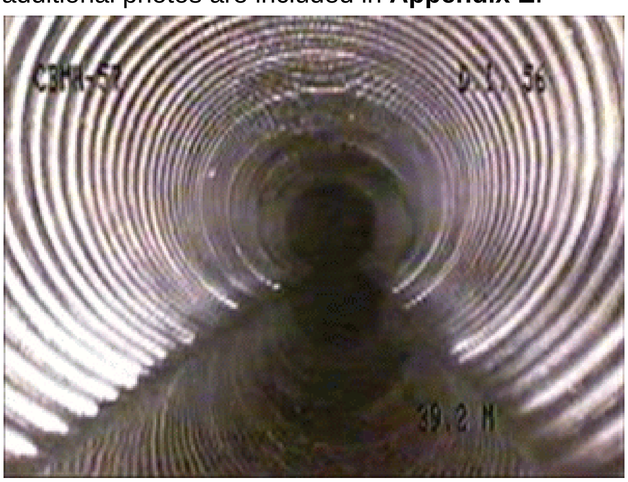


Figure 11a: A frame from the CCTV inspection of the MacFarlane system

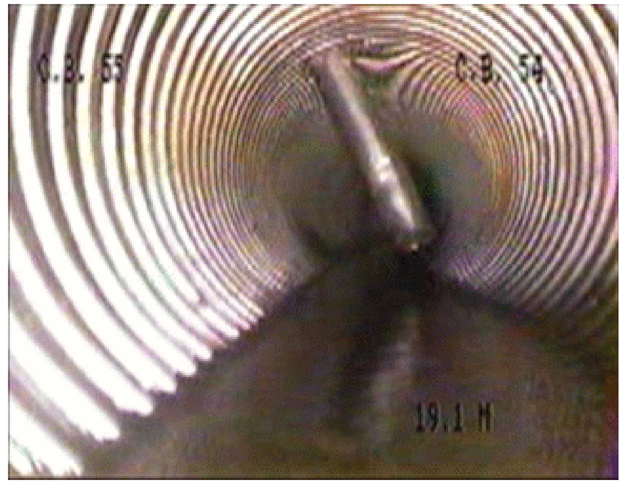


Figure 11b: A frame from the CCTV inspection of the MacFarlane system

Figure 12: A frame from the CCTV inspection of the Heart's Desire system

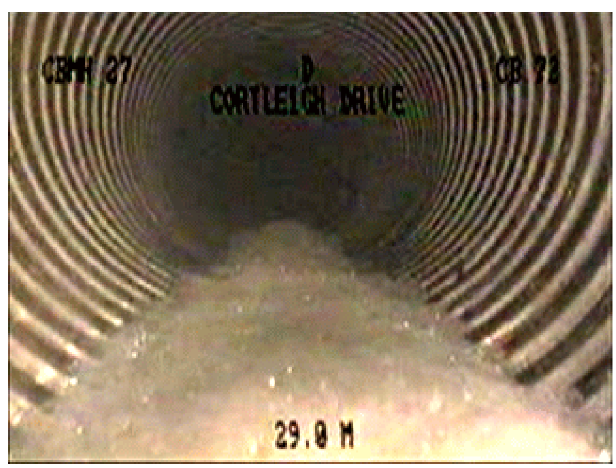


Figure 13: A frame from the CCTV inspection of the Heart's Desire system

7. INFILTRATION TESTS

Infiltration tests were performed over grass swales in the MacFarlane, Heart's Desire and Amberwood sewersheds. The purpose for the tests was to evaluate the infiltration capacity of the swales and to assess any changes in infiltration rates over time.

Over twenty infiltration tests were completed: thirteen in grassed swales and seven in ditches. Table 7 presents a summary of findings and Figures 14a and 14b depict the results graphically. The infiltration rates determined by the field tests are typical for silty loam to loamy sand soils.

Table 7: Summary of Infiltration Test Results

Address	Type of System	Final Infil'n Rate (mm/hr)
Corner of Isbister and Goodwood	Swale	5
28 Goodwood	Swale	10
4 Pineglen	Swale	6
13 Goodwood	Swale	5
68 Eisenhower	Swale	8
14 Brisbane	Swale	9
10/14 Mayo	Swale	9
2 Brisbane	Swale	5
Corner of Brisbane and Deerlane	Swale	5
SE Corner of Briggs	Swale	5
9 Promenade	Swale	4
16 Brookdale	Swale	4
17 Greenside	Swale	1
2081 Merivale	Ditch	2
68 MacFarlane	Ditch	10
13 Newland	Ditch	12
6 Kelowna	Ditch	6
90 MacFarlane	Ditch	5
Corner of MacFarlane and Greenside	Ditch	3
94 MacFarlane	Ditch	10

The infiltration rates determined for the two grass swale sites also used in the 1998 site are an order of magnitude lower than the infiltration rate determined in the 1998 study. This may be indicative a decrease in infiltration capacity or of a greater saturation of the soil. The infiltration rate determined by this study for the ditch site also used in the 1998 site was comparable to the rate determined by the 1998 study.

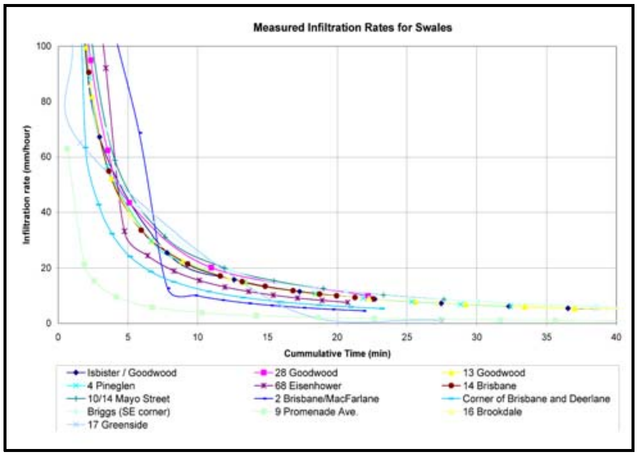


Figure 14a: Infiltration Rates over Grass Swales (Ottawa)

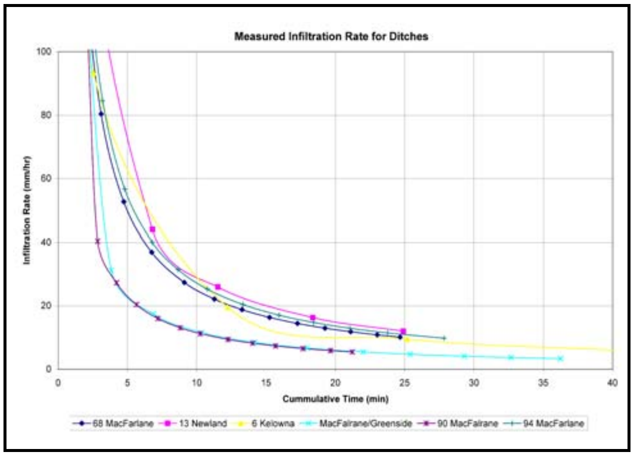


Figure 14b: Infiltration Rates over Conventional Ditches Systems (Ottawa)

Summary

The infiltration capacities of the grassed swales tested were shown to be optimum in that the swales allowed for proper drainage, yet would hold enough moisture to sustain grass/plant life. The grass swale infiltration rates determined by this study remain within the range typically assumed for permeable grassed surfaces.

Information on the infiltration test methods and sites, along with the data and analyses, are included in **Appendix F**.

8. EXFILTRATION TESTS

Exfiltration tests were performed in order to measure the rate at which, water in the granular trench below the pipe can be exfiltrated to the surrounding native soil. The tests were done for a trench within the McFarlane sewershed. For comparison purposes most of the trench which was tested in 1992 and 1998 study was tested in this study.

The exfiltration tests were performed by injecting water at a constant flow rate into an upstream catch basin. A flow monitor located approximately 265 metres downstream of the injection point measured the outflow. The test continued until a somewhat constant outflow had been sustained for over one-hour. The difference between inflow and outflow was what was exfiltrated. The exfiltration rate in (cm/hr) was calculated by dividing this difference by the surface area of the trench over which the water was exfiltrating. Results are summarized in Table 8 below.

Table 8: Summary of Exfiltration Results

Year	1992	1998	2006
Volume in (m^3)	82	76	110
Volume out (m^3)	33	36	69
Duration of inflow (hr)	2	2	3
Exfiltrated volume (%)	60	53	37
Length of system (m)	338	338	265
Exfiltration (cm/hr)	3.5	4.2	3.7
Peak inflow (L/s)	9.8	11.6	9.8
Peak outflow (L/s)	6.3	7	6.9
Approximate Outflow RTP (yrs)	2	2	2

Findings

The exfiltration performance of the perforated pipe system section as tested has not diminished over the years. When the longer test time, greater volume of water and shorter test section are taken into account the exfiltration in the 2006 test is shown to exceed that determined by the 1998 test. Exfiltration tests demonstrate that perforated pipe systems can reduce the runoff-volumes by 35% to 60%. With a direct connection, peak inflows can be reduced by 30% to 40%.

Information on the exfiltration test methods and site, along with the data and analyses, are included in **Appendix G**.

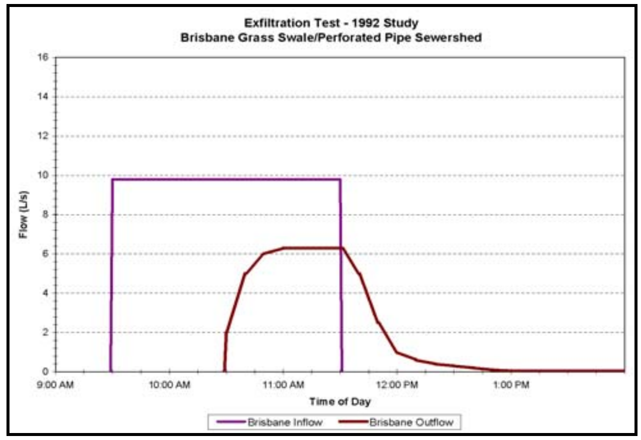


Figure 15: Exfiltration Results - Ottawa, Original Study (PWA, 1992)

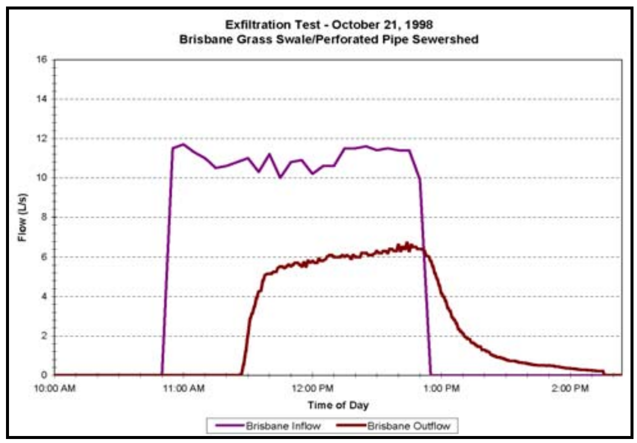


Figure 16: Exfiltration Results - Ottawa, Previous Study (JFSA, 1999)

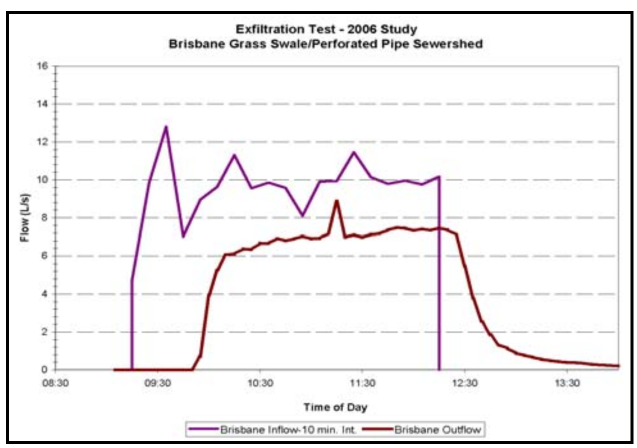


Figure 17: Exfiltration Results - Ottawa, This Study

9. SOIL QUALITY

Surface soil samples were taken from grassed swales in the MacFarlane and Heart's Desire sewersheds and from ditches in the Amberwood sewershed. Ten soils samples were taken in all: 6 from swales and 4 from ditches. The objective of this sampling and analyses was to determine the possible long-term effects of infiltrating road runoff on soil quality. Textural analyses of the soils were performed to determine the percentage of sand, silt and clay, so as to classify each sample's soil type.

The parameters analysed were: pH, lead, mercury, phosphorus, potassium, magnesium, manganese, zinc, copper, iron and EC (total salts). Of these parameters, lead, mercury, copper and zinc, have Canadian Council of Ministers of the Environment Guideline (CCME) concentration guidelines. All samples analysed were within those CCME recommended Soil Quality Guidelines**.** Comparison of this study's results to the soil quality results from three duplicated sites from the 1998 study shows an overall decrease in the nutrient and metal concentrations in both the swale and ditch samples.

Table 9 below, lists the results of the grain size analysis. The composition of the swale soil samples was mostly sand (51-86%), with associated USDA soil class descriptions of: Sand, Sandy Loam and Loam. Because of their infiltration characteristics, the sandy loam type of soils are best-suited for grassed swale applications. Comparison of this study's results to the soil texture results from three duplicated sites from the 1998 study shows an increase in clay content from <1% to 8 to 14% in the swale soils at those sites.

Table 9: Summary of Surface Soil Types (Grass Swales)

Location	Site	System	% Sand	% Silt	% Clay
13 Newland	HD	Ditch	47	29	24
2081 Merivale	AMB	Ditch	47	31	22
9 Promenade	MCF	Swale	86	12	2
4 Pineglen	MCF	Swale	75	17	8
16 Brookdale	MCF	Swale	71	21	8
Briggs / MacFarlane	MCF	Swale	65	21	14
28 Goodwood Street	HD	Swale	65	25	10

10. VEGETATION QUALITY

Vegetation samples were taken along grassed swales in the MacFarlane and Heart's Desire sewersheds and from ditches in the Amberwood sewershed. The objective was to determine if grasses and plants within the swales were affected by possible higher than usual amounts of nutrients or toxic elements associated with road runoff.

A comparison was made with results obtained from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) for fresh cut grass, fresh cut hay and grass haylage and from the 1998 study. The elements compared were calcium, phosphorus, potassium, magnesium, manganese, copper and zinc. Results are shown below in Table 10.

Table 10: Summary of Vegetation Quality on Grass Swales

Parameter		1998	2006 Samples	
	OMAFRA	Swales	Swales	Ditches
Calcium (%)	0.87	0.96	0.56	0.57
Phosphorus (%)	0.29	0.34	0.44	0.38
Potassium (%)	2.2	2.5	2.4	2.3
Magnesium (%)	0.22	0.17	0.17	0.18
Manganese (ppm)	36	34	19	22
Copper (ppm)	5	5	6	7
Zinc (ppm)	26	27	25	28
Total Kjeldahl Nitrogen (%)	N/A	n/a	3.49	2.83
Sodium (%)	N/A	n/a	<0.10	0.11
Boron (ppm)	N/A	n/a	8	10
Iron (ppm)	N/A	n/a	168	170

The data in Table 10 indicates that the vegetation quality along the grassed swales was similar to what would be found along conventional systems (OMAFRA data). The concentrations in the ditch and swale samples are comparable.

As with the soil quality results, there was no indication that vegetation quality was affected by the age of the swale as results varied regardless of the swale's age. There was no marked degradation in vegetation quality due to continuous exposure to street runoff.

More information on the soil and and vegetation sampling, analyses and results are included in **Appendix H**.

11. WINTER AND SPRING MONITORING

Monitoring during 2008 winter and spring thaws was conducted at all three sewersheds. The purpose of the monitoring was to check for the occurrence and extent of catch basin blockages and surface ponding. A total of four site visits were carried out. The sewersheds were visited immediately following precipitation events. The monitoring schedule is summarized in Table 11, with the respective total rainfall, snowfall and the approximate amount of snow cover that existed at the time and as recorded at Environment Canada's Ottawa International Airport weather station.

Table 11: Monitoring Schedule*

Site Visit	Total Rain (mm)	Total Snow (cm)	Snow on Ground (cm)
19/03/2008	15.4	5.4	79
01/04/2008	2.6	Trace	47
10/04/2008	0 **	0	5
11/04/2008	13.2	0.4	1

Notes:
* Precipitation and Snow Data taken from EC Ottawa International Airport weather station
**Ottawa International Airport weather station records however there were light showers in the early morning in the vicinity of the sewersheds.

During the first three site visits the distribution and frequency of surface ponding within each system were noted. The fourth visit (April 11) was conducted to assess the relative turf and road edge damage caused by snow removal during the winter season. Table 12 lists the number of ponding areas and exposed catch basins observed during these site visits. The number of lots with turf damage is noted in Table 13.

Table 12: Site Visit Summary of Observed Ponding Areas and Exposed Catch Basins

	19/03/2008		01/04/2008		10/04/2008	
Site	Ponding	CB	Ponding	CB	Ponding	CB
Amberwood	3	N/A	5	2	0	16
MacFarlane	0	N/A	6	N/A	0	9
Heart's Desire	3	N/A	3	N/A	0	19

Table 13: Road Edge Snow Removal Damages Observed April 11, 2008

Site	Observed Damages
Amberwood	4
MacFarlane	6
Heart's Desire	3

The data noted in Tables 11 and 12 indicate that there was a greater amount of ponding on April 1st as compared to the March 19th even though there was a smaller amount of precipitation prior to the April 1st site visit. As the spring season and snow melt progressed, larger amounts of surface water ponding was observed at all three sites.

At the time of the first site visit, catch basins were not visible at any of the sewersheds due to the snow cover. Streets were ploughed along the crown of the road causing a large accumulation of snow at the road edge, and in the case of the GSPP systems, in the swales. As the snow melt progressed, less ponding occurred as surface water was able to drain to the catch basins. As shown in Figure 18, surface water could still be captured despite a large snow accumulation above catch basins and in the swales .

Figure 18: Dry road surface as surface water is retained by swale (MacFarlane, April 10, 2008)

Summary

Overall, similar results were observed in the conventional and the GSPP sewersheds. During the winter season, road snow removal created snow accumulations on the edge of the roads which caused similar surface ponding conditions within both types of systems. Despite the presence of curbs, winter street maintenance resulted in turf damage in the conventional sewersheds as it did in the GSPP sewersheds. Site maps and additional photos from the winter and spring monitoring are included in **Appendix I.**

12. SUMMARY OF FINDINGS

Measured Precipitation

The monitored period (August 9 to November 22, 2006) received 50% more precipitation than the average for previous years. On the whole, precipitation intensities measured at Hydro Ottawa (close to MacFarlane and Amberwood sewersheds) recorded slightly more precipitation than the gauge at Carleton Lodge (close to Heart's Desire). The most significant precipitation event (September 18, 2006) had a total of 24.8 mm. Statistically, however, this storm had a return period of less than one year.

Flow Monitoring

A comparison of flows for the significant precipitation events, shows that the perforated pipe grassed swale systems are superior to the conventional systems with respect to total flow per impervious area. Peak flows were 14 to 53% of the conventional system. Runoff volumes were only 14 to 27% of those for conventional systems.

Water Quality

The overall quality of the effluent from perforated pipe/grass swale systems is as good as or better than that of conventional systems. When the pollutant load is calculated, the discharge from the perforated pipe systems contribute a notably lower pollutant loading. The TSS concentrations are significantly reduced by the GSPP systems. Based on the difference in the relative TSS concentrations between the conventional systems and the GSPP systems, the reduction represents a potential 81 to 95% sediment removal by the GSPP systems. This is equivalent to MOE guideline's "enhanced" level of TSS removal.

Video Inspections

Video inspections of perforated pipe systems showed no deterioration over time. There was no indication of deformation or signs of tree-root intrusion. The pipes were generally clean, with very little sediment build up, even after more than 20 years of use.

Exfiltration Tests

The perforated pipe system within the McFarlane sewershed is capable still of exfiltrating large volumes of water. Exfiltration tests demonstrate that the GSPP drainage systems can reduce runoff volumes by 35% to 60%. With a direct connection, peak inflows can be reduced by 30% to 40%.

Infiltration Tests

The infiltration capacities of the grassed swales tested were shown to be optimum in that the swales allowed for proper drainage, yet would hold enough moisture to sustain grass/plant life. The grass swale infiltration rates determined by this study remain within the range typically assumed for permeable grassed surfaces.

Soil Quality

Several key soil quality parameters were tested for within the grass swales. The parameters tested were within the Canadian Council of Ministers of the Environment Recommended Soil Quality Guidelines. There was no evidence to show that nutrient or metal concentrations increased with age as concentrations varied regardless of the age of the swale.

Vegetation Quality

It was shown that the quality of vegetation along the grassed swales was similar to what would be found along conventional systems. There was no marked degradation in vegetation quality due to continuous exposure to street runoff. There were no indications that vegetation quality was affected by the age of the swale.

Winter and Spring Monitoring

A comparable degree of surface ponding and potential catch basin blockages were observed in the conventional and GSPP systems.. Despite the presence of curbs, winter street maintenance caused turf damage in the conventional sewersheds as it did in the non-curbed GSPP sewersheds.

IN SUMMARY

Perforated pipe and grass swale drainage systems have been shown to provide many stormwater management benefits in comparison to conventional storm systems. Their low-installation cost, low-maintenance cost, combined with a proven performance, make them a viable drainage solution in low density residential areas. This research project has demonstrated that perforated pipe/grass swale systems continue to function beneficially even after more than 20 years of service.

13. REFERENCES

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