An Evaluation of Roadside Ditches

And Other Related Stormwater Management Practices

Second Edition

February, 2000

THE TORONTO AND REGION CONSERVATION AUTHORITY

Ministry of the Environment
Ontario

LAKE SIMCOE REGION CONSERVATION AUTHORITY

Environment Canada Environnement Canada
GREAT LAKES 2000 CLEANUP FUND

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J.F. Sabourin and Associates Inc.
Water Resources and Environmental Consultants

In cooperation with: City of Ottawa, City of Toronto, Town of Richmond Hill, Rideau Valley Conservation Authority, Totten Sims Hubicki Associates, and Donald G. Weatherbe Associates Inc.

Evaluation of Roadside Ditches and Other Related Stormwater Management Practices

Final Report
Second Edition

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prepared for:

The Toronto and Region
Conservation Authority

by:

J.F. Sabourin and Associates Inc.
Ottawa, Ontario

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The Great Lakes 2000 Cleanup Fund is a component of the Federal Government's Great Lakes 2000 program. The Cleanup Fund provides resources to demonstrate and implement technologies and techniques to assist in the remediation of Areas of Concern and other priority areas in the Great Lakes. The report that follows was sponsored by the Great Lakes 2000 Cleanup Fund and addresses stormwater management issues in the Toronto and Region Area of Concern in Toronto, Ontario. Although the report was subject to technical review, it does not necessarily reflect the views of the Cleanup Fund or Environment Canada.

Preface to the First Edition

Stormwater management plays an integral role in the protection of developing watersheds and in the regeneration of degraded environments. *An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices* was undertaken to promote the use of alternative road drainage measures that could meet current environmental objectives, while also meeting other social and economic objectives. The Metropolitan Toronto and Region Conservation Authority, Lake Simcoe Region Conservation Authority, Ryerson University and Environment Canada's Great Lakes 2000 Clean Up Fund sponsored the study, while significant input was provided by municipal and provincial representatives on a review committee.

The study has compiled information and developed tools that will assist designers and reviewers in determining the appropriate road drainage system for a given location, based on environmental, social and economic objectives. Results of this study underscore the fact that no road drainage system is suitable everywhere, but rather a range of alternatives must be evaluated according to site specific considerations. Although the study focused on conveyance systems, the results support a comprehensive approach to stormwater management by involving the maximal use of source controls and employing end-of-pipe facilities where necessary.

This study marks a beginning - not an end. The tools and procedures proposed herein must be tested and refined, as new information becomes available. The report documents the state-of-the-art. Many questions remain. The study partners look forward to further opportunities to advance this field.

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Preface to the Second Edition

This edition updates chapters 10 (Economic Considerations) and 12 (Alternative Drainage System Selection Tool) of the final report from *An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices* (J.F. Sabourin and Associates Inc., 1997). In the updated chapters, the road drainage system Selection Tool has been enhanced in the following areas:

- revised cost tables, allowing for a comparison of present values using discount rates and life cycles;
- the addition of standardized objective setting tables;
- update and completion of stormwater management performance tables; and
- clearer documentation for the tool's use.

One significant enhancement is the transformation of the tool from a paper copy to a digital spreadsheet format, for on-screen application of the tool. It is expected that this latter improvement will make the tool much easier to use, and will thereby enhance its adoption by designers.

Revisions to the Selection Tool have been made in response to recommendations from a demonstration study (Totten Sims Hubicki and Associates and Donald G. Weatherbe and Associates, 1999). That study, commissioned by the TRCA, tested the Selection Tool in the design of four urban road reconstruction projects, located in the City of Toronto, Town of Richmond Hill, and City of Ottawa. Other partners in the study included: the City of Ottawa, City of Toronto, Town of Richmond Hill, Environment Canada's Great Lakes 2000 Cleanup Fund (GL2000CUF), the Ministry of the Environment (MOE), the Rideau Valley Conservation Authority, Lake Simcoe Region Conservation Authority, and Ryerson University.

The information and tools provided in this report are intended to assist designers and reviewers in determining the appropriate road drainage system for a given location. Results of the study again underscore the fact that no single road drainage system is suitable for all cases. The project partners hope that this information will promote further consideration and testing of alternative technologies.

NOTE: *As of January 1, 1998, the Metropolitan Toronto and Region Conservation Authority (MTRCA) changed its name to Toronto and Region Conservation Authority (TRCA).*

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(April 1997)

Abstract

This report presents the findings of a study in which the use of roadside ditches and other alternative road drainage systems are compared and evaluated. The comparison and evaluation are based on the systems' social acceptance, their economic feasibility, their potential environmental benefits, their use for stormwater management and their engineering and planning compatibility. These individual issues were addressed by means of a literature review, a mailout questionnaire / survey, a review of system specifications and an economic analysis.

Based on the findings of the study, a systematic evaluating procedure was developed to help in the assessment and selection of alternative drainage systems. The procedure accounts for site and development characteristics as well as potential stormwater management benefits. Other factors such as costs (capital and maintenance) and public expectations can further be considered in the final comparison and selection of alternative drainage system components.

The report further makes recommendations for the improved design and maintenance of conventional roadside drainage systems.

The study was coordinated by the Metropolitan Toronto and Region Conservation Authority (MTRCA) with a review committee comprised of representatives from the Lake Simcoe Region Conservation Authority (LSRCA), the Ministry of the Environment and Energy (MOEE), the Ministry of Natural Resources (MNR), the Ontario Ministry of Transportation (MTO), the Town of Richmond Hill, the City of Etobicoke, Environment Canada and Ryerson Polytechnic University.

Funding for the study was received from Environment Canada's Great Lakes 2000 Cleanup Fund, Ryerson Polytechnic University, Lake Simcoe Region Conservation Authority and the Metropolitan Toronto and Region Conservation Authority.

Executive Summary and Study Findings

Background and study objectives

It is now well accepted that urbanization can have adverse impacts on streams and other receiving water bodies. The resulting change in hydrologic regime from increased stormwater runoff may cause flooding, streambank erosion and water quality problems such as pollutant loadings, temperature effects, baseflow reduction, habitat changes and groundwater impacts.

Stormwater management measures which are often implemented in order to mitigate the negative environmental impacts related to urbanization include;

i) **"Lot Level Controls"** which are oriented towards maintaining the hydrologic cycle and are based on the premise of controlling problems at their source,

ii) **"Stormwater Conveyance Controls"** which recognize that the timing of stormwater runoff, and what happens to stormwater as it is being conveyed to a receiving water, can have a major impact on water quality, flooding, erosion, and groundwater recharge, and,

iii) **"End-of-Pipe Stormwater Management Facilities"** which are the more traditional dry / wet ponds and wetlands and deal with the problems at the outlet.

In most cases, it is a combination of various stormwater management practices which should be adopted for a given site. However, because of a potential lack of information and possibly biassed perceptions, the adopted drainage alternatives do not always represent the optimum balanced solution between local environmental, social and economic expectations.

One traditional type of stormwater conveyance system which can offer some advantages over a cub-gutter-sewer system by providing some level of stormwater quality and quantity control is the roadside ditch. This type of system often receives opposing opinions from designers and reviewers over its merits and is therefore often disregarded as a possible component of the drainage alternative.

In order to better understand how, when and where various alternative roadside drainage techniques could be used to provide a system with an optimum balance between the various objectives, the present study was commissioned by Metro Region Conservation. *A copy of the Terms of Reference are provided in Appendix A.*

In general terms, the objectives of the study were to further investigate and report on the environmental, engineering, social, and economic advantages/disadvantages associated with the use of roadside ditches and provide a comparison with other possible alternative road drainage systems.

Study approach

The study objectives were addressed by:

Conducting a Literature Review in order to further document the experience of other jurisdictions with roadside ditches and with other types of BMP's associated with roadside drainage.

Conducting Surveys and Interviews in order to identify and quantify public attitudes and perceptions, the experiences and costs associated with various types of roadside drainage alternatives. Other issues which were identified through such inquiries included safety and possible effect on property values.

Comparing Drainage Alternatives in terms of their capacity for water conveyance, water quality treatment, groundwater recharge and ability to meet SWM requirements, safety, Right-of-Way and lot planning, public attitudes and perceptions, and economics (capital and operational costs).

Developing an Assessment Tool to help identify and compare applicable alternative drainage systems for a given site. The selection tool accounts for site and development characteristics as well as the potential stormwater management functions of the various alternative drainage features and their capital and operational costs.

Highlights of study

Literature Review

Close to 250 relevant references comprised of scientific articles, books and newspaper clippings were collected during the literature search. Most (70%) of the collected literature was published within the last 6 years and from the source of the literature it is clear that concerns related to the management of stormwater runoff is wide spread throughout developed countries.

Very little information was found on the specific use of typical roadside ditches as a BMP option or as part of the treatment train. Although some design information on roadside ditches is available, the information is rarely related to hydraulic or hydrologic considerations.

The literature shows a trend toward the emergence of new approaches to SWM and initial testing to determine advantages / disadvantages. Design information on alternative drainage systems is adequate. However, monitoring data is still sparse and sometimes inconsistent. Furthermore, the literature is weak in areas of maintenance, long term performance, public preference and overall costs.

The potential use of alternative drainage systems is seldom completely and jointly evaluated in terms of SWM objectives, cost, ease of integration in the ROW, and public acceptance. In many European communities, the use of non-structural BMP's, such as public education and citizen involvement programs are emphasized.

The report provides an overall summary of the literature review in Section 2 of the report and a complete list of the collected references is provided in Appendix B.

Actual roadway with conventional ditch

Computer enhanced photo with a grass swale system

Computer enhanced photo with curb and gutter system

Surveys and Interviews

Two questionnaires were formulated for the purpose of the survey. A technical survey was sent to 125 municipal engineers and planners while a more qualitative survey was sent to 72 real estate agents and developers. Because a door to door survey was not feasible, the latter group was selected to reflect public opinions. In order to provide the most realistic and representative sample, the sample group of real estate agents and developers were selected throughout the Greater Toronto Area.

The use of computer enhanced photos (see above) were incorporated to help better visualize a roadway with a ditch, a grass swale, or a curb. By means of sketches, the surveys also made reference to other alternative drainage systems some of which are listed in the table below.

Alternative drainage systems considered in surveys

- Grass swales
- Grass swales with raised culverts
- Grass swales with infiltration systems
- Grass swales with perforated pipe systems
- Curb & gutter with greenbelts
- Oil & grit separator and sumpless catchbasins
- Grass swales with curb & gutter and sewer
- Grass swales with storm sewers
- Grass swales with dipped driveways
- Grass swales with infiltration manhole system
- Curb & gutter and sewer with exfiltration system
- Curb & gutter and sewer with filtration system
- Grass swales with curb and gutter (no sewers)
- Grass swales with check dams

Out of the 197 questionnaires which were sent out, a total of 52 were filled out and returned (32 from the municipal engineers and planners and 20 from the real estate agents and developers). In the latter group, 90% of the respondents were developers.

The questionnaire survey with municipal engineers and planners identified a strong willingness to try alternative drainage systems in either new developments or retrofit situations. In fact, over 30% of the municipalities who participated in the survey have already implemented some types of alternative drainage systems. When asked if they would used such systems again, most said yes. Reasons for not wanting to try alternative types of road drainage systems were highly focussed on the perception that such systems are in general more expensive to construct and maintain.

Although the survey with real estate agents and developers did indicate a preference for the curb and gutter system in urban areas and grass swales and ditches in rural areas it was not concluded if in fact this is a preference or an expectation of what is commonly seen.

The survey results were used in various sections of the report and a general summary is provided in Section 3 while the questionnaires and a complete breakdown of responses are presented in Appendix C.

Comparison of drainage alternatives

The comparison and the selection of drainage alternatives cannot be limited to how well they convey or treat stormwater but should also consider how well they can be integrated in our communities and at what cost. Some of the issues which are addressed in Sections 4 through 10 of the report are described below.

Stormwater conveyance: When the use of surface conveyance systems such as ditches and swales are contemplated, their successful design and implementation will often be based on the proper consideration of: i) the available space, ii) the desired level of service, iii) the type of surface vegetation, and iv) slopes and the effects of culverts. The advantages and constraints associated with such design parameters were addressed in the study through the development and application of a step by step hydrologic / hydraulic analytical procedure which is described in Section 4.

Based on simple geometry it was demonstrated that roadside ditches with 3:1 or 2:1 side slopes can effectively be constructed within Right of Way widths of 20 to 27 m if sidewalks are not present. When sidewalks are located 1 m from the property line, the available space between the sidewalk and the road is significantly reduced such that ditches with 3:1 side slopes are too shallow to provide adequate road base drainage if required. Under such conditions, the use of roadside ditches or grass swales would require the use of under drains.

With respect to the required level of service, and based on the survey results, the conveyance capacity of any drainage system should in general be 1:5 yrs for the minor system and 1:100 yrs for the major system.

The type of surface vegetation in roadside ditches and swales was found to have an important role in controlling flow velocities below critical levels for erosion in steeper areas. For example, the allowable flow in a typical roadside ditch can be more than tripled when the vegetation height is maintained at 30 cm as compared to 5 cm.

The combined effect of the shape of a roadside ditch or swale and the type of vegetation can also significantly attenuate runoff peak flows. As such it was demonstrated that for a 5 ha area with 40% imperviousness, the design peak flow in a roadside ditch with 3:1 side slopes and natural vegetation could be 30% lower than the design peak flow of a conventional curb and gutter system. Such reductions in flows could represent significant savings for downstream infrastructure.

Culverts and their spacing can significantly reduce the maximum drainage area which can be serviced by roadside ditches or swales. For example, it was found that the use of 450 mm culverts spaced at 20 m could limit the maximum serviceable area to 2.5 ha (per side of road) as compared to approximately 30 ha if culverts were not present.

The use of check dams or raised culverts was shown to be most effective where surface slopes are small (ie. 0.5% or less). The maximum height of check dams or raised culverts should be based on the consideration that the retained water must infiltrate within a reasonable time (ie. less than 12 hours). For typical infiltration rates of 3 to 7.5 mm/hr for a topsoil layer and grass cover this would possibly limit the height of a check dam or raised culvert to 50 mm or less. At such low heights, raised culverts or check dams would only provide some tangible benefits if they were used in swales with side slopes of 5:1 or less.

Stormwater quality treatment erosion and groundwater recharge: The potential effectiveness of a given drainage feature in providing some level of quality control is dependent on many factors, some of which are still being studied and understood. Although monitoring data is still limited for some types of BMP's, they can nonetheless provide an indication of performance. The table below provides a summary of documented pollutant removal rates for various BMP's. It is clear from the reported variability in the effectiveness of some BMP's that design and maintenance standards are still evolving. Stormwater quality, erosion, groundwater recharge and maintenance issues are discussed in Section 5 of the report.

Ranges of BMP pollutant removal rates (%)

Type of BMP	TSS	TP	TN	Zn	Pb	BOD	Bacteria	Oil & grease
Infiltration	0-99	0-75	0-70	0-99	0-99	0-90	75-98	—
Infiltration Trenches	90-99	60-75	60-70	90-99	90	90	90-98	—
Grass swales	65-98	9-100	24-100	50-90	50-91	—	—	—
Grass swales w/perforated pipes	90	75	—	75	93	—	—	—
Grass swales with check dams	20-40	20-40	20-40	0	0	—	—	—
Curb and gutter with exfiltration system	Such a system was constructed in the City of Etobicoke Preliminary monitoring results indicate that 100% of runoff is infiltrated at the site Theoretical volumetric retention is in the order of 90%							
Vegetative buffer strip	28-70	70	—	51	25	—	—	—
Sand Filters	60-85	60-80	(-110)35	10-80	60-80	60-90	50-70	—
Curb and gutter with filtration system	Such a system was constructed in the City of Etobicoke Monitoring results were not available during the study							
Extended Detention pond (dry)	29-75	10-56	24-60	40-57	24-61	—	50-90	—
Extended Detention pond (wet)	60-91	30-90	40-80	50	57	—	75	—
Wetland	40-94	(-4)-90	21	(-29)-82	27-94	18	n/a	—
Stormceptors*	50-80	—	—	39	51	—	—	98
Porous pavement	80-95	60-65	75-85	98	80	80	n/a	—

* Stormceptors represent one type of oil/grit separators for which data were readily available during this study Data from other oil/grit separator manufacturers should also be referenced when possible Mention of Stormceptor does not constitute endorsement or recommendation for use

Public attitudes, perceptions and preferences: The knowledge and/or the understanding of public attitudes, their perceptions and preferences with respect to streetscape features can become a valuable asset in determining what type of alternative drainage systems could be acceptable or could become a resistance factor. From the interpretation of the survey responses, it was found that public opinions can vary from area to area and mostly between urban and rural settings. As such, general public opinions are summarized in the table below and further discussed in Section 6.

Summary of general public preferences

Urban Setting	**Rural Setting**
▸ A curb & gutter drainage system is somewhat expected ▸ One sidewalk located next to or away from the curb. ▸ Underground franchise utilities. ▸ Street lighting should be available. ▸ Municipal trees should be planted. ▸ Curved street layouts. ▸ Parking on streets allowed. ▸ No pooling of water on street.	▸ Grass swales or roadside ditches are acceptable but grass swales are somewhat preferred in terms of maintenance requirements and perception of safety. ▸ Sidewalks are not important. ▸ Above or below ground franchise utilities. ▸ Street lighting should be available. ▸ Municipal trees should be planted. ▸ Curved street layouts are somewhat preferred but not has much as in an urban setting. ▸ Parking on streets is not as important as in an urban setting. ▸ No pooling of water on street.

Municipal perspective and tendencies: According to the surveys and interviews conducted with municipal representatives, the majority of the respondents indicated the willingness to positively consider the use of alternative drainage systems in new developments or retrofit situations in either urban or rural settings.

The most popular alternative drainage systems that have been or would be considered are; i) grass swales, ii) grass swales or ditches with raised culverts, iii) grass swales or ditches with infiltration trench systems, iv) grass swales with perforated pipe systems, and v) curb and gutter with greenbelt system (ie. backyard swale system). Reasons which were given for not wanting to consider the use of alternative drainage systems are presented in Section 7 and include; i) perceived additional maintenance costs, ii) perceived lower level of standards for road, and iii) lack of long term maintenance and operations history of systems.

Safety considerations: Safety issues can be related to motorists, pedestrians, cyclists and homeowners. Drainage components which may have an influence on safety include: i) the presence of a curb, ii) the presence of ditches, iii) the presence of culverts, and iv) the presence of catch basins. Drainage functions which may influence the level of safety include: i) depth of water on street, ii) surface flow velocity, iii) system backups and basement flooding.

With respect to documented causes of accidents very little information has been found during the course of this study to provide viable statistics on urban accidents or damages which may been caused by drainage related features or functions. Inquiries with insurance companies have found that such information is not collected or analysed. Even basement flooding is not documented to determine if the cause was from the failure of a sump pump, a sewer backup or from water entering through a basement window.

However, some statistics of highway accidents in which drainage structures were involved are available and are presented in Section 8 of the report.

Right-of-way, road and lot planning: The potential use of alternative drainage systems must consider; i) possible integration of the system within development and right-of-way widths, ii) presence and location of sidewalks, iii) presence and location of trees within the public road allowance, iv) type of roadside landscape treatment, v) presence and location of utilities, vi) road design, and vi) lot imperviousness, widths and drainage. Each of these issues are discussed in Section 9 of the report and are incorporated in the Selection Tool.

Economics (capital and maintenance costs): Details on capital and maintenance costs were obtained from various municipalities, developers and literature. The information was used to develop itemized tables of annualized costs for most features which can be found in a drainage system. Annualized costs were obtained by dividing the construction or replacement cost of a given item by its expected longevity and by then adding the associated annual repair and maintenance costs. This information was updated in the 1999 Study using a Present Value approach.

Although it was found that prices and the frequency of various maintenance activities can vary from one municipality to another, the approach developed in the study provides a method with which a comparison of total annual costs can be made between practically any drainage systems. Based on this approach it was found that the total present value cost (capital and maintenance) associated with roadside ditches is much less than usually perceived.

As an example, the total present value capital and maintenance costs for four different systems, designed to provide at least a 1:5 year level of service with quality and erosion controls based on a 25 mm storm, are compared in the table below.

Comparison of Total Present Value Costs
per 10 ha of drainage area at 40% imperviousness based on 1000 x 8.5 m of roadway with a 20 m ROW and 20 x 40 m deep lots (using a 7% annual discount rate and an 80 year life cycle)

System #1	**System #2**	**System #3**	**System #4**
Conventional curb and gutter system with concrete pipes and end of pipe facility for quality and erosion control.	**Like System #1 but with Stormceptor units for source control and an end of pipe facility for additional quality and erosion control.**	**Conventional ditch system with end of pipe facility for quality and erosion control. Road has no subdrains.**	**Grass swale system with perforated pipe system and infiltration trenches capable of retaining and infiltrating the runoff of a 25 mm storm.**
$\$1,352,283^{*,2}$	**$\$1,396,174^{*,2}$**	**$\$821,679^{*,1,2}$**	**$\$1,001,097^{2}$**

Notes *) Because of the potentially large differences from one area to another, the cost for land required by end of pipe facility or losses in tax revenues are not included.
1) Cost assumes that ditches are 50% efficient at removing sediments. If properly constructed, ditched roads may not require an end of pipe facility in which case the cost can be reduced by $70,747. Total cost can be further reduced by $95,384 if subdrains can be installed.
2) Total annual costs are based on "average" total costs and individual costs may vary between municipalities

Details on the compilation of the various costs are presented in Section 10 of the report.

Assessment tool: The selection and identification of the most appropriate drainage alternative(s), for a given site, can be complicated and, unless a detailed assessment is conducted, the results of such an exercise can easily be regarded as subjective.

Based on the study findings, a simple to use systematic procedure was developed in order to help determine which types of alternative drainage features could be incorporated within a specific project while at the same time addressing the local environmental, social and economic expectations.

Drainage features are defined as components which are part of a drainage system. Examples of drainage features include; curbs, porous pavements, ditches, swales, perforated pipes, dipped driveways, check dams, culverts, oil & grit separators, storm sewers, infiltration trenches, ponds, etc... A drainage system is the result of the combined use of various drainage features.

The developed procedure can be used for new developments or retrofit situations and accounts for the following aspects;

i) compatibility with physical site characteristics;
ii) compatibility with planning objectives and ease of integration within the road right of way;
iii) ability to meet stormwater management objectives:
iv) economics;
v) public acceptance;

Through a process of elimination, drainage features which are compatible with site characteristics and/or with the type of development are first identified. Based on the identified list of compatible drainage features, the designer can proceed to formulate various conceptual drainage systems which are then compared in terms of their ability to meet local stormwater management objectives, and in terms of costs (capital and maintenance), and public expectations.

The selection tool, complete with examples, is described and presented in Section 12.

Other Conclusions and Recommendations

Other conclusions and recommendations are presented in Section 13 of the report.

Acknowledgments

This report was prepared for the Metropolitan Toronto and Region Conservation Authority (MTRCA) by J.F. Sabourin and Associates Inc (JFSA). The project manager and principal writer of the report was Mr. J.F. Sabourin. The project officer was Ms. Sonya Meek of MTRCA to whom special thanks are extended for her continuous support and valuable comments. In addition, many other individuals and organizations which are listed below, have also positively collaborated towards the execution and completion of this study. Their assistance and guidance are most gratefully acknowledged.

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Evaluation of Roadside Ditches and Other Related Stormwater Management Practices

FINAL REPORT
(April 1997)

1.0 Introduction

It is now well known and accepted that urbanization can have adverse impacts on streams and other receiving water bodies. The resulting change in hydrologic regime from increased stormwater runoff may cause flooding, streambank erosion and other environmental problems due to pollutant loadings, changes in water temperature, reduction of baseflows and groundwater recharge.

Stormwater management measures which are often implemented in order to mitigate the negative environmental impacts related to urbanization include; i) "Lot Level Controls" which are oriented towards maintaining the hydrologic cycle and are based on the premise of controlling problems at their source; ii) "Stormwater Conveyance Controls" which recognize that the timing of stormwater runoff, and what happens to stormwater as it is being conveyed to a receiving water, can have a major impact on water quality, flooding, erosion, and groundwater recharge; and iii) "End-of-Pipe Stormwater Management Facilities" which are the more traditional dry / wet ponds and wetlands and deal with the problems at the outlet.

In most cases, it is a combination of various stormwater management measures which should be adopted for a given site. However, because of a potential lack of information and possible biassed perceptions, the adopted drainage alternatives do not always represent the optimum balanced solution between the local environmental and social and economic expectations.

One traditional type of stormwater conveyance system which can offer some advantages over a curb-gutter-sewer system by providing some level of stormwater quality and quantity control is the roadside ditch. This type of system often receives opposing opinions from designers and reviewers over its merits and is therefore often disregarded as a possible component of an alternative drainage system.

There is a need to better understand how, when and where various alternative techniques could be used jointly to provide an acceptable drainage system from an environmental, engineering, economic and social perspective. As such, the purpose of this study is to further investigate and report on the environmental, engineering, social, and economic advantages or disadvantages associated with the use of roadside ditches and provide a factual comparison with other possible alternative road drainage systems.

1.1 Review of Study Objectives and Approach

The main objective of the study is to further investigate and report on the environmental, engineering, social, and economic issues associated with the use of roadside ditches and provide a comparison with other possible alternative road drainage systems. Based on the findings of these investigations, a procedure is to be developed and recommended for the selection of the appropriate road drainage alternative. The procedure should account for various site characteristics, development conditions and the expected level of service, and should be applicable in both new developments and retrofit situations.

Other objectives of the study are to recommend modifications to traditional roadside ditch designs that would address potential current concerns and to recommend a strategy for the improved management and maintenance of existing roadside ditches with potential implementation roles for municipalities, agencies, and home owners. The Terms of Reference for the study are provided in Appendix A.

In order to address the objectives of the study the following specific tasks were undertaken:

Conduct a Literature Review in order to further document the experience of other jurisdictions with various BMPs associated with roadside drainage and to identify their advantages and disadvantages. The general findings of the literature review are presented in Section 2 while a complete reference list is provided in Appendix B. Copies of individual references are provided, when possible, in separate binders in the form of Appendix G.

Conduct a series of Surveys / Interviews / Questionnaires in order to identify and quantify public attitudes and perceptions, the experiences and costs associated with various types of roadside drainage alternatives. Other issues identified through such inquiries are related to safety and the possible effect on property values. An overview of the survey results are presented in Section 3 while the complete surveys and breakdown of responses are provided in Appendix C. References to the survey results are also made in various sections of the report where appropriate.

Compare the Various Drainage Alternatives in terms of water conveyance, water quality treatment, infiltration to groundwater, ability to meet SWM requirements, safety, Right-of-Way and lot planning, public attitudes and perceptions, and economics (capital and operational costs). Each individual aspect is discussed separately in Sections 4 to 11. Appendix E presents typical ROW and road designs some of which incorporate alternative drainage components. Appendix F provides a summary on capital and maintenance cost data which was collected during the study.

Develop a simple and effective decision tool to help compare and select the most appropriate alternative drainage system. The selection tool which was derived is presented in Section 12 and accounts for site and development characteristics as well as the potential stormwater management functions of the various alternative drainage features and their construction and maintenance costs. To demonstrate the use of the selection tool a step by step example is also presented in the same section.

Provide conclusions and recommendations based on the findings of the study. These are presented in Section 13 of the report.

Provide a Fact Sheet that highlights the purpose of the study and its main findings. The Fact Sheet should be brief, easily reproducible and easy to understand. The Fact Sheet is presented in Section 14.

1.2 Description of Drainage System Components

Drainage systems are made from the combined use of various components. Each individual component can have a specific role within the system. Examples of drainage system components which can be part of various alternative drainage systems are described below.

Curb and gutter: Curbs (Figure 1.1a) are usually concrete barriers that separate the road pavement and the roadside vegetation. Sidewalks, when constructed next to the roadway, can also act as curbs. Gutters (Figure 1.1b), when incorporated in the road design, are basically a horizontal extension of curbs which can reduce water infiltration between the curb structure and the road pavement. From a drainage point of view, curbs and gutters contain and convey the surface runoff along the edge of the roadway.

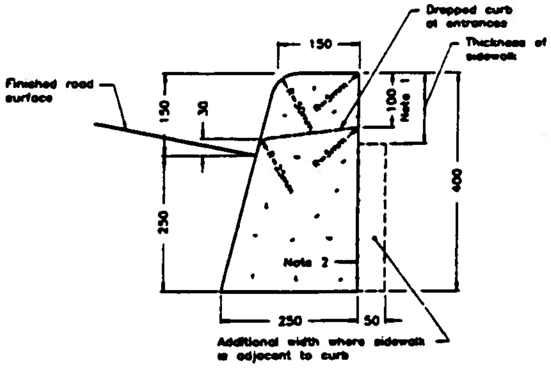


Figure 1.1a: Standard Curb

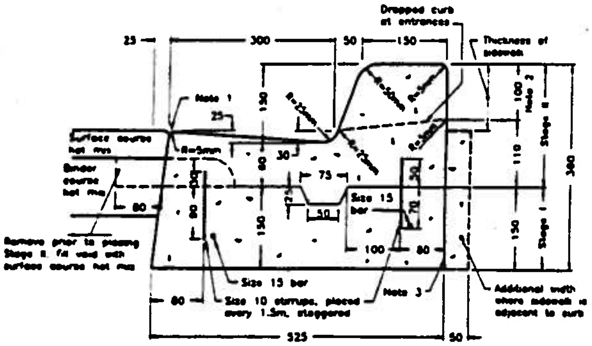


Figure 1.1b: Standard Curb with Gutter

Source: Ontario Provincial Standards for Roads and Municipal Services

Porous pavement: As the name implies, porous pavements are surface structures which by their design and construction can allow some surface runoff to flow through them. Porous pavements such as high porosity concrete pavers or asphalts can be used for low traffic roads and parking areas. Figure 1.2 shows a typical section through a porous pavement. Porous pavements can be installed over pervious or impervious soils. However, where the underlying soil is impermeable, sub-base drains can be installed and the infiltration structure will act more as flow attenuation device.

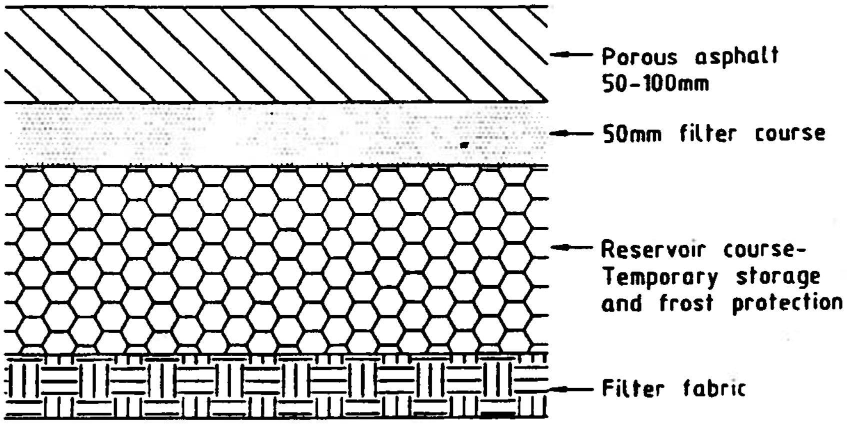


Figure 1.2: Typical section through a porous pavement
Source Recent Developments in the Control of Urban Runoff, Beale, 1992

Catchbasins: Catchbasins are vertical structures which collect stormwater runoff from the surface in order to redirect it to some kind of underground conveyance system. Although most commonly found along a curbed road, catchbasins can also be installed in grassed areas.

Manholes: Unlike catchbasins which are constructed and situated to collect surface runoff, manholes are larger structures which permit access to the underground system for inspection and maintenance purposes. Manholes are also used as junctions for several connecting pipes and where changes in alignment are required.

Storm Sewers: These are usually watertight pipes which are part of an underground system to convey stormwater.

Perforated Pipes: As the name implies, these are pipes which are perforated around their circumference. The purpose of the perforations is to either capture infiltrated water from the surface and/or to exfiltrate collected stormwater to subsurface soils. Depending on the system design in which they are used, perforated pipes can also act as storm sewers.

Roadside ditches and swales: These are constructed longitudinal surface depressions made to convey stormwater. Ditches are usually deeper and have steeper side slopes than swales. Swales are normally grassed lined while most ditches will be naturally vegetated.

Culverts: Culverts are usually single sections of pipes found under private entrances and roadways. Their use is to provide an uninterrupted flow path along ditches and swales.

Check dams: These can be earthen or log structures, used in grass swales or ditches to reduce water velocities, promote sediment deposition, and enhance infiltration. An example of a typical log check dam is shown in Figure 1.3.

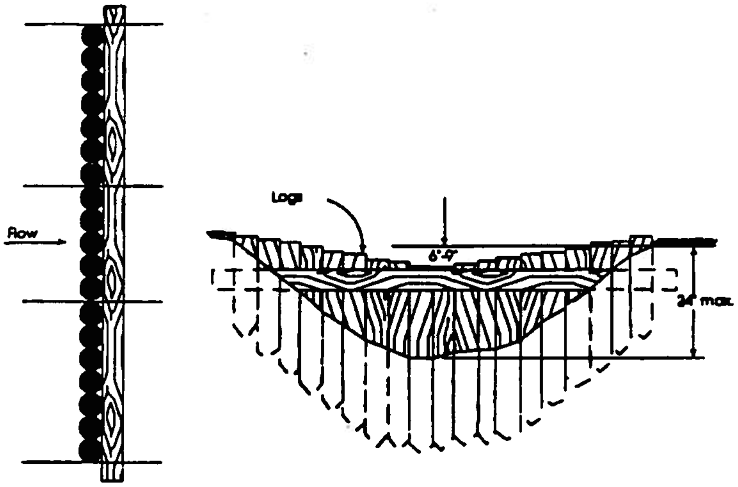


Figure 1.3: Typical log check dam *(EPA, 1992)*

Oil and Grit Separators: These are large manhole structures which are designed and constructed to remove suspended sediments and floatable pollutants such as oil and grease from collected stormwater. Oil and grit separators are also know as water quality inlets.

Infiltration Trenches: Infiltration trenches are subsurface storage structures usually comprised of a clear stone layer and a sand filter layer. Infiltration trenches can be constructed to intercept overland flows at the surface or underground as part of a storm sewer system. The intercepted water can slowly be directed to sub-surface soils or to another collection system.

End of Pipe Facilities: Infiltration basins, extended detention ponds and artificial wetlands are examples of end of pipe facilities.

1.3 Examples of Conventional and Alternative Drainage Systems

Examples of conventional and alternative drainage systems which are considered in this report are described below.

1.3.1 Curb & gutter with catchbasins and storm sewers (Figure 1.4)

This is the conventional type of drainage system which is found in most urban areas and can be constructed almost anywhere given that an appropriate outlet is available.

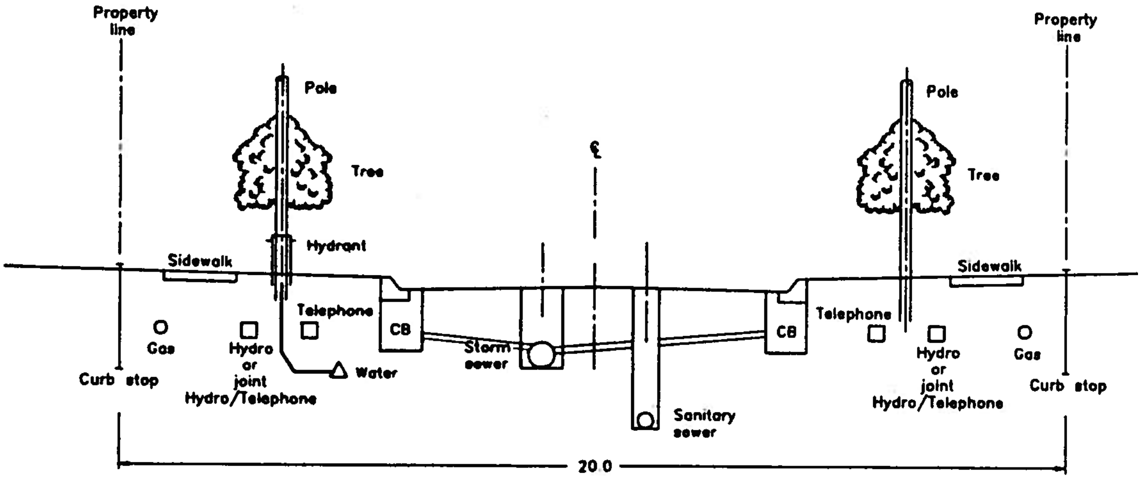


Figure 1.4: Typical curb and gutter drainage system with catchbasins and storm sewers

Source Ontario Provincial Standards for Roads and Municipal Services

How the system works: Surface runoff is conveyed along the curbs of the road until it is captured by catchbasins. Once in the catchbasin the stormwater is directed to a common storm sewer. The storm sewer collects the stormwater from all catchbasins and may discharge to a receiving water body or to an end of pipe control facility.

By itself, the curb and gutter with storm sewer system can provide an adequate level of service with respect to flood control but will provide little benefits in terms of water quality control, groundwater recharge and the control of erosion in receiving waterways.

1.3.2 Curb & gutter with catchbasins and exfiltration system (Figure 1.5)

Examples of this alternative drainage system, which is intended for use in areas of granular soils, were recently constructed in the City of Etobicoke. From above ground, the system appears to be similar to the conventional curb and gutter with storm sewer system.

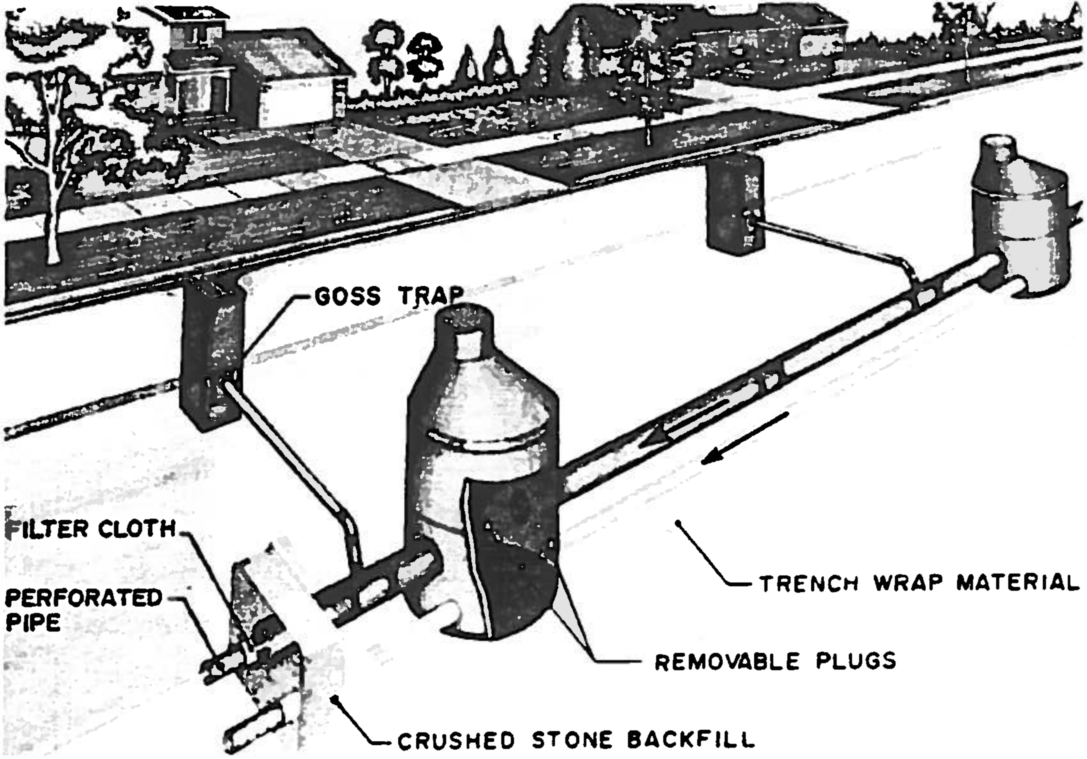


Figure 1.5:: Typical curb & gutter drainage system with catchbasins and exfiltration trenches
Source Environmental Science & Engineering, March 1994

How the system works: Surface runoff enters the local catchbasins which are connected to a standard design storm sewer. When the water reaches the next downstream manhole the flow drops into two perforated pipes which are installed along and under the standard storm sewer. The perforated pipes are plugged at the downstream end. From the perforated pipes, the water is exfiltrated into the stone filled trench and from there seeps into the surrounding native soil. When the flow exceeds the exfiltration capacity of the perforated pipes, the water surcharges and the flow continues in the standard storm sewer located above. The process is then repeated in the next downstream pipe section.

This system can basically provide the same level of service as the conventional curb and gutter with storm sewer system but due to the nature of its innovative underground piping concept, the system can also provide significant water quality control, groundwater recharge and erosion control benefits.

1.3.3 Curb & gutter with catchbasins and filtration system (Figure 1.6)

Examples of this alternative drainage system which is suitable for use in areas where the soils are impervious or with low infiltration rates were recently constructed in the City of Etobicoke. From above ground, the system is similar to the conventional curb and gutter with storm sewer system.

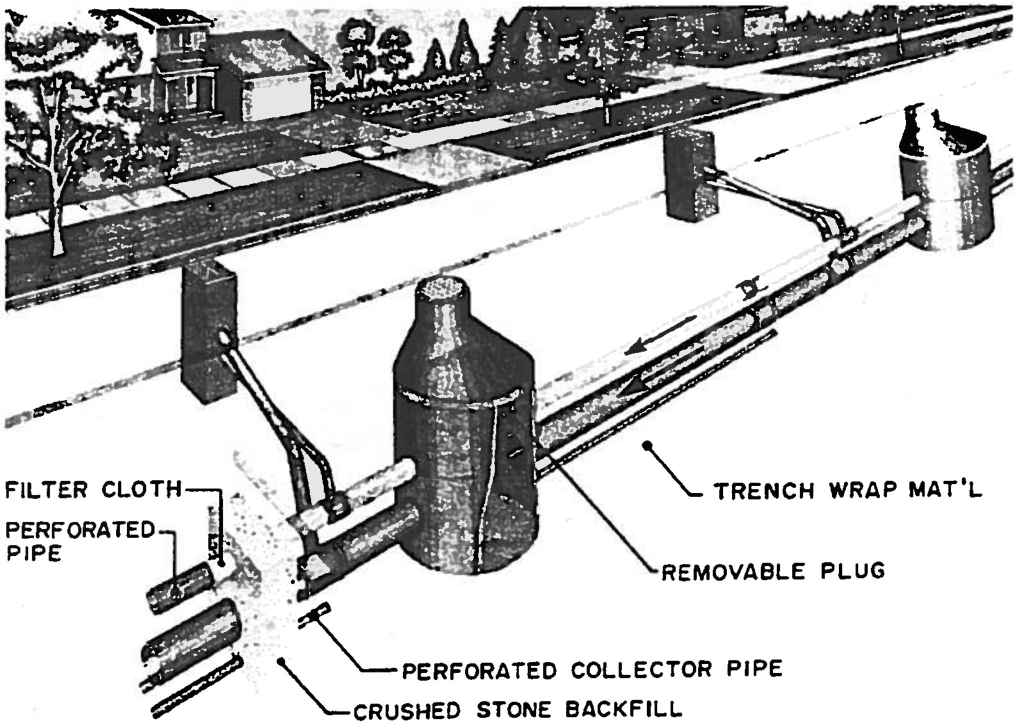


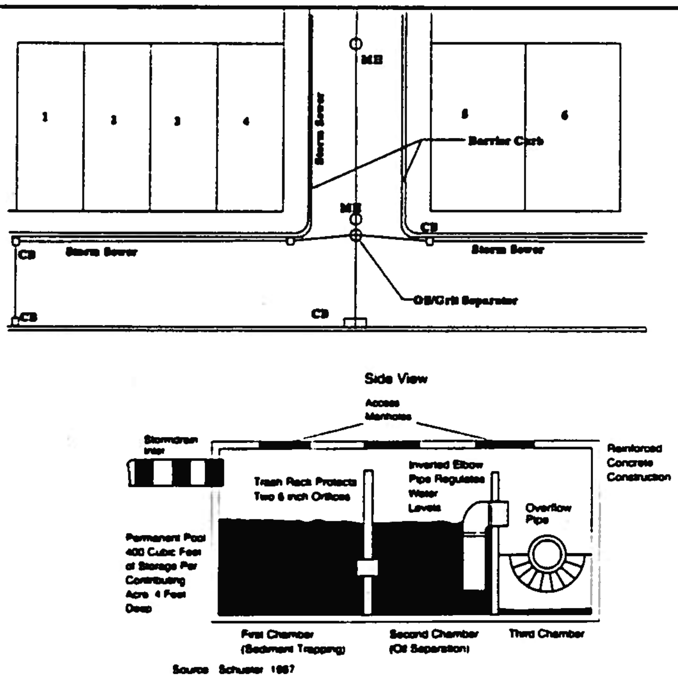
Figure 1.6: Typical curb & gutter drainage system with catchbasins and filtration trenches
Source Environmental Science & Engineering, March 1994

How the system works: Storm runoff is filtered through a perforated pipe into a stone filled trench and the water is collected again at the bottom of the trench by a smaller perforated foundation drain pipe which discharges back into the storm sewer system at the next downstream manhole. To accomplish this, the catchbasins have two leads arranged vertically where the lower lead is connected to the perforated pipe and the higher lead is connected to the standard storm sewer.

This system can basically provide the same level of service as the conventional curb and gutter with storm sewer system but it is expected that the filtration component of the system will provide some water quality control (eg. removal of suspended sediments) and because of its water retention characteristics, the system can also provide some erosion control benefits.

1.3.4 Curb & gutter with storm sewers and oil and grit separators (Figure 1.7)

Numerous examples of systems using oil and grit separators have been installed over the last decade. In most cases, oil and grit separators are used to provide stormwater quality control from single properties such as gas stations. However, in other instances, they can be part of the road drainage system where the road surface and adjacent properties can be serviced by a single unit. Such systems, seen from above ground, are visibly similar to a conventional curb and gutter with storm sewer system.



Source Schuster 1987

Figure 1.7: Typical curb & gutter drainage system with catchbasins and oil & grit separators

How the system works: The surface runoff which is collected by catchbasins is conveyed to an oil and grit separator by means of a standard storm sewer. As demonstrated by the schematic in Figure 1.7, stormwater which enters a typical oil and grit separator travels through three chambers. In the first chamber, called the grit chamber, the coarse sediments are trapped; in the second chamber, called the oil chamber, the oil and other floatable pollutants are retained; and in the third chamber the stormwater flow outlets the oil and grit separator.

Earlier models of oil and grit separators were found to be less effective than anticipated due to the frequent resuspension and flushing of sediments during storms. However, newer and improved versions of oil and grit separators have eliminated this problem by incorporating a flow by-pass for high flow conditions. Although oil and grit separators may provide some level of strormwater quality control they provide little or no benefits in terms of erosion control and groundwater recharge.

1.3.5 Curb & gutter with storm sewers and backyard swales (Figure 1.8)

Different variations of this type of system exist. For example, backyard swales with catchbasins connected to standard storm sewers may be used to provide rear lot drainage. In other instances, larger backyard swales could be designed to also convey the major system flow (during rare events) to a quantity control facility. The diagram in Figure 1.8 suggests that if deeper backyard swales are constructed, they can also be used to convey the flows collected from the road drainage system.

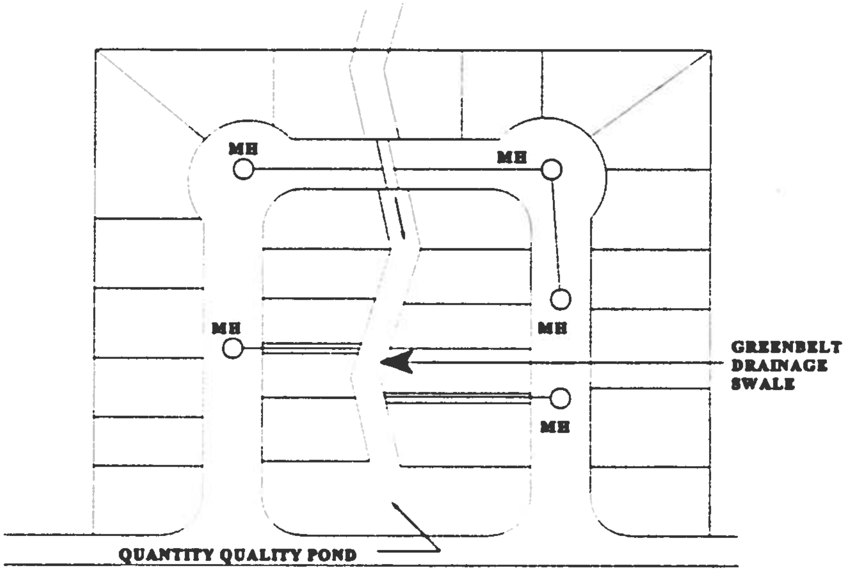


Figure 1.8: Example of a curb & gutter drainage system with storm sewers and backyard swales

How the system works: The surface runoff from adjacent properties, the road or even storm sewers is directed to a backyard swale from which the water can be conveyed to rear yard catchbasins or to a centralized stormwater facility.

The use of backyard swales in conjunction with a curb and gutter drainage system with storm sewers can provide the same level of service as the conventional urban system. However, the use of grass swales can also provide some water quality and groundwater recharge benefits by filtrating and infiltrating the runoff of small storms. The flow retardant effects of the grass cover can also provide some erosion and flood control benefits to downstream properties.

1.3.6 Roadside ditches and culverts (Figure 1.9)

This is the conventional type of drainage system which is found in most rural areas and can be constructed almost anywhere. In general, ditches must be deep enough (ie. 0.50 m) to also provide a positive drainage of the road base. Typical V-shape ditches should not have side slopes which are steeper than 2h:1v although milder slopes of 3h:1v or less are preferred for maintenance purposes. Minimum culvert sizes vary from 300 mm to 600 mm.

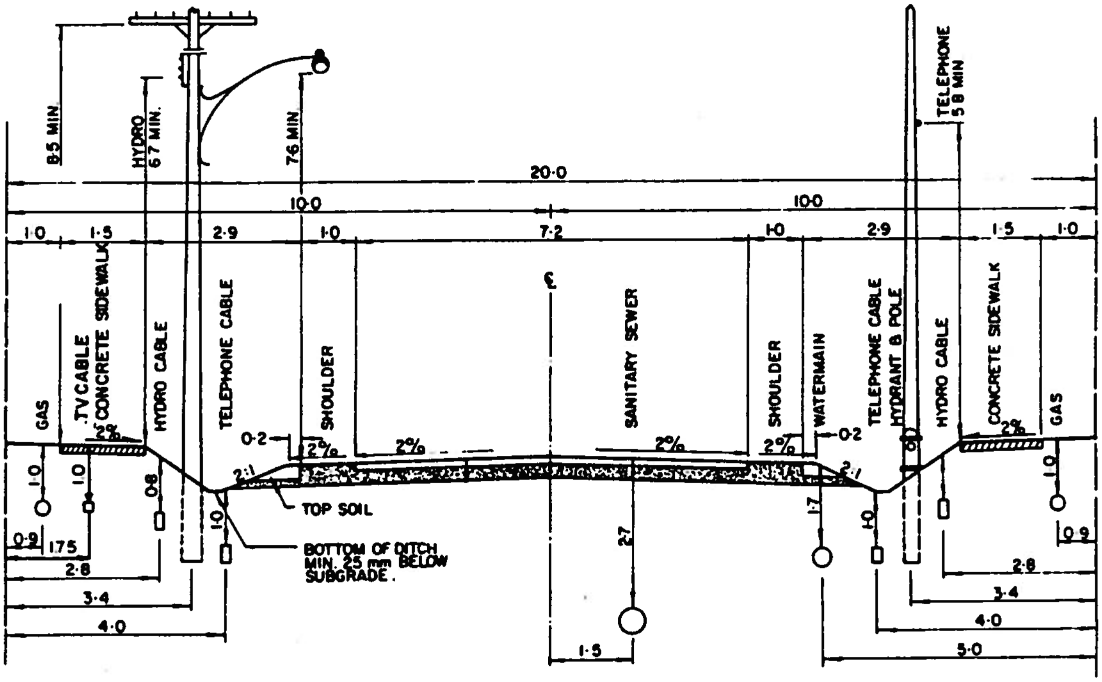


Figure 1.9: Typical roadside ditch drainage system with culverts

Source: City of Etobicoke Standards

How the system works: The surface runoff from the road and adjacent properties drains to the roadside ditch where the water is slowly conveyed towards a given outlet. Culverts are installed under driveways and road intersections in order to provide an uninterrupted flow path.

Depending on their physical characteristics (eg. size, shape, slope and vegetative cover) and the size of the drainage area, roadside ditches can provide the same level of service as a conventional curb and gutter with storm sewer system. However, the vegetation in roadside ditches can also provide some water quality and groundwater recharge benefits by filtrating and infiltrating the runoff of small storms. The flow retardant effects of the vegetative cover can also provide some erosion and flood control benefits to downstream properties.

1.3.7 Roadside ditches with raised culverts or check dams (Figures 1.10 and 1.11)

In every aspect, this type of system is similar to the conventional roadside ditch and culvert system except for the fact that the culverts are installed so that their inverts are raised above the ditch bottom elevation. Alternatively, check dams can also be used to create the same effect. A few examples of this type of system exist but monitoring data is not available.

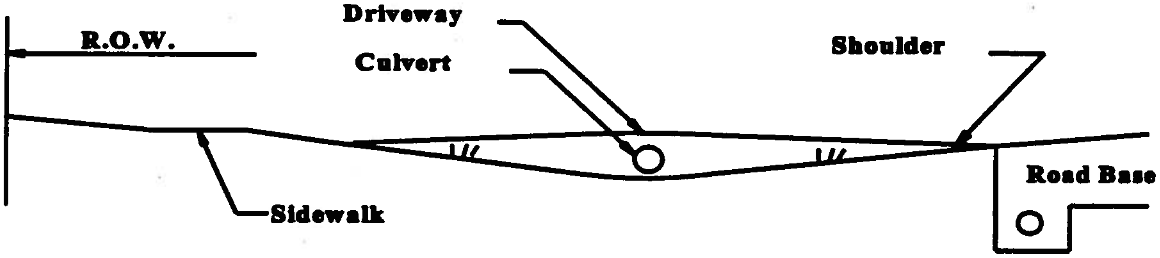


Figure 1.10:: Typical roadside ditch drainage system with raised culverts

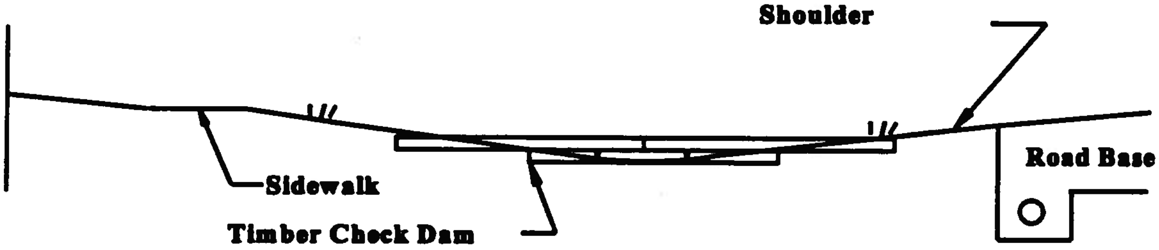


Figure 1.11:: Typical roadside ditch drainage system with check dam

How the system works: As with the conventional use of roadside ditches, the surface runoff from the road and adjacent properties drains to the ditch where by the water is slowly conveyed towards a given outlet. However, the culverts which are installed under driveways and road intersections can be raised slightly above the ditch invert in order to increase the system storage during small storms. The same effect can be achieved if small check dams are inserted across the flow path at regular intervals along the ditch.

The system can provide the same benefits as conventional roadside ditches except that the use of raised culverts or check dams can further enhance the infiltration and flow retardant capabilities of ditches.

1.3.8 Grass swales with perforated pipes and infiltration trenches (Figure 1.12)

This type of drainage system consists of a shallow grass swale underlain by a continuous section of perforated pipes which are enclosed in an exfiltration trench. Small catchbasins, directly connected to the perforated pipes, are installed along the grass swale between each driveway and capture the surface runoff. Numerous successful retrofit examples of such systems exist in the Ottawa area.

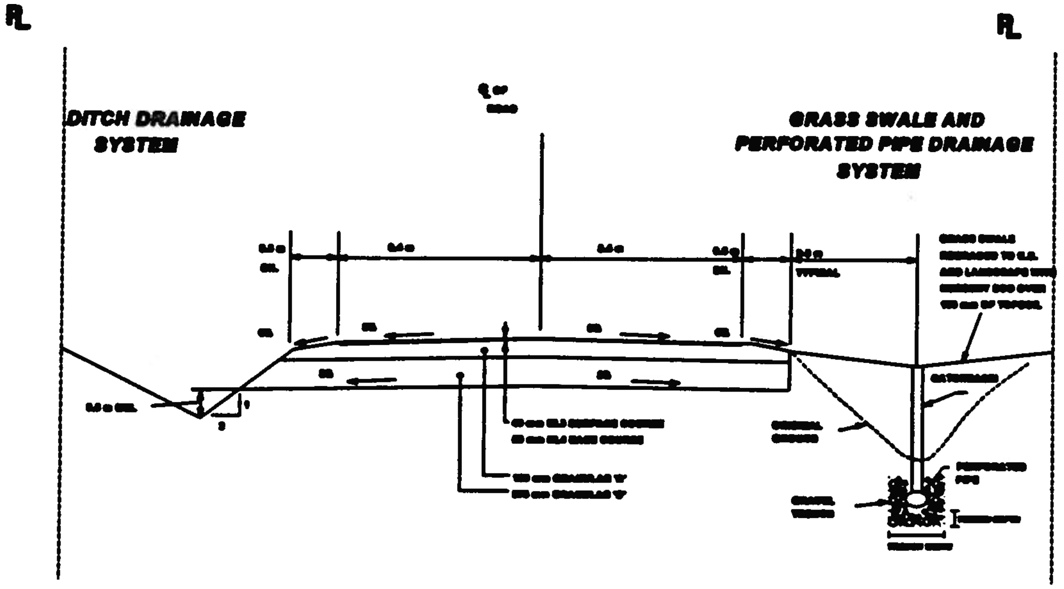


Figure 1.12:: Grass swales with perforated pipes and infiltration trenches

How the system works: The surface runoff from the road and adjacent properties drains to a swale where the water is infiltrated or slowly conveyed towards a catchbasin which is connected to a perforated pipe. The water in the pipe is then exfiltrated to the gravel trench and to the surrounding native soils. When the gravel trench is saturated, the perforated pipe works like a conventional storm sewer and the water is conveyed to a given outlet.

The combined use of grass swales and perforated pipes can provide the same level of service as a conventional curb and gutter with storm sewer system. However, the vegetated surface of the swales can also provide some water quality and groundwater recharge benefits by filtrating and infiltrating the runoff of small storms. The perforated pipes and exfiltration trench enhance the system's capabilities of retaining and infiltrating the captured runoff.

2.0 Literature Review

Over 200 relevant references comprised of scientific articles, books and newspaper clippings were collected during the literature search. Sources of information included the IQUEST service available through the Internet, the CISTI online reference system from the National Research Council, the University of Ottawa library, members of the review committee, and the JFSA library.

Topics or key words used to locate relevant literature during the searches of electronic databases were not limited to stormwater management topics but also included such key words as; Groundwater Pollution, Groundwater Contamination, Groundwater Recharge, Road Drainage Design, Traffic Accidents, Vehicular Safety, Pedestrian Safety, Urban Planning, Environmental Urban Planning, Right of Way, and Road Standards.

The reference list of the literature which was found to be of some relevance for the study is presented in Appendix A. Individual copies of each reference are provided, when possible, in a separate document (Appendix G).

One observation which was made with respect to the collected information was with the year of publication. As shown in Figure 2.1, most of the relevant literature is quiet recent and has been published within the last five years. It was also observed that in earlier references in which stormwater management issues were discussed, the emphasis was generally focussed on conveyance and the control of peak flows for flood protection and erosion control. With time, the topics evolved to include stormwater quality issues followed by temperature effects on downstream ecosystems. Groundwater depletion and reduction in baseflows are some of the most recent topics. In general, issues related to stormwater management have moved, with time, from the outlet to the source.

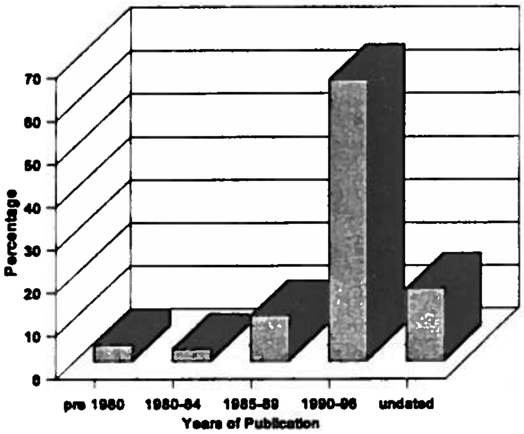


Figure 2.1: Distribution of dated literature

The most recent literature confirms that the problems associated with stormwater as a whole are widely known within the scientific community and have raised concerns in every developed country. However, the quest for effective and economical solutions to address some or all the concerns is often documented through experiences with new control measures. Unfortunately, many of these new systems lack the long term monitoring data required to demonstrate and quantify their effectiveness and maintenance requirements.

Literature data is referenced throughout the report where appropriate. In particular, Section 5 summarizes the information found on non-structural BMPs and Section 11 contains many references to structural BMPs.

3.0 Questionnaires and Surveys

Two questionnaires were formulated for the purpose of the survey in order to identify public attitudes and perceptions and experiences and costs associated with alternative drainage practices. The first survey had more technical questions and was developed mainly for engineers and planners while the second survey was more qualitative and derived for a non- technical audience. Copies of the surveys are presented in Appendix C with a detailed breakdown of responses.

A summary of the main sections of the questionnaires are summarized in Table 3.1 below.

Table 3.1: Description of Questionnaire Sections

Technical Questionnaire (sent to municipal engineers and planners)	**Qualitative Questionnaire** (sent to real estate agents and developers)
Section 1: Definitions - description of terms used in survey.	**Section 1: Definitions** - description of terms used in survey.
Section 2: Description of Alternative Drainage Systems - determines the level of experience with the different types of systems.	**Section 2: Real Estate Values** - determines if the type of drainage system influences property values.
Section 3: New Drainage Systems in Urban Areas - determines what would be an acceptable drainage system in a new urban area. - what standards or level of service would be expected.	**Section 3: Sale / Resale (Urban Areas)** - determines experience with the sale and resale of properties in urban areas with different drainage systems. - identifies if type of drainage system influences the sale and resale of properties in urban areas.
Section 4: New Drainage Systems in Rural Areas - determines what would be an acceptable drainage system in a new rural area. - what standards or level of service would be expected.	**Section 4: Sale / Resale (Rural Areas)** - determines experience with the sale and resale of properties in rural areas with different drainage systems. - identifies if type of drainage system influences the sale and resale of properties in rural areas.
Section 5: Upgrade of Drainage Systems in Older Areas - determines what type of system could be considered in an upgrade situation.	**Section 5: Public Attitudes and Perceptions** - identifies public attitudes towards aesthetics, safety, perception of service, maintenance requirements, house market value and environmental benefits with respect to the type of local drainage system.
Section 6: General SW M Guidelines - identifies what guidelines are used if any.	**Section 6: Customer Preferences** - identifies what seems to be preferred in terms of sidewalks, type of utilities installed, light standards, road geometrics, parking on streets, and trees.
Section 7: Attitudes and Perceptions - (same as Section 5 in the questionnaire for real estate agents).	**Section 7: Safety** - identifies levels of perceived safety with respect to driving, walking, and cycling on streets with different types of drainage systems.
Section 8: Safety - (same as Section 7 in the questionnaire for real estate agents).	
Section 9: Right of Way and Lot Planning - identifies what is thought to be the requirements in terms of ROW widths for different types of drainage systems. - identifies other concerns that may be raised with respect to parking and roadside landscaping if alternative drainage systems were proposed.	

The technical questionnaire was sent to 125 municipal engineers and planners in all of the Greater Toronto Area (GTA) municipalities and to a sample of municipalities in the Ottawa Region.

The scope of the study and budget limitations did not provide the necessary resources to undertake an intensive public survey. Therefore, the qualitative questionnaire was sent to individuals, such as real estate agents and developers, who constantly deal with the public in the selling and purchasing of houses. A total of 72 real estate agents and developers were selected across the GTA including municipalities in the Lake Simcoe area in order to provide a wide representation of opinions in both urban and rural settings. The selected individuals were asked to answer the survey questions based on their understanding of customer preferences.

3.1 General Summary of Survey Results

Out of the 197 questionnaires which were sent out, a total of 52 were returned, 32 (26%) from the municipal engineers and planners and 20 (28%) from the real estate agents and developers. It should be noted that in the latter group, 90% of the respondents were developers. Although a 26% to 28% response rate is usually considered good in such surveys, the actual number of responses received may not be sufficient to provide adequate data to represent the opinions of the entire population.

A complete breakdown of all responses is given with the questionnaires in Appendix C. Although other parts of the report will refer to the survey results, a general summary of the responses is provided below. It is emphasized that the statements are general in nature and due to the limited response rates, the survey results may not be entirely representative.

3.1.1 Public attitudes and perceptions

a) Curbs and gutters are preferred in urban areas, while drainage grass swales and ditches are preferred in the rural areas.
b) Ditch drainage systems are perceived to be inappropriate for urban areas because of; i) aesthetics, ii) safety, iii) perception of service, iv) maintenance requirements, and v) housing values.
c) Swale drainage systems are preferred more than drainage ditches but are not as preferred as the conventional curb and gutter systems. There is still a concern over aesthetics, maintenance and safety.
d) Curb and gutter systems are the most preferred in urban areas, with the most important qualities being level of service and aesthetics.
e) Seasonal considerations do not seem to influence the preference for a particular type of drainage system. However, curb and gutter systems are perceived to be the most appropriate for urban areas.
f) Sidewalks are preferred in both urban and rural areas on at least one side of the street,

and away from the edge of road.

g) Light standards are preferred, and all utility services are preferred underground.
h) Curved streets are preferred over straight streets.
i) Curbs on urban roads are perceived to be safer than curb-less roads.
j) Comfort level for driving, walking, and riding is highest on roadways with curbs and swales were a close second.
k) Pooling of water was not seen as a major concern but most preferred to have the water off the road.

Independently of the survey, articles from newspapers in North York, Etobicoke and Richmond Hill have shown that public preferences can vary from neighbourhood to neighbourhood. For example, in one particular article, local residents were protesting the potential upgrade of their street from a ditch drainage system to a curb & gutter. Some of their concerns included the fear that the changes would force the removal of old trees, dramatically alter the landscape, and that their street would turn out to be a new arterial route. It was also felt that motorist would drive faster under the pretence that the street would be safer.

From the above it may also be concluded that, in some cases, what is perceived to be safer for drivers, may also be perceived to be less safe for pedestrians.

3.1.2 Municipal opinions and experience

3.1.2.1 New Drainage System in an Urban Area

a) Approximately 1/3 of the respondents indicated that they had designed or constructed some alternative drainage system in a new urban area while almost 2/3 said that they would consider the use of an alternative drainage system if they had the chance.
b) The most popular alternative drainage system that would be considered are grass swales with raised culverts (33%) followed by grass swales with or without infiltration trench system (27%). The least considered system was the grass swale with check dams (0%) followed by the curb and gutter exfiltration or infiltration system (7%) or grass swales with infiltration manhole systems or with curb and gutter but no sewers.
c) Almost all expect the same level of service with an alternative drainage system as would be expected with a conventional curb and gutter system.
d) For those who would not consider the use of an alternative drainage system, their main reasons were; i) perceived or known additional maintenance costs, ii) lack of system history, and iii) perceived lower level of service. Their least concern was with safety.

3.1.2.2 New Drainage System in a Rural Area

a) Again approximately 1/3 of the respondents indicated that they have designed or constructed an alternative drainage system in a rural area while almost all respondents would consider using an alternative drainage system.
b) The most popular choice for a potential alternative drainage system was the grass swale (64%) followed by the grass swale with raised culverts or with infiltration trenches (29%). The least considered system was the grass swale with curb and gutter but no

sewer (0%) followed by the curb and gutter exfiltration or infiltration system (7%) and grass swales with check dams (also 7%).

c) As for urban areas, almost all expect the same level of service with an alternative drainage system as would be expected with a conventional system.

d) For those who would not consider the use of an alternative drainage system, their main reasons were; i) perceived or known additional maintenance costs, ii) lack of system history, and iii) perceived lower level of service. Their least concern was with safety.

3.1.2.3 Upgrade (Retrofit) of Drainage System in Older Areas

a) As above, approximately 1/3 of the respondents indicated that they have designed or constructed an alternative drainage system as an upgrade in older areas while almost all respondents would otherwise consider using an alternative drainage system.

b) The most popular choice as an alternative was the grass swale (47%) followed by the grass swale with perforated pipes (42%) and the grass swale with raised culverts (37%). The least desirable options were the grass swale with check dams and the curb and gutter sewer with exfiltration or filtration systems (5%).

c) Almost 2/3 of the respondents indicated that a better level of service would be expected in a retrofit situation.

d) For those who would not consider the use of an alternative drainage system for an upgrade, their main reasons were; i) perceived lower level of service, ii) perceived or known additional maintenance costs, and ii) lack of system history. Their least concern was with the possible need for special construction techniques.

In summary, the most preferred potential alternative drainage systems are presented in Table 3.2 below. The least preferred alternative drainage systems are presented in Table 3.3.

Table 3.2: Most Preferred Potential Alternative Drainage Systems

System No. and Description	New Urban	New Rural	Upgrade
1) Grass swales	2	1	1
2) Grass swale with raised culvert	1	2	3
5) Grass swale with infiltration trench	2	2	4
8) Grass swale with perforated storm	3	3	2

Table 3.3: Least Preferred Potential Alternative Drainage Systems

System No. and Description	New Urban	New Rural	Upgrade
4) Grass swales with check dam	last	2nd last	last
11) Curb gutter and sewer with exfiltration	2nd last	2nd last	last
12) Curb gutter and sewer with filtration	2nd last	2nd last	last
7) Grass swale with curb & gutter (no sewer)	2nd last	last	2nd last

The most common reason for not considering an alternative drainage system as an option were; i) perceived additional maintenance costs, and ii) lack of longer maintenance and operation history.

3.1.2.4 Experience with Designed or Constructed Alternative Drainage Systems

Section 10 of the questionnaire inquired about any existing experience with alternative drainage systems. A total of thirteen municipalities responded with details of such experiences. The following is a summary of the responses.

City of Mississauga

1) ***Grass swale with infiltration manhole***: Urban, new area, 1985, approximately 200 m length servicing approximately 3 ha at a 1:10 level of SWM. Urban - minor local street, typical width used standard 17.5 m, with minimum 12"culverts. Would use system again, higher maintenance costs.
2) ***Grass swale with perforated storm sewer***: Urban, upgrade, 1994, approximately 500 m length servicing ROW at a 1:10 level of SWM. Urban - minor local street, typical width used standard 17.5 m, with minimum 12"culverts. Would use system again, higher maintenance costs.

Town of Ajax

1) ***Grass swale with dipped driveways***: Rural, new area, 1980's, approximately 200 m length at 1:5 level of SWM. Rural - residential with only telephone, power, gas, typical width used standard 20 m, culverts were used with system. Many complaints from residents regarding drainage, bugs, maintenance, would not use system again, higher maintenance costs.

City of Etobicoke

1) ***Curb, gutter and sewer with exfiltration, filtration system***: Urban, upgrade, 1993, approximately 1700 m length servicing 30.5 ha at a 1:2 year level of service. Urban - local street, typical width used standard 20.0 m with no culvert. When asked if system would be used again, response was: "systems are under observation due to high costs", higher maintenance costs.

Town of Richmond Hill

1) ***Grass swale with curb, gutter and sewer***: Urban, upgrade, 1995, approximately 200 m length. Urban - local street, typical width used standard 20 m, with minimum 380 mm culverts. Would use system again, lower maintenance costs.

City of Ottawa

1) ***Grass swale with perforated culverts and partial storm sewers***: Urban, upgrade. urban - minor local street and urban local streets, typical width used standard 20 m with culverts used. Complaints from residents on surface ponding, wheel rutting, improper parking and snow removal damage, tree roots. Would use system again, higher maintenance costs.
2) ***Grass swales with culverts and storm sewer***: Urban, upgrade. Urban - minor local street and urban local streets, typical width used standard 20 m with culverts used. Complaints from residents on blocked and frozen culverts, ponding, weeds, culvert heaving, wheel rutting, improper parking, headwall deterioration. Would not use system again with culverts, higher maintenance costs.
3) ***Grass swale with curb, gutter and sewer***: Urban, upgrade. Urban - minor local street and urban local streets, typical width used standard 20 m some with culverts. Same complaints as #2. Would not use system again with culverts, higher maintenance costs.

Totten Sims Hubicki

(acting on behalf of the Township of Uxbridge)

1) ***Catchbasins in shallow ditches***: Urban, upgrade, 1979, 300 m length, 1:5 yr level of SWM. Urban - minor local street, typical width used standard 20 m no culverts. Would use system again, same maintenance costs.

City of Barrie

1) ***Ditches and culverts***: Urban (industrial), new area, 1986 - 1989, total city industrial subdivision, south end of city at a 1:100 yr level of SWM. Urban - local street (industrial), urban collector (industrial), urban - minor arterial. Typical width used was 26 m+, which was greater than the 20 m+ required for curb and gutter system, with minimum culvert size of 450 mm. Several complaints regarding stagnant water, contamination of water in ditches from septic, weeds, maintenance for erosion. Would use system again for specific applications, higher maintenance costs.

Regional Municipality of York

1) ***Curb and gutter with storm sewer and swale***: Urban, upgrade, 1995/96, servicing 14 ha at a 1:5 level of SWM. Urban - arterial 6 lane, typical width used standard 36 m, with minimum 375 culverts. Too new to tell if they would use again, same maintenance costs.

City of Kanata

1) ***Grass swale with perforated storm sewer***: Industrial park, upgrade, 1995, 1100 m length servicing 1 ha at a 1:5 level of SWM. Semi urban industrial collector with only sanitary sewer and power, typical width used standard 26 m, with minimum 400 mm culverts. Would use system again, higher maintenance costs.
2) ***Grass swale with raised culvert***: rural, new areas, 1:5 level of SWM. rural - residential, rural collector, telephone and power utilities only, typical width used standard 20 m with culverts. Would use system again, same maintenance costs.

Regional Municipality of Halton

1) ***Grass swale***: Rural, upgrade, 1989, 500 m length servicing 10 ha at a 1:50 level of SWM. Urban arterial, typical width used standard 36 m, with minimum 450 mm culverts. Would use system again, some maintenance costs.

Town of Oakville

1) ***Grass swale with curb and gutter (no sewer)***: Urban, new area, 1996, approximately 400 m servicing 22 lots at a 1:5 minor with 1:100 outlet level of SWM. Urban - minor local street, typical width used standard 18 m, with minimum 300 mm culverts. System designed but not constructed yet.

City of Kingston

1) ***Ditch***: Urban, upgrade, 1992, approximately 500 m length servicing 50 ha at a 1:2 level of SWM. Urban - local street, typical width used standard 20 m, with minimum 375 mm culverts. Would use system again, higher maintenance costs.

City of North York

1) ***Grass swale with curbed gutter (with sewer)***: Urban, upgrade, 1995, 600 m in length servicing 3 ha at a 1:2 level of SWM. Urban - residential collector, typical width used standard 200 m, no culverts. Would use system again. Appears to have the same maintenance cost as conventional system, but too early to fully assess.

City of Nepean

(based on a personal communication with
Mr. T. Penfound, City of Nepean)

1) ***Grass swale and perforated pipe systems***: The city has been installing this type of system for over 10 years in order to upgrade the drainage of older subdivisions. They consider this system to be less expensive (by 20%) than upgrading to a curb and gutter system. The system was meant to only provide a 1:2 yr level of service but has been shown to provide more due to its infiltration capacity. The systems are virtually maintenance free except for the occasional sod replacement because of snowploughs or excessive drying. Although the city continues to use the system in retrofit situations, they have not yet considered making use of it in their new subdivisions because it does not meet their municipal standards.

To further summarize the above, 13 municipalities filled out Section 10 of the questionnaire involving 17 different applied projects. In urban areas, three (3) projects were implemented in new subdivisions while eleven (11) were for upgrades. In rural areas, two (2) projects were implemented in new areas and only one (1) as an upgrade.

The alternative drainage systems which were implemented and documented by the respondents are presented in Table 3.4.

It is also important to note that for 11 out of the 18 systems, the respondents said that they would use the system again even if in most cases the costs associated with the systems were noted or perceived to be higher.

For 3 out of the 18 systems they would not use the system again because of problems associated with culverts or poor drainage. These include the "Grass swale with dipped driveways", "Grass swale with culverts and storm sewers" and one of the "Curb gutter with grass swales and storm sewer". It was also noted that the latter two systems would however be considered if culverts were not included.

The "Curb gutter with sewer and exfiltration system", "Curb gutter with sewer and filtration system" and one of the "Curb gutter with storm sewers and grass swales" were recently installed and an opinion to "use again" could not be yet formulated.

Table 3.4: Alternative Drainage Systems and Number of Applications

Type of Alternative Drainage Systems	No. of applications
Grass swales only	2
Grass swale with dipped driveways	1
Grass swale with raised culverts	2
Grass swale with infiltration manhole	2
Grass swale with curb & gutter with sewer	1
Grass swale with perforated storm sewer	3(*
Grass swale with culverts and storm sewer	1
Grass swale with culverts, curb gutter and sewer	2
Curb gutter with grass swale and storm sewers	2
Curb gutter with sewer and exfiltration system	1
Curb gutter with sewer and filtration system	1
	Total 18

*) The City of Nepean has a dozen of successful applications of this system

3.1.3 Public and Municipal Opinions on Right of Way, Road and Lot Planning

a) Almost 50% of the respondents felt that grass swales could be accommodated within a standard 20 m ROW while the same number felt that ditches could not. About 20% to 25% indicated that it was site dependent.

b) With respect to parking on the street, the comfort level was the highest with curb and gutter streets followed by grass swales and ditches.

c) Most (77%) prefer grass as the type of roadside treatment as compared to 23% who indicated that they would prefer natural vegetation.

d) Almost 2/3 of respondents felt that grass swales would not compromise tree planting in the ROW while for ditches the same opinion was almost evenly divided between YES and NO.

4.0 Consideration of Surface Stormwater Conveyance and Storage Functions

One of the main functions of a road drainage system is to convey the water away from the surface as quickly as possible and to prevent the lengthy accumulation of standing water. It is well known that the standard curb and gutter system with storm sewers can effectively achieve this objective. Such a system, however, may not directly address other potential stormwater related concerns such as quality, quantity and erosion control, and groundwater recharge. Where any of these concerns exist, the use of alternative drainage systems should be considered.

Because of the nature of their design and construction, alternative drainage systems may not be as efficient as a curb and gutter system with storm sewers in collecting and conveying surface stormwater runoff. If such a limitation is present and is not properly understood or evaluated, there is a risk that the design of the system will provide a lower than expected level of service. Unfortunately, when this occurs, a potentially attractive system is quickly stigmatized and can be used as a deterrent in future proposed applications.

Stormwater conveyance can be provided by means of surface and/or subsurface systems. Examples of surface systems may include; i) roads and pathways; ii) ditches; and iii) swales. Subsurface systems refer mainly to underground pipe networks which can, in most cases, be sized to accommodate almost any flow. As such, this section of report will only discuss and compare how various surface drainage systems can be evaluated to account for the following:

1. ease of physical integration within development
2. desired level of service
3. conveyance capacities (based on geometry, surface vegetation and effects of culverts)
4. storage capacities (based on the use of raised culverts or check dams)

In order to investigate the conveyance and storage functions of various alternative systems with respect to the above aspects, the following types of surface drainage systems are considered in this section.

a) Roads with conventional Curbs and Gutters
b) Roads with V-Shaped Ditches and 2:1 side slopes
c) Roads with V-Shaped Ditches and 3:1 side slopes
d) Roads with Trapezoidal Shaped Swales and 5:1 side slopes and 0.75 m bottoms
e) Roads with Shallow V-Shaped Swales and 25:1 side slopes

It is noted that although BMPs such as infiltration trenches, oil and grit separators, and end of pond facilities provide several SWM benefits, they cannot be used as conveyance systems and therefore they are not discussed in this section.

4.1 Physical Integration of System within Development

The feasible physical integration of a surface conveyance system within a development can be evaluated based on the assessment of the system dimensions and available space. It is noted that within urban developments, drainage systems are most often located on public property or clearly identified easements.

As an example, a standard 0.5 m deep V-shape ditch with 2:1 side slopes will require at least a 2 m wide strip of land within the Right-of-Way in order to be constructed. For a ditch of the same depth but with 3:1 side slopes to be constructed, then the required width increases to 3 m (on both sides of the road). Taking a typical ROW of 20 m, with a pavement width of 7.2 m, 1.0 m shoulders, and 1.5 m sidewalks located 1.0 m from the property line, leaves roughly 2.9 m of space on both sides of the road to integrate a ditch or swale. As can be seen, the maximum dimensions of roadside drainage systems will, in most cases, be constrained by the available space.

Conveyance systems which incorporate infiltration measures such as infiltration trenches, pervious catchbasins and perforated pipes require adequate pre-treatment. Such measures may include the combined use of buffer strips or grass swales. As with roadside ditches and swales, narrow ROW and the use of sidewalks may interfere with this requirement unless alternative pre-treatment measures such as oil and grit separators are used.

Other surface features of stormwater conveyance systems such as curbs and gutters are integrated within the roadway structure and space requirements are not a constraint.

End of pipe facilities can require, based on upstream land use and imperviousness, anywhere from approximately 50 to 200 m^3/ha (SWMP Planning and Design Manual) of active storage volume for water quality and erosion control. Assuming that the active storage volume depth is limited to 1 m above any permanent pool volume, then it can be determined that the water surface of such utilities will occupy 0.5% to 2.0% of the total drainage area. This space requirement can easily increase to 1% to 4% if we account for the side slopes of such installations and the space needed for other structures (eg. outlet, access roads, etc.).

4.2 Desired Level of Service

Based on the survey with municipal engineers and planners, the majority of respondents indicated that the expected level of service in both urban and rural areas should be 1:100 yrs for the major system and 1:5 yrs for the minor system (see Figure 4.1). When asked if the same level of service would be expected if an alternative drainage system was used, over 80% responded YES (see Figure 4.2).

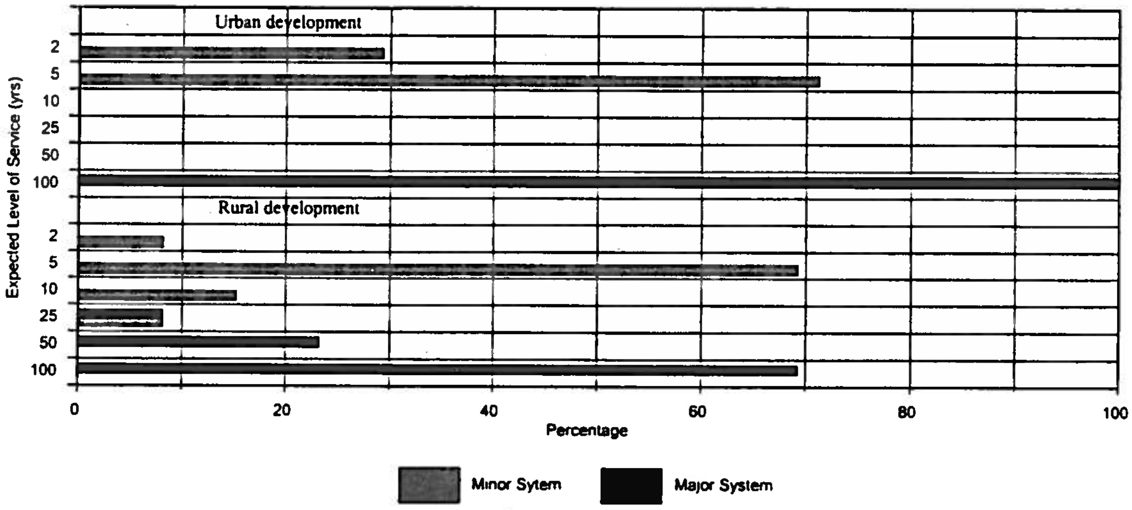


Figure 4.1: What level of service is expected for a new conventional curb and gutter system in an urban or rural area? How does this vary between the Minor and Major drainage systems?

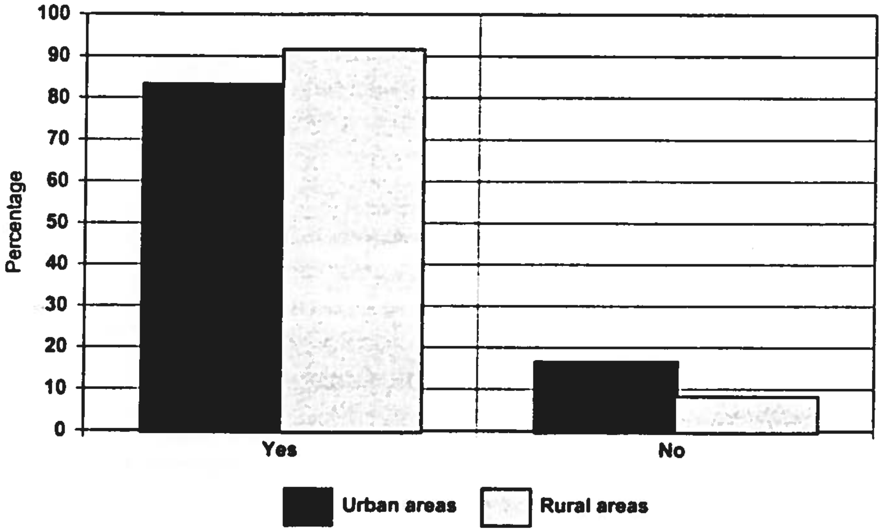


Figure 4.2: Would you expect the same level of service if an alternative type of drainage system was constructed instead of a conventional curb and gutter? Is the answer the same for a new development in a urban or rural area?

4.3 Maximum Allowable Flow Depths

Maximum flow depths in surface drainage conveyance systems can be evaluated based on their size and geometry which in part is dictated by the available space (see Section 4.1). As such and for each of the selected example conveyance systems, the maximum allowable flow depths presented in Table 4.1 were calculated based on typical road sections. The maximum depths were calculated in order to contain the flow within the conveyance system (ie. within the ditch or swale). It was also assumed that property limits or sidewalk elevations (when constructed) are 0.15 m higher than the edge of road.

As shown in Table 4.1, the maximum flow depths vary from 0.01 m to 1.05 m. It can also be seen that the space required for the integration of sidewalks significantly increase this constraint. For example, a shallow grass swale with 25:1 side slopes cannot be constructed within the standard ROW widths of 20 m or 27 m if a sidewalk is present. This is explained by the fact that it is assumed that the sidewalk elevation is 0.15 m higher than the edge of the road; and under such conditions the slope between the edge of sidewalk and edge of road is greater than 1:25.

Even if adequate space was available in order to provide greater depths, it should be noted that the 1988 Flood Plain Planning Policy Statement - Implementation Guidelines by the Ministry of Natural Resources suggests that in stagnant backwater areas, depths in excess of about 1 m could be a threat to young children.

Furthermore, for ditches or swales with depths of 0.60 m or less, subdrains would most likely be required to provide the proper road base drainage.

On roads with curbs and gutters, the maximum allowable flow depths are often limited to 0.3 m based on safety and access / egress purposes.

Table 4.1: Maximum allowable flow depths in typical roadside ditches and swales (based on geometry)

Type of roadside stormwater conveyance system		**Maximum Allowable Flow Depth (m)**	
		Arterial Streets with a ROW of 27.0 m. (See Standard E-15 in Appendix E)	Residential Street with a ROW of 20.0 m. (See Standard E-6 in Appendix E)
2:1 Ditch	w/ sidewalk	0.67	0.60
	w/o sidewalk	1.05	0.97
3:1 Ditch	w/ sidewalk	0.43	0.37
	w/o sidewalk	0.67	0.63
5:1 Grass Swale with 0.75 m bottom	w/ sidewalk	0.15	0.12
	w/o sidewalk	0.3	0.27
25:1 Grass Swale	w/ sidewalk	impossible	impossible
	w/o sidewalk	0.015	0.01

Notes:
- at maximum flow depth the water is contained within the drainage feature.
- sidewalk or property line is 0.15 m higher than edge of road.
- sidewalks are located 2.9 and 3.3 m from the shoulders of the road.
- subdrains would be required for depths which are less than 0.60 m.

4.4 Maximum Allowable Flow Velocities

Maximum allowable flow velocities can be defined in order to prevent soil or vegetation erosion. As such, Table 4.2 presents maximum permissible flow velocities for various types of vegetation cover and soils. As can be seen, maximum permissible flow velocities vary between 1.2 m/s to 2.4 m/s and also vary with the longitudinal slope.

Another criteria which can be used to define maximum allowable velocities is safety. The Ministry of Natural Resources Flood Plain Planning Policy Statement - Implementation Guidelines states that, in shallow areas, flow velocities in excess of 1.8 m/s can pose a threat to the stability of many individuals. The same document also states that the product of the flow depth and velocity should not exceed 0.4 m^2/s (4 ft^2/s). When considering the weight of a small child (20 kg), Table 4.3, obtained from the Stormwater Management Guidelines for the Province of Alberta, lists approximate flow depths and velocities which should not be exceeded. Although the use of this table is for concrete lined channels, it is expected that permissible flow velocities would be reduced for grass channels due to more slippery conditions.

Table 4.2: Maximum permissible flow velocities in grass channels
(based on erosion)

	Maximum Permissible Flow Velocities for		
Type of cover	Slope Range (%)	Erosion resistant soils m/s	Easily eroded soils m/s
Kentucky bluegrass:	5 - 10	1.8	1.2
Bermuda grass:	0 - 5 5 - 10	2.4 2.1	1.8 1.5
Buffalo grass	0 - 5	2.1	1.5
Grass mixture	0 - 5	1.5	1.2

Source: MTO Drainage Manuals

Table 4.3: Maximum permissible flow velocities in depths
(based on safety)

Permissible Water Velocities and Depths to limit forces to safe levels for a 20 kg child standing on a concrete lined channel	
Water Velocity (m/s)	Permissible Depth (m)
0.5	0.8
1	0.32
2	0.21
3	0.09

Source: Stormwater Management Guidelines for the Province of Alberta

4.5 Determining the Maximum Allowable Flow

Maximum allowable flows for ground level alternative drainage systems can be defined by the limiting condition of one of the following factors;

- flow must be contained within the drainage feature
- flow velocities must not exceed maximum permissible velocities

Both above factors are a function of the following characteristics;

- conveyance system geometry
- conveyance system slope
- conveyance system roughness (type of vegetation)
- presence of culverts, their sizes and spacing

The conveyance system geometries are simply defined by the shape and size of the drainage alternative. The system slope is given by the local site characteristics while the system roughness can be estimated based on the type of bottom vegetation. Proposed roughness coefficients for various types of grass cover are given in Table 4.4. We recall from our survey that grass was the preferred landscape treatment for ditches and swales.

Culvert sizes can vary from 300 mm to 600 mm and their spacing is determined by the location and spacing of entrances and driveways.

Table 4.4: Manning Roughness Coefficients for Grassed Channels and Swales

Type of vegetation	Depth of Flow up to 0.2 m and for velocities of 0.6 m/s to 1.8 m/s	Depth of Flow between 0.2 to 0.5 m and for velocities of 0.6 m/s to 1.8 m/s
Kentucky bluegrass: 1. Mowed to 0.05 m 2. Length 0.1 to 0.15 m	 0.070 to 0.045 0.090 to 0.060	 0.050 to 0.035 0.060 to 0.040
Good stand, any grass: 1. Length 0.30 m 2. Length 0.60 m	 0.180 to 0.090 0.300 to 0.190	 0.120 to 0.070 0.200 to 0.100

Source: MTO Drainage Manuals

In order to fully assess and understand how the above system characteristics influence the definition of the maximum allowable flow, a step by step analysis which is described below can be conducted. In other words, by following this process, a designer could determine the ability of a drainage alternative to meet a maximum flow target. The results of such an analysis are discussed at the end of this section.

<u>Step 1</u>: Determine maximum allowable flow depth based on system geometry and ROW width.

- refer to Table 4.1.

Step 2: Determine maximum allowable design flow velocity based on type of vegetation cover and soils.

- refer to Table 4.2 for constraints based on erosion although the analysis may have to be revised based on the data presented in Table 4.3 (constraints imposed by safety). As an example, a maximum permissible flow velocity of 1.25 m/s was selected. *This value is approximately the lowest limit given in Table 4.2.*

Step 3: Derive series of rating curves for the selected drainage alternatives based on geometry, slope and roughness.

- such rating curves are presented graphically in Figures 4.3a, b and c, and in tabular form in Appendix D for various ditch and swale configurations and different types of bottom vegetation. *For comparison purposes, similar rating curves were produced for roads with curbs and gutters and are also presented in Appendix D.*

Step 4: Determine maximum allowable design flow from rating curves based on maximum allowable velocity and/or maximum depth.

- the results of such analysis for typical V-Shaped ditches and Grass Swales for various side slopes and bottom vegetation are summarized in Tables 4.6a, b for typical ROW widths of 20 m and 27 m, respectively. Similar results are presented in Table 4.6c for typical roads with curbs and gutters.

Step 5: Determine maximum serviceable drainage area based on a selected level of service and if system is not affected by culverts or check dams.

- based on the maximum allowable design flows which were calculated in Step 4, a Rational Method analysis was conducted to determine what drainage area would generate such flows for a 1:5 yr event.
- the analysis was conducted with the Greenwood MTRCA IDF curves for a series of imperviousness ratios and accounted for the varying flow velocities in a V-Shape ditch with 2:1 side slopes constructed within a 20 m and 27 m ROW with and without sidewalks. IDF curves are provided in Appendix D.
- the results are presented in Figures 4.4a and b.

Step 6: Determine effects of culverts and their spacing.

- the intrusion of culverts along the flow path of the conveyance system was investigated by considering culvert capacities and potential backwater effects to other upstream culverts.
- the analysis was conducted for conveyance systems installed within a 20 m ROW and with average slopes of 0.5% and 1.0%.
- the results of this analysis are presented in Figures 4.5a and b for various culvert sizes and the selected roadside conveyance systems.

Step 7: Determine maximum potential contributing drainage area based on land use characteristics and return period.

- based on the maximum flow which the system can convey, a preliminary estimate of the maximum drainage area which can be serviced can be determined with the use of the Rational Method.
- for example, based on the analyses conducted with and without culverts, the results presented in Table 4.7 can be obtained for a 40% impervious area with various culvert sizes and spaced at 20 m.

Discussion of results

Maximum allowable flows

- The results of the rating curve analyses (Tables 4.6a and b) show that within the selected types of roadside drainage systems, the most hydraulicly efficient is the typical V-Shaped ditch with 2:1 side slopes except for where the longitudinal slopes are above 2.5%, in which case a V-Shaped ditch with 3:1 side slopes can, in some cases, accommodate 50% more flow. As discussed further below, for slopes above 1%, the height of vegetation can have an important role in determining the maximum flow capacity of ditches.
- Typical grass swales with 5:1 side slopes and 0.75 m bottoms have, in general, approximately 10% to 15% the flow capacity of a typical ditch.
- The shallow grass swales with 25:1 side slopes have limited capacities which vary between 1 and 5 l/s.
- A comparison of the results presented in Tables 4.6a and b (Ditches and Swales) with Table 4.6c (Roads with curbs) shows that a typical ditch can convey as much as to two times the flow which can be allowed on a roadway with curbs. It should be noted that under the present analysis, the flow in the ditch is fully contained while the flow on the roadway with curbs can have a depth of up to 0.3 m.

Effects of sidewalks

- The effects of including a sidewalk within a given ROW reduces the space available for the construction of a roadside drainage system. In most cases, this can significantly reduce the flow capacity of the system and hence the maximum serviceable area. For example, Figure 4.4a shows that for a typical V-Shape ditch with 2:1 side slopes and a longitudinal slope of 1% installed within a 27 m ROW, the serviceable area (40% impervious) can be reduced from approximately 26 ha to 10 ha if sidewalks are introduced. It is reminded that this is for only one ditch, so for a road with two similar ditches, the total serviceable area is in fact multiplied by two.

Effect of bottom vegetation

- in general, the maximum allowable flow decreases with the height of vegetation within ditches or swales. However, the opposite occurs when high slopes are encountered. For example, Figure 4.6 shows that the maximum allowable flow in a V-Shape ditch with 2:1 side slopes and a longitudinal slope of 2.5% increases from approximately 0.40 m^3/s to 1.75 m^3/s if the bottom vegetation is kept at a 0.3

m height instead of being mowed to a 50 mm height. This is the case because for a 2.5% longitudinal slope, the flow velocities (due to erosion) can become the limiting criteria in defining the maximum allowable flow. With higher vegetation, the flow velocity can be reduced below critical values and the full depth of the drainage system can be utilized.

Effects of ROW widths

- A review of results presented in Table 4.6a (ROW=20 m) and Table 4.6b (ROW=27 m) shows that the effects of a reduced ROW are more pronounced for the lower longitudinal slopes of 0.25% and 0.50% (where the limiting factor is defined by the depth of the system). For steeper slopes the effects of reduced space is less critical but still important for grass swales and ditches with long grass.

Effects on the Time of Concentration

- As the flow velocity within a roadside drainage system changes with the shape, slope and roughness it follows that the time of concentration also varies with the same parameters. As the time of concentration 'tc' increases, the design peak flow for a given area decreases. Figure 4.7 compares how the various alternative drainage systems influence the 'tc' with respect to the drainage area. For example, the figure shows that for a 10 ha area, a curb and gutter system can have a 'tc' of approximately 20 minutes while for the same area, a V-Shape ditch with 3:1 side slopes and a 0.3 m grass cover can have a 'tc' of approximately 40 minutes. These values were calculated for areas with 40% imperviousness and a 5 yr design event.
- The effects of the increased time of concentration with respect to the type of drainage alternative is demonstrated in Figure 4.8. The figure shows how the 5yr design peak flows are reduced when they are compared with the design flow for a curb and gutter system. For the conditions considered, the results indicate that peak flows can be reduced from 2% to as much as 38% based on the shape of the conveyance system and type of bottom vegetation. Such reductions in peak flows can substantially reduce the requirements on downstream stormwater infrastructure and at the same time provide beneficial implications for preventive erosion and flood control. For comparison purposes, Figure 4.9 presents the 5 yr peak flows for a typical curb and gutter system.

Effects of culverts

- The culvert analysis demonstrated that both the culvert size and culvert spacing have a significant impact on the maximum allowable system flow. For example, Figure 4.5a (longitudinal slope = 0.5%), shows that 300 mm culverts will limit the flow in any of the systems considered to approximately 55 l/s when the culverts are spaced by only 20 m. Such a flow represents a serviceable area of only 0.7 ha at 40% imperviousness for a level of service of 1:5 yr. By comparison, if 600 mm culverts are used, the maximum permissible flow increases to approximately 250 l/s (20 m spacing) which corresponds to a serviceable area of approximately 4 ha. Figure 4.5b is similar to Figure 4.5a but represents a system slope of 1.0%. The increased slope reduces the backwater effects between closely spaced culverts and consequently increases the maximum allowable flow by as much as 40%.

Table 4.6a: Maximum flow (m^3/s) in roadside ditches or swales constructed within a 20 m ROW

		Flow limitations are based on maximum depth (see Table 4.1) or maximum flow velocity of 1.25 m/s							
	Longitudinal Slopes=>	S=0.25%		S=0.5%		S=1.0%		S=2.5%	
Ditch and Swale specs		no sidewalks	with sidewalks	no sidewalks	with sidewalks	no sidewalks	with sidewalks	no sidewalks	with sidewalks
Typical V-Ditch with 2:1 Side Slopes	Mowed grass	1.25(a	0.35(a	1.75(a	0.50(a	1.80(b	0.70(a	0.43(b	0.43(b
	0.1 to 0.15 m grass	1.10(a	0.30(a	1.50(a	0.45(a	2.20(a	0.60(a	0.75(b	0.75(b
	0.3 m high grass	0.55(a	0.13(a	0.78(a	0.24(a	1.13(a	0.29(a	1.78(a	0.50(a
Typical V-Ditch with 3:1 Side Slopes	Mowed grass	0.65(a	0.15(a	0.82(a	0.21(a	1.25(a	0.30(a	0.65(b	0.47(a
	0.1 to 0.15 m grass	0.54(a	0.13(a	0.75(a	0.18(a	1.06(a	0.26(a	1.05(b	0.41(a
	0.3 m high grass	0.28(a	0.07(a	0.39(a	0.09(a	0.55(a	0.14(a	0.88(a	0.22(a
Typical Grass Swales with 5:1 Side Slopes and 0.75 m bottom	Mowed grass	0.15(a	0.03(a	0.22(a	0.04(a	0.30(a	0.05(a	0.47(a	0.08(a
	0.1 to 0.15 m grass	0.12(a	0.02(a	0.17(a	0.03(a	0.23(a	0.04(a	0.37(a	0.06(a
Typical Grass Swales the 25:1 Side Slopes	Mowed grass	0.001(a	—	0.002(a	—	0.003(a	—	0.005(a	—

Note: Maximum allowable flows are for only one side of road and does not account for effects of culverts if any.
a) limited by maximum allowable flow depth in system.
b) limited by maximum allowable flow velocity to guard against erosion.

Table 4.6b: Maximum flow (m^3/s) in roadside ditches or swales constructed within a 27 m ROW

		Flow limitations are based on maximum depth (see Table 4.1) or maximum flow velocity of 1.25 m/s							
	Longitudinal Slopes=>	S=0.25%		S=0.5%		S=1.0%		S=2.5%	
Ditch and Swale specs		no sidewalks	with sidewalks	no sidewalks	with sidewalks	no sidewalks	with sidewalks	no sidewalks	with sidewalks
Typical V-Ditch with 2:1 Side Slopes	Mowed grass	1.60(a	0.45(a	2.25(a	0.70(a	1.80(b	0.90(a	0.43(b	0.43(b
	0.1 to 0.15 m grass	1.35(a	0.40(a	1.90(a	0.55(a	2.65(a	0.75(a	0.75(b	0.75(b
	0.3 m high grass	0.72(a	0.23(a	1.00(a	0.28(a	1.40(a	0.35(a	2.20(a	0.68(a
Typical V-Ditch with 3:1 Side Slopes	Mowed grass	0.75(a	0.21(a	1.05(a	0.32(a	1.45(a	0.46(a	0.65(b	0.63(b
	0.1 to 0.15 m grass	0.63(a	0.18(a	0.88(a	0.27(a	1.25(a	0.39(a	1.05(b	0.61(a
	0.3 m high grass	0.34(a	0.10(a	0.47(a	0.14(a	0.67(a	0.20(a	1.06(a	0.32(a
Typical Grass Swales with 5:1 Side Slopes and 0.75 m bottom	Mowed grass	0.19(a	0.04(a	0.28(a	0.05(a	0.38(a	0.08(a	0.62(a	0.12(a
	0.1 to 0.15 m grass	0.15(a	0.03(a	0.21(a	0.04(a	0.30(a	0.06(a	0.50(a	0.09(a
Typical Grass Swales the 25:1 Side Slopes	Mowed grass	0.002(a	—	0.003(a	—	0.003(a	—	0.005(a	—

Note: Maximum allowable flows are for only one side of road and does not account for effects of culverts if any.
a) limited by maximum allowable flow depth in system.
b) limited by maximum allowable flow velocity to guard against erosion.

Table 4.6c: Maximum permissible flow (m^3/s) on a roadway with curbs and gutters

	Flow limitations are based on maximum depth of 0.3 m or if product of (Velocity x Depth) > 0.4 m^2/s			
Roadway specs Longitudinal Slopes=>	S=0.25%	S=0.5%	S=1.0%	S=2.5%
ROW=20 m, 8.5 m road, 2% cross-slopes, 150 mm curb, 2.6% shoulders with mowed grass cover	3.52 m^3/s (a	3.37 m^3/s (b	2.66 m^3/s (b	2.45 m^3/s (b
ROW=26 m, 11.0 m road, 3% cross-slopes, 150 mm curb, 2.6% shoulders with mowed grass cover	3.67 m^3/s (a	4.42 m^3/s (b	3.44 m^3/s (b	2.20 m^3/s (b

a) limited by max. depth of 0.3 m b) limited by product of velocity x depth

Table 4.7: Typical Maximum Serviceable Areas with culverts spaced at 20 m for slopes of 0.5%

Type of drainage	Maximum serviceable drainage area[1] (40% imp.)			
	without culverts	300 mm culverts	450 mm culverts	600 mm culverts
grass swales (25:1 side slopes)	0.035 ha	n/a	n/a	n/a
swale with 0.75 m bottom and 5:1 side slopes and mowed grass	3.50 ha	0.80 ha	2.25 ha[2]	3.60 ha[2]
roadside ditch with mowed grass and 3:1 side slopes	13.0 ha	0.77 ha	2.00 ha	3.20 ha
roadside ditch with mowed grass and 2:1 side slopes	32.0 ha	0.73 ha	1.90 ha	3.10 ha

Notes: 1) drainage areas are for one swale or ditch. For a road with swales or ditches on both sides, the maximum serviceable drainage area is twice the value shown in the table.
2) the use of 450 mm and 600 mm culverts along swales with 5:1 side slopes may not be possible due to space limitations.

4.6 Storage Volumes Created by Raised Culverts or Check Dams

The purpose of installing raised culverts or check dams is to create a small ponding area which can retain and infiltrate some of the rainfall runoff. It is hoped that the retained volume is significant enough to reduce the requirements of an end of pipe facility meant for quality or erosion control. It can be noted from our survey that grass swales with raised culverts systems were the most preferred potential alternatives, but grass swales with check dams were among the least preferred alternatives.

It should be kept in mind that the use of raised culverts may reduce the maximum allowable flows which in turn may limit the serviceable area.

The effective storage volume that can be retained by a raised culvert or check dam is a function of the differential height between the invert of the culvert and the invert of the channel, and the channel slope. This is demonstrated in Table 4.7 where the required maximum spacing for raised culverts was calculated as a function of culvert height and channel slope. The results presented in Table 4.7 are based on the assumption that the raised invert elevation of one culvert is the same as the downstream invert elevation of the next upstream culvert. As could be anticipated, the length over which water can be retained is most effective for smaller slopes. Accordingly, Table 4.7 shows that for the purpose of providing online storage, the use of raised culverts or check dams would be questionable for channels with slopes greater than 1% due to the short required distances.

Table 4.8: Maximum spacing of raised culverts or check dams

Height of raised culvert or check dam above channel invert (mm)	Maximum spacing of raised culverts or check dams for maximum effective retention length based slope (m)				
	Slope=0.25%	Slope=0.5%	Slope=1.0%	Slope=2.5%	Slope=5%
50	20	10	5	2	1
100	40	20	10	4	2
150	60	30	15	6	3
200	80	40	20	8	4
250	100	50	25	10	5

The storage volumes created by raised culverts or check dams will also vary with the cross sectional channel shape. For the drainage alternatives considered, storage volumes were calculated for various check dam or culvert heights based on the maximum spacing given in Table 4.7. The calculated volumes in m^3 per m of channel length are presented in Table 4.8. Also provided in Table 4.8 are the wetted top widths which would be observed when the storage volumes are full.

To make the results of Table 4.8 more useful, it is possible to transform the storage volumes from m^3 to equivalent millimetres of water over a corresponding drainage area. As an example, this transformation was done for different heights of raised culverts with 20 m, 30 m and 40 m lot depths and a fixed ROW of 20 m. These results are presented in Table 4.9 and indicate that equivalent volumes can theoretically vary from 0.06 to 28.8 mm.

In order to further evaluate the benefits of the calculated equivalent volumes, the runoff volume from the area to be controlled must be estimated. As an example, if the area to be controlled has an imperviousness of 40% (which corresponds to a runoff coefficient of approximately 0.48) and based on 20 m deep lots with a 20 m ROW the runoff per metre for a design event of 13 mm would be 6.24 mm (0.48 x 13 mm). According to Table 4.10, a drainage system consisting of 5:1 swales with 0.75 m bottom width with check dams or culverts raised by 200 mm could retain the equivalent of 6.32 mm, hence the entire runoff from a 13 mm storm. If such a system was feasible it could eliminate the need for an end of pipe facility. However, since the maximum allowable flow depth in such a grass swale is limited to a maximum of 0.27 m (see Table 4.1) and that the draw down time to infiltrate a column of water of 200 mm could be in the order of one day (see Section 4.7), it would seem improbable that such a roadside drainage system would be acceptable.

Table 4.9: Storage volumes created by raised culverts or check dams

Type of conveyance system	Storage volume (vol. m^3/m) and top width (TW m) of water surface created by raised culverts or check dams at maximum spacing									
	H=50 mm		H=100 mm		H=150 mm		H=200 mm		H=250 mm	
	Vol	TW	Vol	TW	Vol	TW	Vol	TW	Vol	TW
2:1 V-Ditch	0.0028	0.20	0.0111	0.40	0.0250	0.60	0.0443	0.80	0.0690	1.00
3:1 V-Ditch	0.0042	0.30	0.0166	0.60	0.0374	0.90	0.0665	1.20	0.1040	1.50
5:1 Swale w/0.75 m bottom	0.0267	0.58	0.0670	1.12	0.1215	1.73	0.1895	2.30	0.2720	2.88
25:1 V-Swale	0.0346	2.50	0.1385	5.00	0.3115	7.50	0.5550	10.00	0.8650	12.50

TW = Maximum Top Width (m) of water surface when water retained at depth H

Table 4.10: Equivalent storage volumes created by raised culverts and check dams for varying lot depths

Type of conveyance system	Equivalent storage volume in (mm) generated by different height of raised culverts or check dams with varying lot depths (ROW fixed at 20 m)														
	20 m deep lots					30 m deep lots					40 m deep lots				
	H50	H100	H150	H200	H250	H50	H100	H150	H200	H250	H50	H100	H150	H200	H250
2:1 V-Ditch	0.09	0.37	0.83	1.49	2.30	0.07	0.28	0.62	1.11	1.72	0.06	0.22	0.50	0.89	1.38
3:1 V-Ditch	0.14	0.55	1.25	2.22	3.47	0.11	0.41	0.93	1.66	2.60	0.08	0.33	0.75	1.33	2.08
5:1 Swale, 0.75 m bot.	0.89	2.23	4.05	6.32	9.07	0.67	1.67	3.04	4.74	6.80	0.53	1.34	2.43	3.79	5.44
25:1 V-Swale	1.2	4.6	10.4	18.5	28.8	0.9	3.5	7.8	13.9	21.6	0.7	2.8	6.2	11.1	17.3

H50 represents a 50 mm height for the raised culverts or check dams

4.7 Time Required for Water Dissipation

Stormwater dissipation is a function of many factors such as the system's length and slope, surface infiltration capacities and temperature.

From our survey with municipal engineers and planners, two pertinent questions were asked; the first one asked if temporary water accumulations in roadside drainage features were acceptable and if so for how long? The results of these questions are presented in Figures 4.10 and 4.11. It is seen that most (over 70%) responded that it was acceptable to have temporary water accumulations in roadside drainage features. In terms of water dissipation, the opinion was almost evenly divided between 1 hr, 12 hrs and 24 hrs within rural areas while 50% responded that water should dissipate over a maximum of 12 hrs within urban areas.

In general, alternative drainage systems should be able to dissipate any stormwater within a reasonable time period. Problems could arise if the surface soils have low infiltration capacities or the groundwater is near the surface. These problems can further be aggravated if the system slopes are not properly maintained.

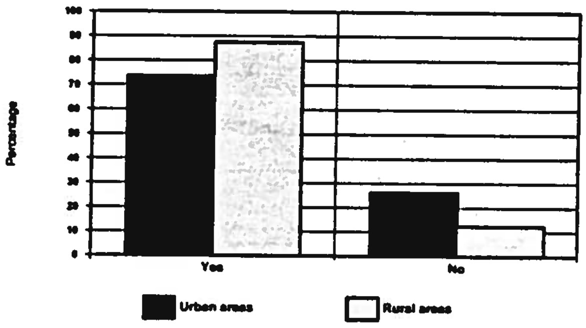


Figure 4.10. During more frequent storm events (ie. 25 mm or less) would temporary water accumulations in roadside swales be acceptable?

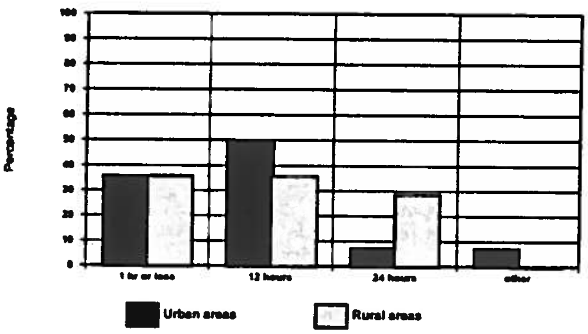
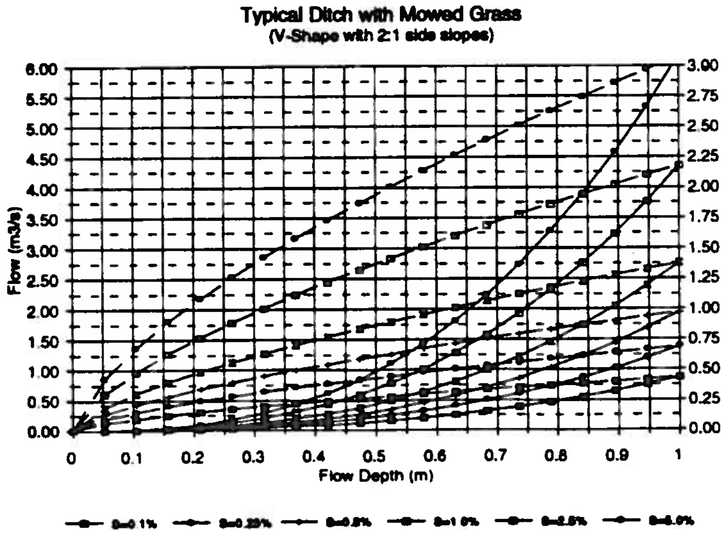
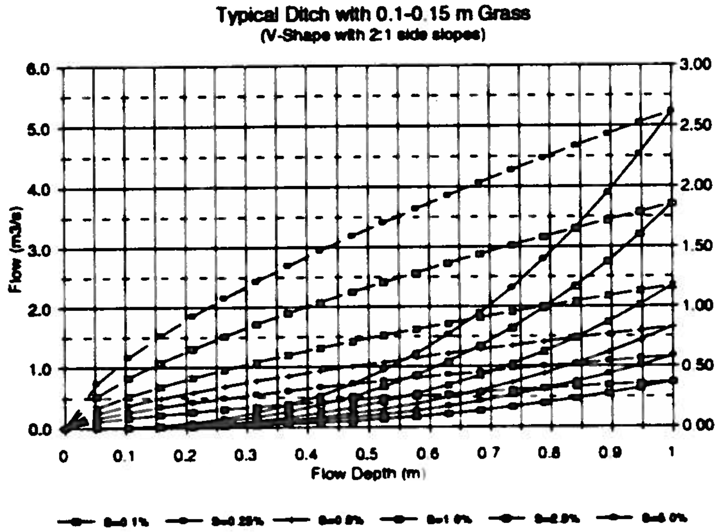


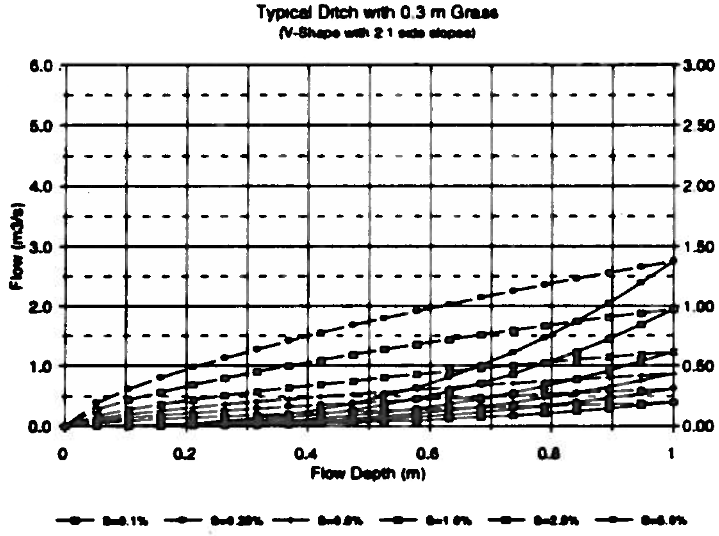
Figure 4.11: If YES, How long after the storm event should the water take to drain?



Typical Ditch with Mowed Grass
(V-Shape with 2:1 side slopes)



Typical Ditch with 0.1-0.15 m Grass
(V-Shape with 2:1 side slopes)



Typical Ditch with 0.3 m Grass
(V-Shape with 2:1 side slopes)

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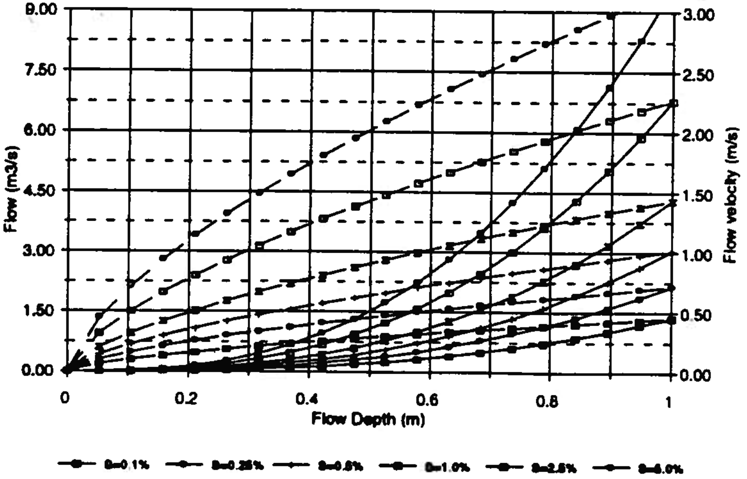
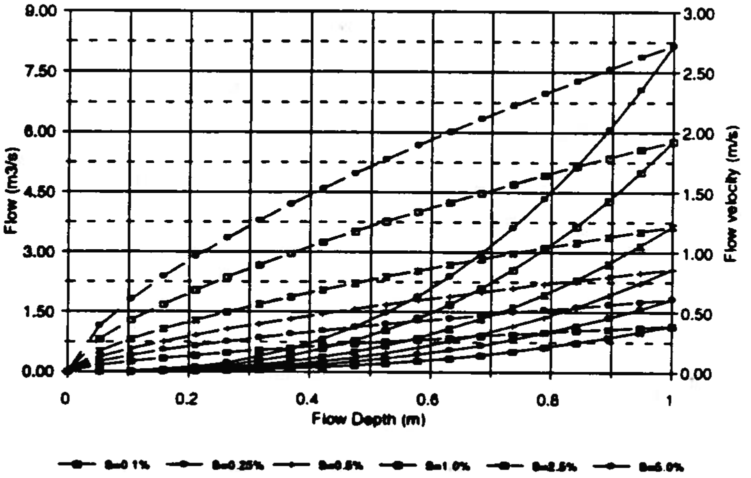
Figure 4.3a Flow and velocity curves for typical v-shape ditches with 2:1 side slopes and various types of grass cover.

Typical Ditch with Mowed Grass
(V-Shape with 3:1 side slopes)



Typical Ditch with 0.1-0.15 m Grass
(V-Shape with 3:1 side slopes)



Typical Ditch with 0.3 m Grass
(V-Shape with 3:1 side slopes)

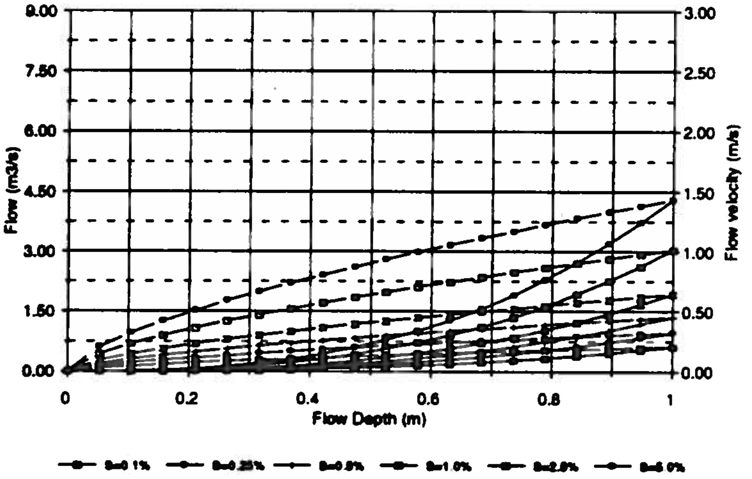


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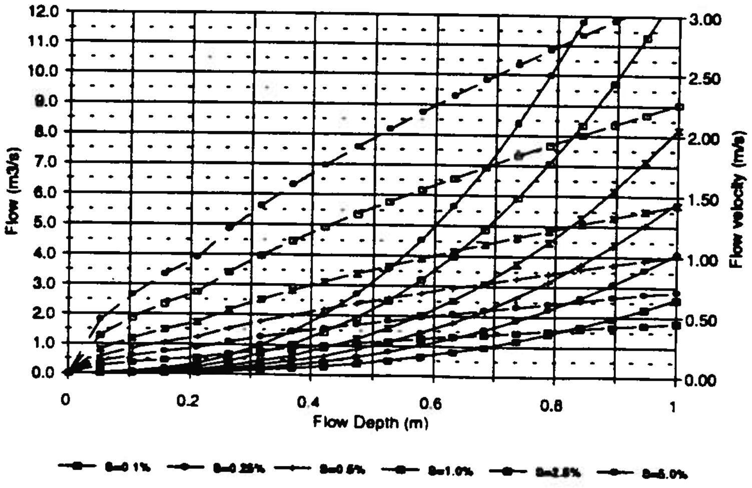
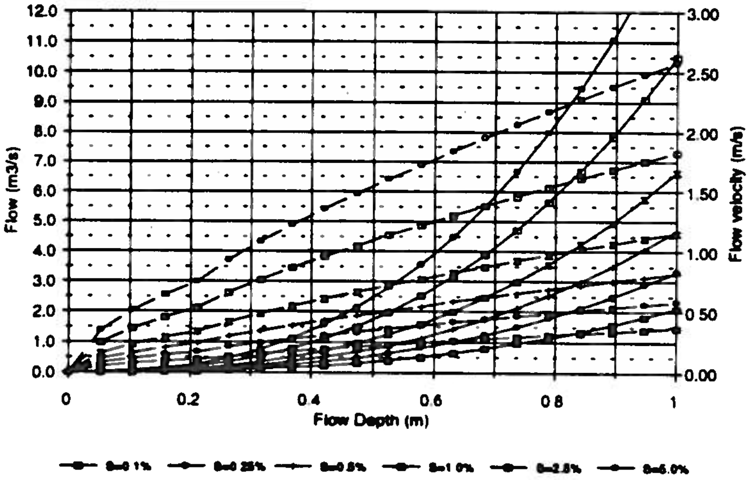
Figure 4.3b Flow and velocity curves for typical v-shape ditches with 3:1 side slopes and various types of grass cover.

Deep Swales with Mowed Grass
(5:1 side slopes, Bottom Width=0.75 m)



Deep Swales with 0.1-0.15 m Grass
(5:1 side slopes, Bottom Width=0.75 m)



Shallow Swales with Mowed Grass
(V-Shape with 25:1 side slopes)

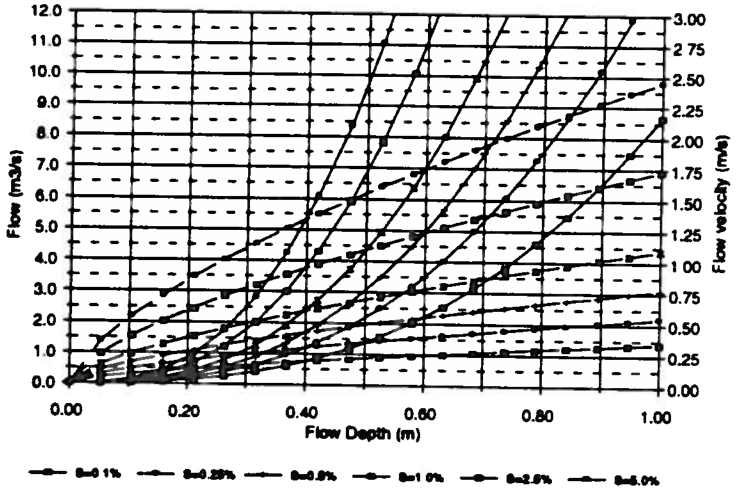


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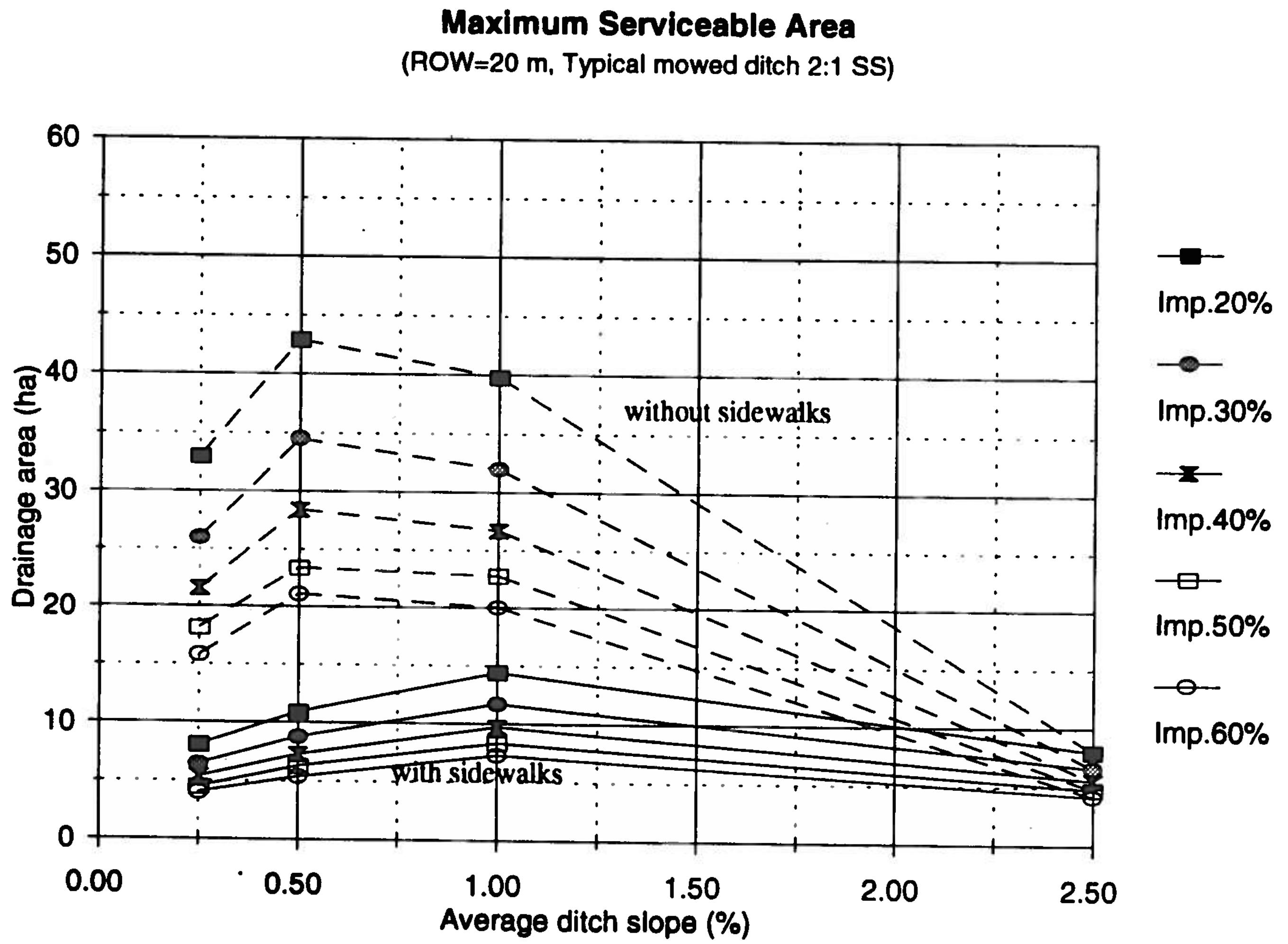
Figure 4.3c Flow and velocity curves for typical grass swales and various types of grass cover.



Maximum Serviceable Area

(ROW=20 m, Typical mowed ditch 2:1 SS)

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Figure 4.4a Maximum serviceable areas for a ROW of 20 m and a typical mowed ditch with 2:1 side slopes

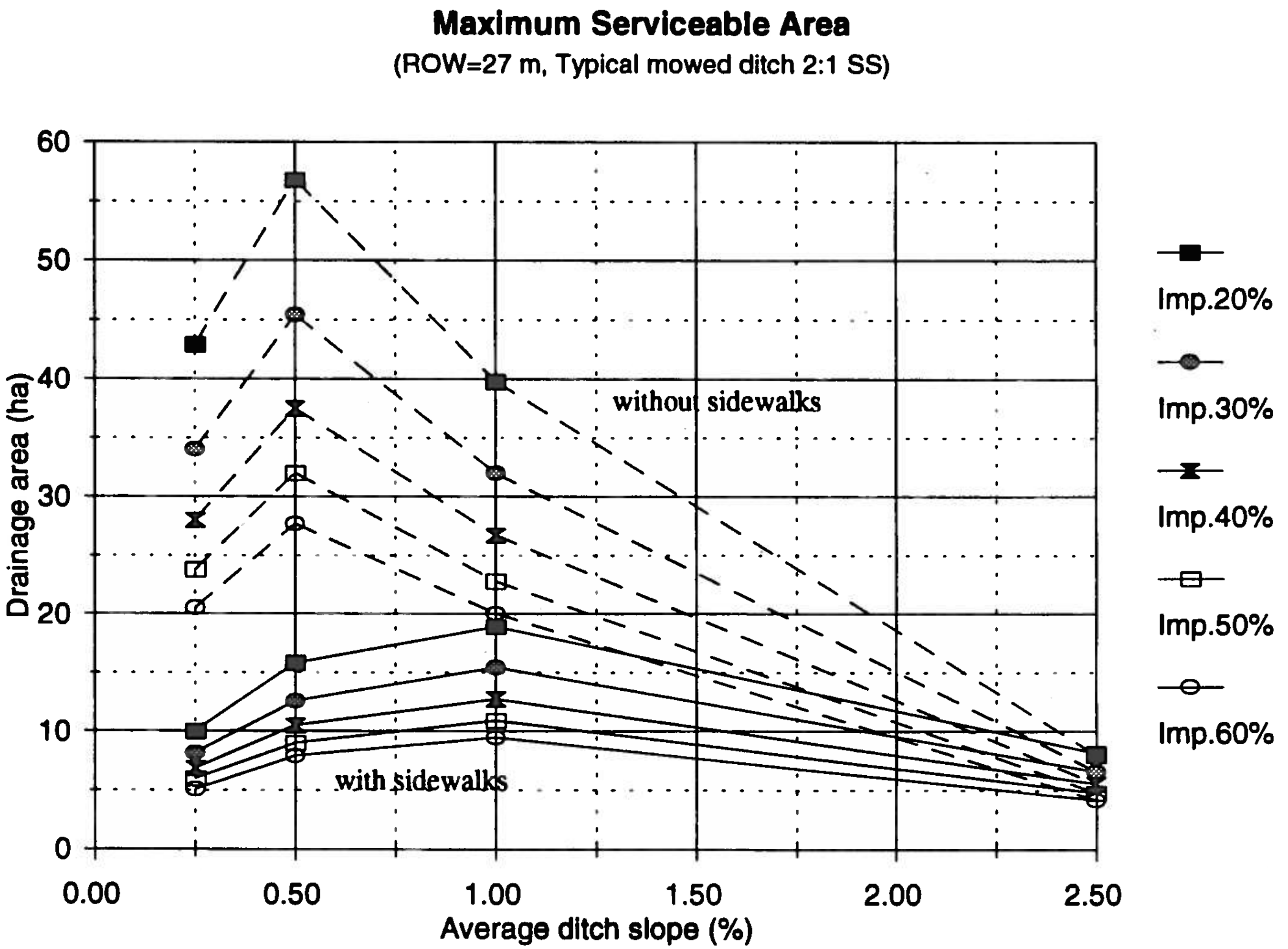

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Figure 4.4b Maximum serviceable areas for a ROW of 27 m and a typical mowed ditch with 2:1 side slopes

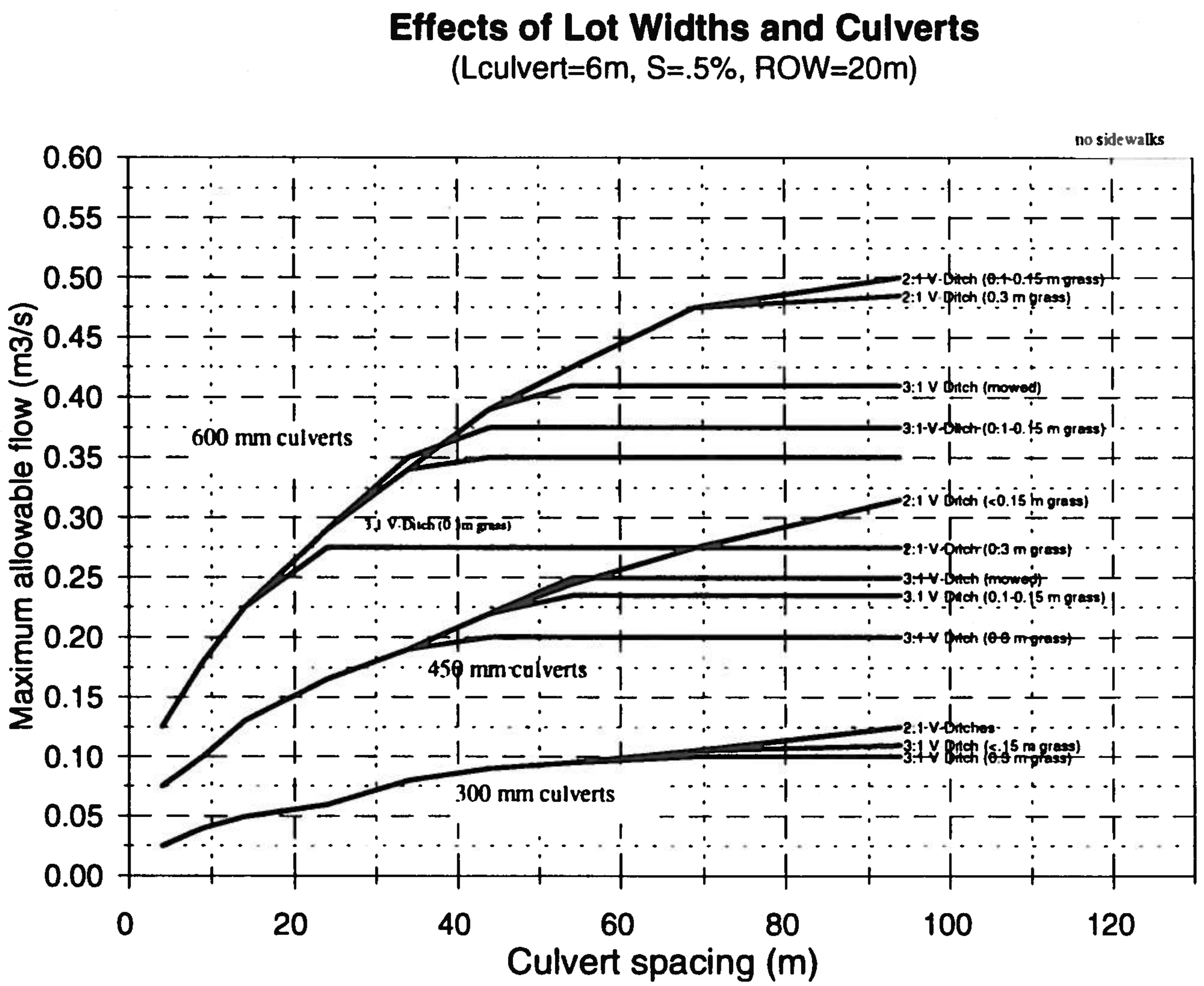

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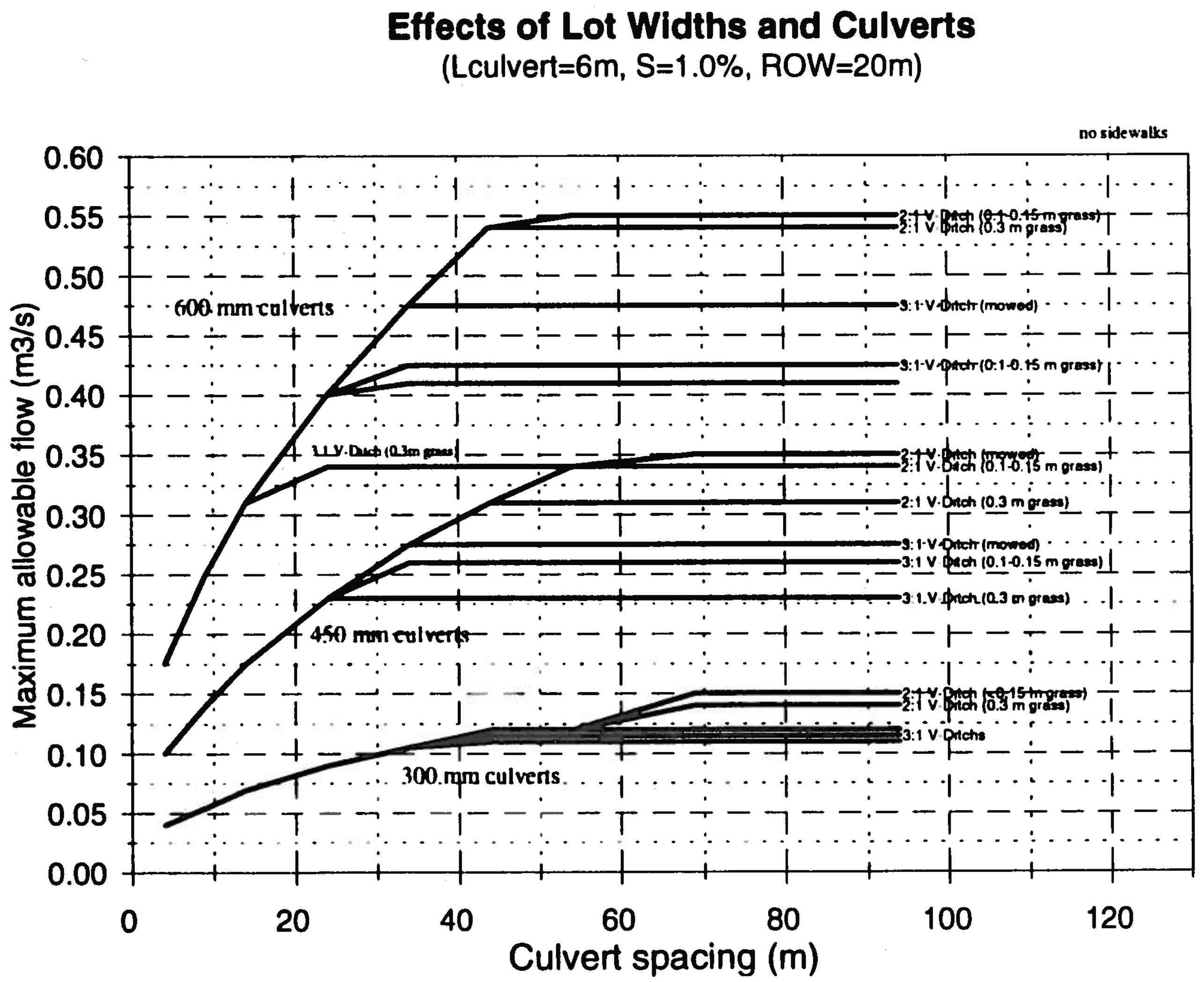
Figure 4.5a Effects of culvert sizes and spacing for a longitudinal slope of 0.5%



Effects of Lot Widths and Culverts
(Lculvert=6m, S=1.0%, ROW=20m)

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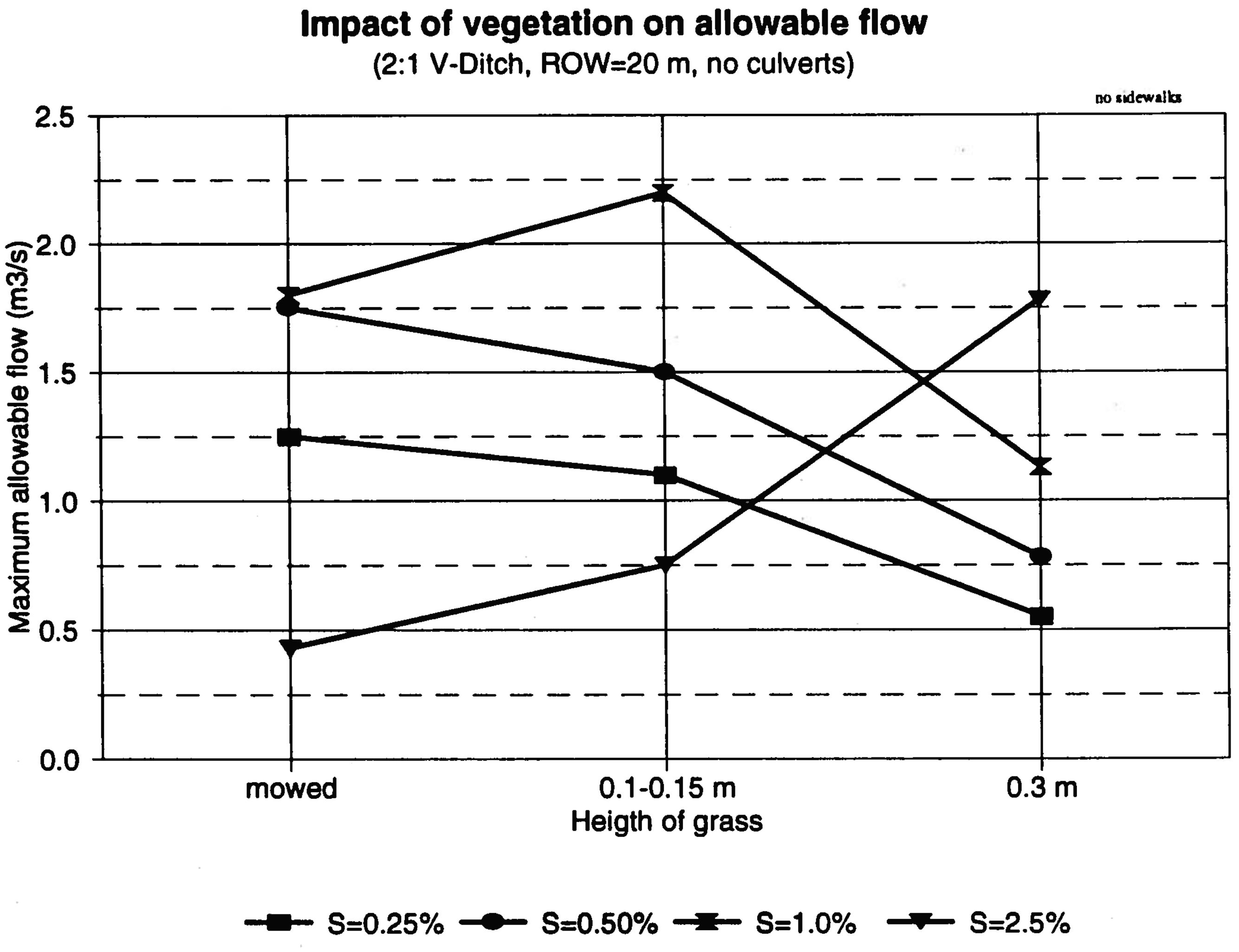
Figure 4.5b Effects of culvert sizes and spacing for a longitudinal slope of 1.0%



Impact of vegetation on allowable flow
(2:1 V-Ditch, ROW=20 m, no culverts)

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Figure 4.6 Effects of ditch bottom type of vegetation on the maximum allowable flow.

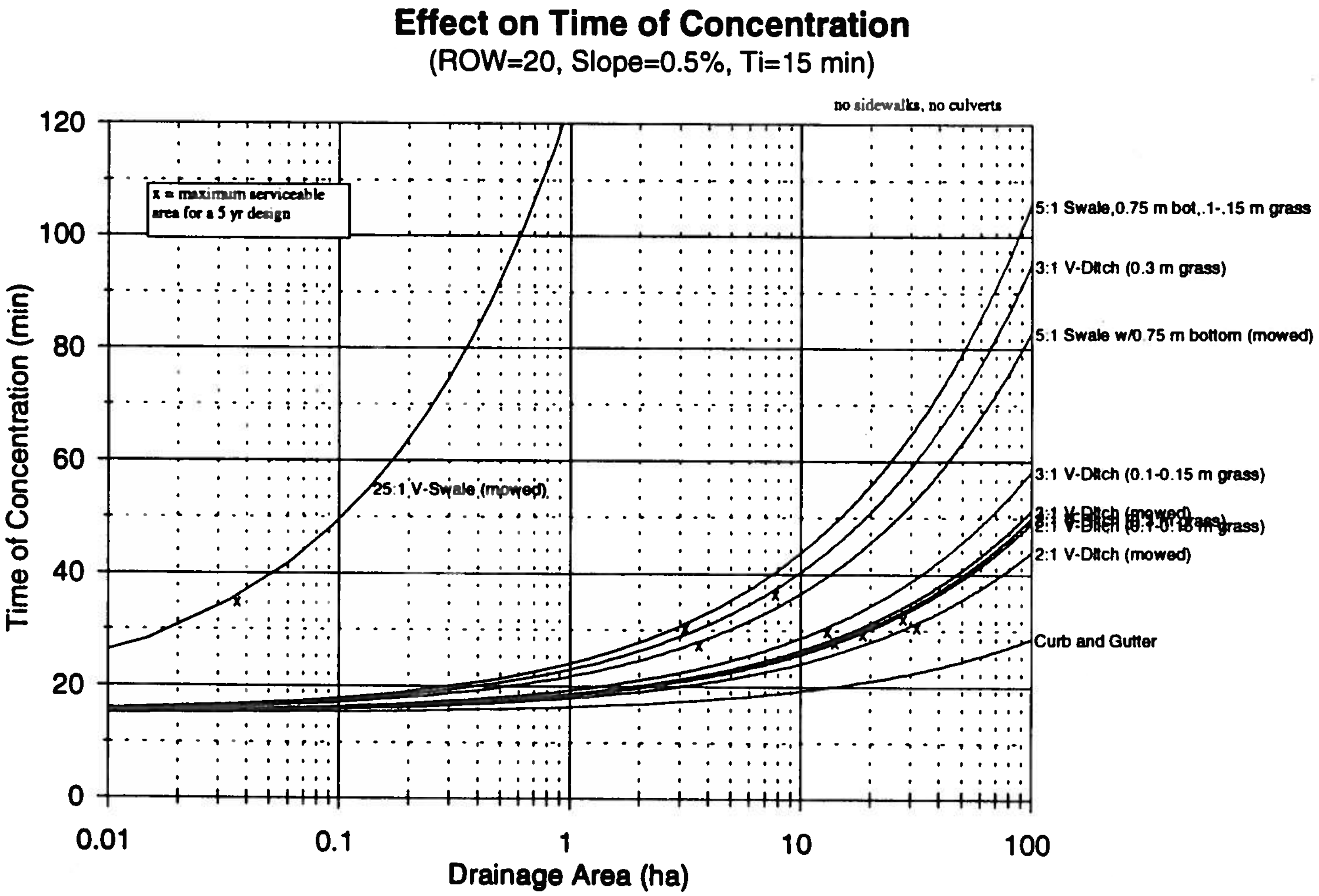

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Figure 4.7 Alternative drainage systems and their effect on the time of concentration.

Peak flow attenuation effects (40%imp)
(Slope=.5%, no sidewalks, no culverts)

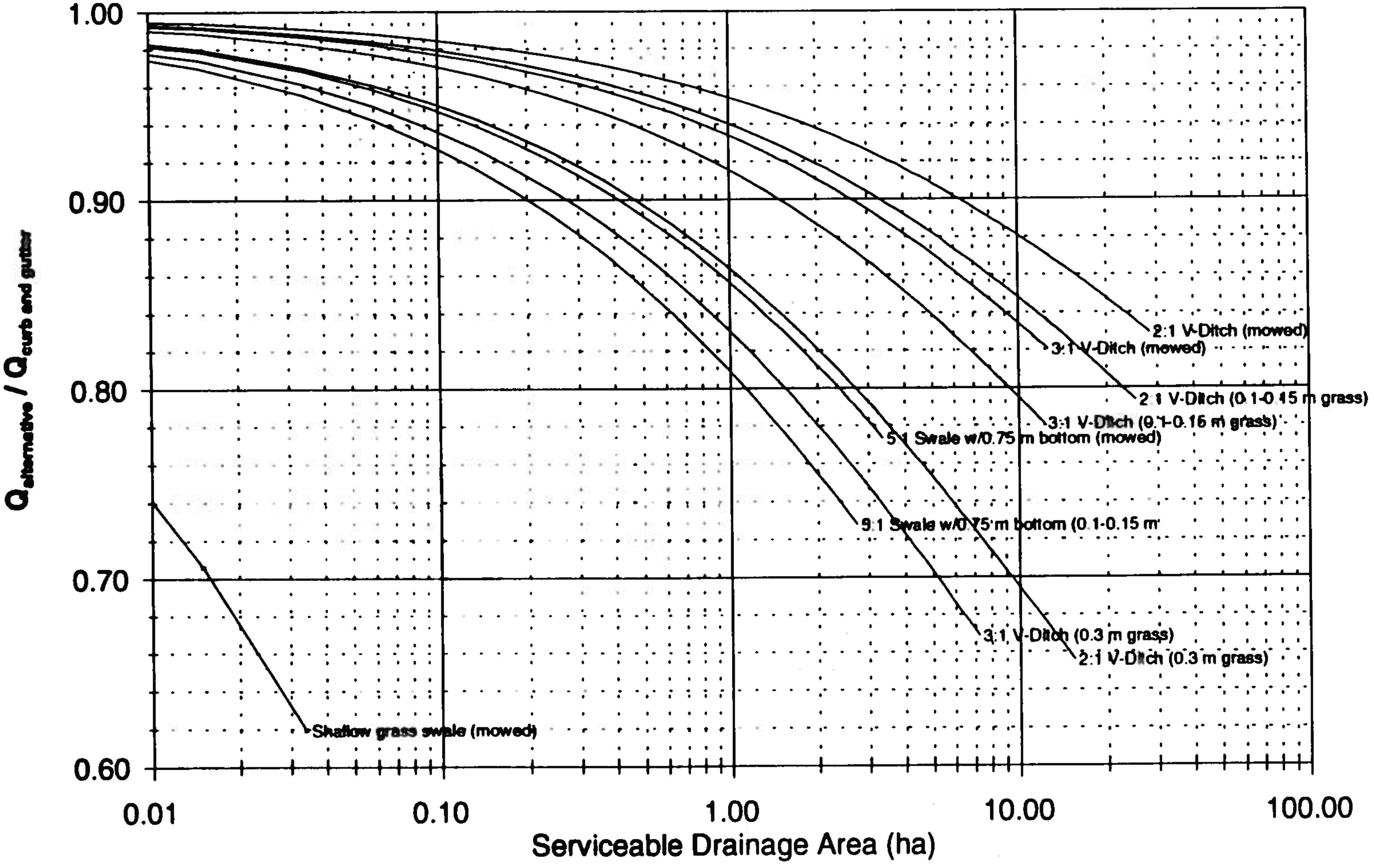

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Figure 4.8 Effects of increased time of concentration on the 5 year design peak flow.

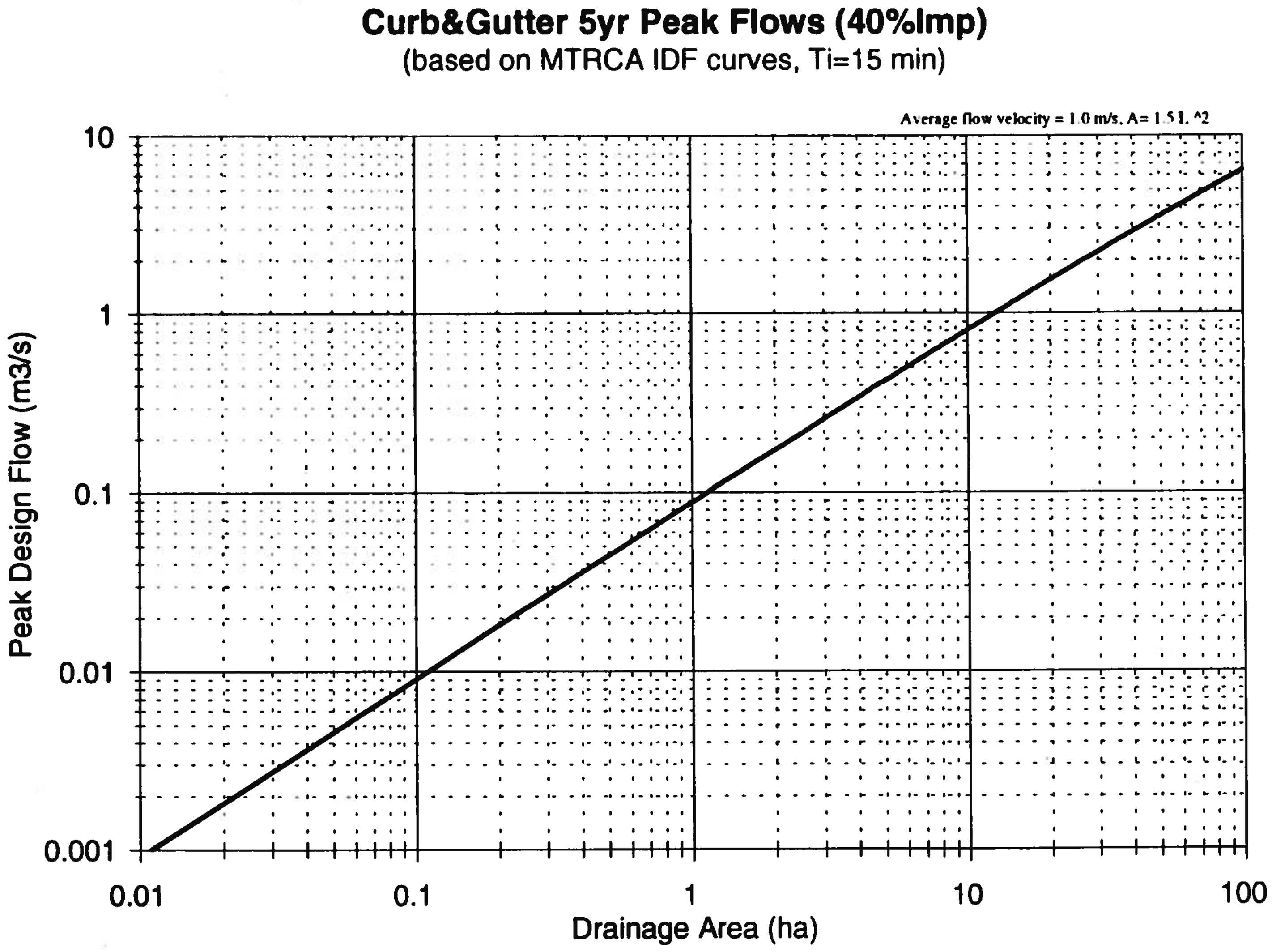

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Figure 4.9 5 yr peak design flows for a Curb and Gutter System and 40% imperviousness

5.0 Water Quality Treatment, Erosion Control, Groundwater Recharge and Quantity Control

In order to mitigate the degradation of water quality, erosion problems and reduction of baseflows, BMP measures must be designed to accommodate the frequent type of storm events. In contrast, when the concerns are related to the quantity of stormwater, BMPs must be designed to control the rare events (eg. 1:5 yr and 1:100 yr).

With respect to water quality, the design of an individual BMP or a BMP system should be based on the existing or desired uses of the receiving body of water and the goals established for the watershed as a whole. Reduced pollutant loading targets can be established during the development of the watershed plan, using technical data and inventories of resources, in conjunction with extensive consultation with regulatory agencies, municipalities and the public. It should be noted that pollutant loading targets may vary from one watershed to another and from one site to another based on local concerns. General issues pertaining to stormwater quality are further discussed in Section 5.1.

Soil erosion by water is a complex natural process which, given our current level of understanding, cannot be definitively predicted. However, it is clear from basic principles and experience that the increase in stormwater runoff due to urban developments can aggravate and accelerate the natural process of stream erosion. Section 5.2, further discusses the need to implement erosion controls.

When groundwater is a major constituent of baseflow in streams, its recharge must be maintained as close as possible to the natural levels. In the absence of a Subwatershed Plan, the protection of baseflow characteristics in streams should be ensured by infiltrating as much surface runoff as is reasonable, given the characteristics of the site and the layout of the development, without compromising the quality of groundwater. Guidelines which can be used to address potential groundwater concerns are presented in Section 5.3.

As indicated above, the design of BMPs to address the need for quality and erosion control and groundwater recharge is done to accommodate the more frequent events (eg. 25 mm or less). However, it must not be forgotten that the main purpose of an urban stormwater drainage system is to rapidly and safely remove surface runoff from roads and away from buildings, for both frequent and rare events. In terms of quantity control, many BMPs have limited value. It is therefore important to understand how, in the design of a drainage system, the various BMP components will interact to address all of the stormwater management objectives (see Section 5.4).

Finally, the longevity and effectiveness of various BMPs can only be assured by undertaking the proper maintenance activities. It has been shown that the frequency of such activities can sometimes be a major consideration.

5.1 Stormwater Quality Control

In a natural setting, surface water is cleansed in streams and wetlands by aquatic plants and also by terrestrial vegetation and the soil itself as it slowly moves through the subsurface. However, in an urbanized landscape, nature's ability to clean and filter water can be severely impaired.

Uncontrolled stormwater from urbanized areas can have dramatic effects on the hydrology of a watershed and more specifically on the sensitive ecological balances of our streams and rivers. Examples of such effects are listed in Table 5.1.

Table 5.1: Potential effects from the discharge of uncontrolled stormwater quality
(ref: CVC Stormwater Management Guidelines, May 1996)

Pollutants	Potential Impact
Silt	• Changes in water quality (turbidity, nutrients, etc.). • Physical destruction of spawning beds (habitat). • Effects on primary and secondary productivity. • Physical damage to some species (gill damage). • Suspension of nutrients/contaminants.
Nutrients	• Water clarity, oxygen, odour, aesthetic appeal.
Metals	• Bioaccumulation in aquatic/terrestrial species. • Safety for human consumption. • Sub-lethal effects on aquatic ecosystem. • Trapping/no trapping in wetlands.
Organic Matter	• Oxygen demand (BOD, COD). • Putrefaction and odours.
Chlorides	• Impairment of respiration in aquatic organisms.

5.1.1 Stormwater pollutants

Many authors have measured pollutant concentrations in untreated stormwater collected from various sites. It has also been found that rainwater does not only pick up pollutants from the surface but also from the air as it falls to the ground. For reference purposes, examples of measured pollutant concentrations in rainwater and urban stormwater are provided in Table 5.2a whileTable 5.2b provides a list of typical sources of stormwater pollutants.

Table 5.2a: Comparison of urban stormwater pollutant concentrations

(all concentrations are in mg/l except for Fecal Coliform which is in No./100 ml)

Parameter	US EPA[1]	East York[2]	St. Catharines[3]	Kingston[4]	Richmond[5] Hill	Nepean[6]	Rainwater[7]	PWQO
Total Suspended Solids (TSS)	125	281	250	72	175	71	2 - 55	--
Biological Oxygen Demand (BOD)	12	14	8.2	8.5	7.1	n/a	n/a	--
Total Phosphorus (TP)	0.41	0.48	0.33	n/a	0.28	0.42	0.04 - 0.14	0.03
Total Kjieldahl Nitrogen (TN)	2	2.2	0.89	n/a	1.42	0.93	0.64 - 3.20	--
Total Zinc (Zn)	0.21	0.33	0.1	0.064	0.08	0.059	0.03 - 3.90	0.02
Total Lead (Pb)	0.165	0.57	0.084	0.013	0.008	0.003	0.02 - 0.30	0.001
Fecal Coliform	21000	11000	68000	21000	56992	1366	n/a	--

Notes:
1- Mean concentration for median urban site Nationwide Urban Runoff Program (NURP) (U.S. EPA 1983).
2- Arithmetic mean, 18 events, 1 site, Toronto, Ontario (Kronis 1982).
3- Geometric mean, 4 events, 1 site, City of St. Catharines, Ontario (SCAPCP 1990).
4- Geometric mean, 8 events, 1 site, City of Kingston, Ontario (CH2M Hill, 1990).
5- Mean summer/autumn concentrations, 15 events, 1 residential site of 36 ha (MOEE and MTRCA, 1996).
6- Arithmetic mean, 7 events, 1 residential site of 12 ha. (Amberwood), Ontario (PWA, 1993).
7- Sampling of rainfall precipitation between 1978-1982 at four U.S. sites (M.M. Dillon, 1990). Note that such data is limited and that air quality at these site may not be representative or comparable to Ontario air quality levels.

Table 5.2b: Common sources of stormwater pollutants

(ref: Highway Runoff Water Quality, Literature Review, MTO, Dillon March 1990)

Pollutant	Primary Source
Particulates	Pavement wear, vehicles, atmosphere, highway maintenance.
Nitrogen, phosphorous	Atmosphere, roadside fertilizer applicaion.
Lead	Leaded gasoline (auto exhaust), tire wear (lead oxide filler material), lubricating oil and grease, bearing wear.
Iron	Autobody rust, steel highway structures (guardrails, etc) moving engine parts.
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides applied by maintenance operations.
Cadmium	Tire wear (filler material), insecticide application.
Chromium	Metal plating, moving engine parts, brake lining wear.
Nickel	Diesel fuel gasoline (exhaust) and lubricating oil, metal plating, bushing wear, brake lining wear, asphlat paving.
Manganese	Moving engine parts
Bromide	Auto exhaust.
Cyanide	Anticake compound (ferric ferrocyanide, Prussian Blue or sodium ferrocyanide, Yellow Prussiate of Soda) used to keep deicing salt granular.
Sodium, Calcium	Deicing salts, grease.
Chloride	Deicing salts.
Sulphate	Roadway beds, fuel, deicing salts.
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate.
Polychlorinated biphenyls, pesticides	Spraying of highway right-of-ways, background atmospheric deposition, PCB catalyst in synthetic tire.
Pathogenic bacteria (indicators)	Soil, litter, bird droppings, and trucks hauling livestock and stockyard waste.
Rubber	Tire wear.
Asbestos	Clutch and brake lining wear.

5.1.2 Stormwater pollutant removal

A simplified guideline to achieve stormwater quality control, as suggested in the 1991 MOEE/MNR Interim Stormwater Quality Control Guidelines for New Developments, is to retain for 24 hours the runoff of a 13 mm or 25 mm storm (13 mm for a warm water fishery, and 25 mm for a cold water fishery). Another similar guideline, proposed by the EPA in 1974 (Table 5.3), is based on the amount of rainfall required to washoff 90% of pollutants from an impervious surface.

Table 5.3: Rainfall intensities and durations for 90% particle removal from impervious surfaces

2.54 mm/hr for	300 minutes
8.38 mm/hr for	90 minutes
12.70 mm/hr for	60 minutes
25.40 mm/hr for	30 minutes

Source: U.S. Environmental Protection Agency (1974)

Although, such guidelines are sometimes still used, a preferred approach is to test the theoretical effectiveness of pollutant removal achieved with various BMPs by means of continuous rainfall-runoff simulations using several years of meteorological data. However, because of the many assumptions which must be made combined with the complex physical, chemical and biological processes involved in the removal of pollutants by various BMPs, such modelling exercises (with the currently available models) can also have their limitations. This is especially true when we try to account for the effects of non structural BMPs (eg. street sweeping) and the combined effects of the joint use of multiple structural BMPs (eg. grass swales with check dams, perforated pipes and granular trenches).

The following section presents and discusses the merits of various non-structural BMPs while the subsequent section will present a summary of the measured effectiveness of various structural BMPs.

5.1.2.1 Non-structural BMPs

Non structural BMPs rely on good housekeeping and public education and do not include the construction of any physical facility. Based on reviewed literature, examples of non structural BMPs are presented below.

Public Education and Citizen Involvement Programs

- following substantial improvements in point source control and treatment through the 1970s and 1980s, the Australian Water Resources Council concluded that non-point sources of pollution represented the major source of turbidity, nutrients, and heavy metal pollution. Based on the emerging recognition of the benefits of adopting a fully integrated urban water and waste management system (ie. total water cycle management), "gutter education" as a non-point source control was proposed by Lawrence et al. (1993) as the need for community participation will become even more critical.

- to be effective, it is necessary to actually modify how each individual uses and disposes of fertilizers, pesticides, herbicides, crankcase oil, antifreeze, etc.
- in Canada there is an increasing number of citizen led SWM awareness programs that promote lot level controls and awareness of measures. For example, in Toronto, the Watershed Infrastructure and Ecology Program (WIEP) and the work of the Don Watershed Regeneration Council and the Yellow Fish Road program increase public awareness of the connection between our developments and nearby creeks and rivers.

Street Sweeping, Leaf Pickup and Deicing Programs

- it has been demonstrated by Mineart et al. (1994) that unless it is done on a regular basis (ie. once per month) street sweeping has little effect on improving the quality of stormwater runoff. As such, street sweeping at this time appears to be most effective at picking up litter and is used for aesthetic purposes.
- a recent article by Sutherland (1996), indicates that reductions of up to 80% in annual total suspended solids and associated pollutant washoffs might be achieved using bimonthly to weekly sweepings with new types of vacuum-assisted dry sweepers. It is also suggested that the effectiveness in pollutant removal was largely dependent on the operator's procedure (speed and frequency). It should also be noted that the effectiveness of street sweeping is highly dependent on the number of cars that are parked on the road during the operation.
- scheduled street sweepings in the fall and early spring can however reduce the loads of leaf litter and street deicing products that can reach the receiving waters.
- proper storage and handling of deicing chemicals, coupled with sound application practices will provide significant reduction for potential ground and surface water contamination. An article (Technical Note 55) published in the Watershed Protection Techniques journal presents a comprehensive review of the various available deicing agents. Based mainly on environmental, infrastructural, and cost factors, the article indicates that conventional road salt (Sodium Chloride) remains a competitive choice.

Curb Elimination

- Yu (1993) suggested that curbed roadways act as traps for particulate and other pollutants. Omission of the curbs allows winds and vehicle-generated air turbulence to scatter the pollutants along the shoulder and right-of-way, thus reducing the pollutant load available to the runoff. It also allows runoff to filter directly over vegetated shoulders.

Local Government Rules and Regulations

- ordinances, rules, regulations and criteria, and their enforcement can provide the basis for an effective stormwater management program.
- recent laws in Sweden (Stahre, 1993) require pet owners to pick up and properly dispose of pet droppings. Some cities have even set aside specific pet sanitation areas. Many municipalities in Ontario already have pet litter control by laws, especially in public parks.
- the development of roof downspout disconnection programs can be an effective approach to quantity control at source. Li (1995) reported that several municipalities such as the Cities of York, Windsor, and St. Catharines have implemented such programs. Other lot level BMPs (eg. rainbarrels, cisterns, soak away pits) are being evaluated as part of Downspout Disconnection Programs in the City of Toronto.
- "User pays" is another method to increase awareness. For example, in the U.S., there are more than 100 municipalities that have setup stormwater utilities in order to provide the financing required to build maintain and upgrade the drainage infrastructure. Some Canadian cities are now considering to do the same.

Elimination of Illicit Discharges

- untreated wastewater discharged through illicit connections can be a public heath problem, which can justify efforts to find and eliminate illicit wastewater connections.

Changes in Design Standards

- Wells (1994) demonstrated that a 10 to 20% percent reduction in impervious surfaces associated with new development is a reasonable goal. Such reductions can be achieved by reducing the size of parking areas, making more use of multi-story parking structures or underground parking, reducing residential street widths, retrofitting existing cul-de-sacs with vegetated islands designed to hold stormwater, making use of narrow-low-use sidewalks on only one side of the street, encouraging cluster development that minimizes impervious surfaces and building taller buildings.
- based on an analysis of the relationship between pavement width, construction and maintenance costs, and accident costs in Idaho, Shannon (1978) suggested new minimum pavement width standards for rural two-lane highways. For various ranges of average daily traffic (from 0 to 2999) his suggested pavement widths varied from 6.1 to 12.1 m which in some cases represents reductions of 4.1 m in road widths.
- in Scandinavia (Stahre, 1993), the trend in new developments is to dewater the paved areas to roadside swales, in which the water is detained before it reaches the storm drainage system.
- one sided slope streets with only one drainage ditch or swale can reduce construction and maintenance costs while providing the same level of service. Such a system was constructed in Orangeville, Ontario.
- "Imagineering" rather that traditional engineering, as suggested by Lawrence (1995), may provide new ideas towards integrated urban water planning.

Minimizing Directly Connected Impervious Areas

- can be most effective in developing and redeveloping areas.
- under ideal site conditions, surface runoff from storms with less than 13 to 25 mm in rain can almost be eliminated.

Regulated Transport of Chemicals and Hazardous Waste

- many cities in Scandinavia (Stahre, 1993) have routes which are clearly marked with special road signs, directing vehicles that carry hazardous wastes and chemicals. This reduces the potential risks associated with spills, especially in areas where infiltration BMPs are implemented.
- in Ontario, certificates of approval for waste handlers also specify which routes can be used.

Use of Proper Roadside Vegetation

- the selection of salt tolerant grasses can provide better vegetative covers along roadways where deicing products are used.
- some states have strict weed control laws. As such the Minnesota State Statute No. 18.211 states that "... all noxious weeds standing, being or growing on all trunk highways and other public highways, to be cut down, otherwise destroyed or eradicated ...". In order to improve safety and reduce the number of bare ground areas the DOT now uses chemical mowing techniques and has re-seeded over 100 acres of land. It is not known however, what chemicals are used and if their impact on the environment was evaluated.

5.1.2.2 Structural BMPs

Structural BMPs involve the construction of some kind of facility. Examples of structural BMPs include grass swales, grass buffer strips, porous pavements, percolation / exfiltration trenches, infiltration basins, sand filters, filter inlets, water quality inlets (eg. oil and grit separators), and end of pipe facilities.

Based on past experience and for reference purposes, Table 5.4 summarizes observed pollutant efficiencies for several types of structural best management practices. As can be expected due to differences in site-specific characteristics, some types of BMPs can exhibit a wide range of performance. It is also possible that some differences can be explained by the fact that certain BMPs were not properly designed and constructed for local conditions.

Using the data presented in Table 5.4 as a reference, one could state that grass swales can remove from 9% to 100% of Total Phosphorus (TP). However, it would be preferable to state that under ideal design conditions grass swales can remove up to 100% of TP. Poor pollutant removal efficiencies due to poor designs or incorrect use should not be used in the overall statistics of specific BMPs. However, such cases should still be documented and used for learning purposes and design improvements.

Furthermore, many authors have adopted to present measured pollutant removal efficiencies in percentages rather than in absolute concentrations. This approach can be misleading when the inflow concentrations are low as compared to average concentrations (refer to Table 5.1). In such cases, outflow concentrations may be acceptable but the BMP removal efficiency may be presented by a low value. Such conditions could be more frequent where numerous lot and conveyance controls are implemented throughout a catchment. It may be more useful to show how the outflow concentrations relate to the target concentrations.

Table 5.4: Ranges of measured pollutant removal rates (%) for various BMPs

Type of BMP	TSS	TP	TN	Zn	Pb	BOD	Bacteria	Oil & grease
Infiltration (1	0-99	0-75	0-70	0-99	0-99	0-90	75-98	—
Infiltration Trenches (1,8	90-99	60-75	60-70	90-99	90	90	90-98	—
Grass swales (2	65-98	9-100	24-100	50-90	50-91	—	—	—
Grass swales w/perforated pipes (3	90	75	—	75	93	—	—	—
Grass swales with check dams (4	20-40	20-40	20-40	0	0	—	—	—
Curb and gutter with exfiltration system (5	A system of this type was recently constructed in the City of Etobicoke. Preliminary monitoring results indicate that 100% of runoff was captured and infiltrated at the site. Based on long term simulations conducted by J. Li, the volumetric retention of this system is in the order of 90%.							
Vegetative buffer strip (5,8	28-70	70	—	51	25	—	—	—
Sand Filters (1	60-85	60-80	(-110)35	10-80	60-80	60-90	50-70	—
Curb and gutter with filtration system	A system of this type was recently constructed in the City of Etobicoke. Monitoring results were not available at the time of this study.							
Extended Detention pond (dry) (1,8	29-75	10-56	24-60	40-57	24-61	—	50-90	—
Extended Detention pond (wet) (1,7,8	0-98	25-90	0-80	21-72	22-57	36-57	56-99	—
Wetland (1	40-94	(-4)-90	21	(-29)-82	27-94	18	n/a	—
Stormceptors* (6	50-80	—	—	39	51	—	—	98
Porous pavement (1,8	80-95	60-65	75-85	98	80	80	n/a	—

* Stormceptors represent one type of oil/grit separators for which data were readily available during this study. Data from other oil/grit separator manufacturers should also be referenced when possible. Mention of Stormceptor does not constitute endorsement or recommendation for use.

Notes:
1- Urbonas (1994), Yu (1993)
2- based on tests performed in Florida with good to poor cover.
3- based on a complete year of monitoring in Nepean, Ont.
4- Yu (1993), based on very limited data.
5- Yu (1993)
6- Stormceptor Study Manual, MNR Field Study based on three precipitation events. Also Pratt et al., 1996 and Labatiuk et al., 1997.
7- MOEE, MTRCA (1996) Heritage Estate Stormwater Management Pond, Richmond Hill, Ontario.
8- Schueler et al (1992)

An important design consideration for infiltration BMPs is clogging. According to Fujita (1987), the clogging factors presented in Table 5.5 should be used for the design of infiltration BMPs in order to account for their reduction in effectiveness due to clogging. The clogging factors indicate how much of the infiltration area will be unuseable after a given number of years.

For example, if the construction of an infiltration trench is expected to function for at least 10 years then its original design should be oversized by 1.25% (1/0.8).

Table 5.5: Proposed Clogging Factors for Infiltration Practices

(factors to be applied to infiltration area of facility)

Years of Use	**< 5 Years**	**10 Years**	**30 Years**	**50 Years**
Reduction Factor	0.9	0.8	0.5	0.3

5.2 Erosion Control

One of the preferred methodologies to identify the need to implement erosion controls is by means of continuous simulations using an erosion index which is based on either tractive force or velocity-duration information. Simulations conducted for existing and future conditions are compared to provide an assessment for the increased risk for erosion. Unfortunately, such an approach can be expensive due to the need for extensive data which must be collected about the downstream reaches of the receiving stream.

A simpler criteria used to determine erosion control requirements for a single development, if a subwatershed plan has not been prepared, is to detain the runoff from a synthetic 25 mm storm for a minimum of 24 hours. Such synthetic storms are often given the shape of a 4 hour Chicago distribution. It should be recognized however that the use of a 25 mm storm is an interim solution for erosion control and as such does not take into account the actual conditions of the receiving stream.

Another simple approach to assess potential erosion problems involves using the simplified chart presented in Figure 5.1. Based on a mean streambed particle size a comparison between existing and estimated future flow velocities can identify whether the erosion threshold will be exceeded.

It should be noted that erosion problems should not only be related to the receiving body of water but also include the control of upland erosion and of the conveyance system where this one is comprised of ditches and swales. The latter issue was addressed in Section 4.

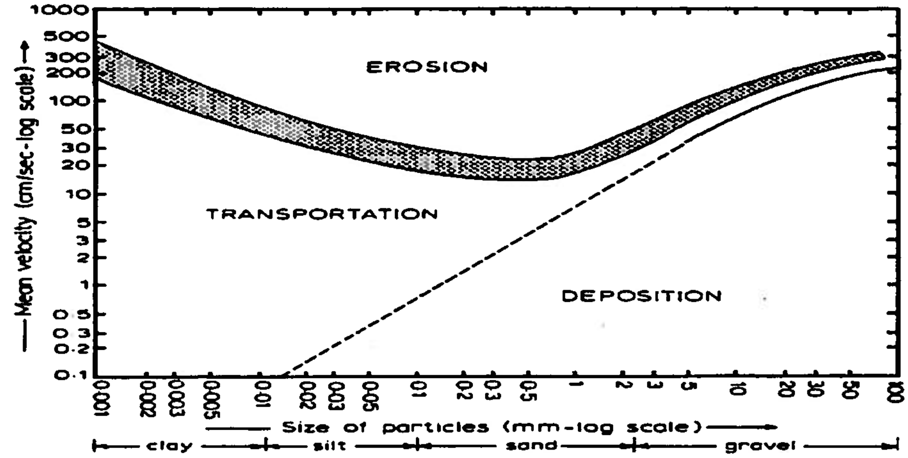


Figure 5.1: Relations between particle size, erosion, velocity, and settling velocity for uniform sediments (after Hjülstrom, 1939)

Source: Geomorphology in Environmental Management

5.3 Groundwater Recharge

Groundwater in Ontario is an important source of water for various uses, including domestic, public, agricultural and industrial water supplies. Groundwater is often the primary source of rural and urban supplies in the Province, especially in southern Ontario, and is frequently an important component of stream flow, especially during dry weather periods.

With respect to groundwater quality management, the Provincial Water Quality Objectives indicate that in cases where urban runoff is to be recharged to groundwater, the chemical suitability of the infiltrated waters should be determined to ensure that toxic chemicals are not present in excessive amounts.

It is a known fact that infiltrating stormwater runoff can create some risks of groundwater contamination. It is said (Pitt et al., 1994) that the risk of contamination is a function of a compound's relative mobility and that the stormwater pollutants with the greatest potential for groundwater pollution are: i) nitrate-nitrogen (low to moderate potential for contamination because nitrate is generally found in relatively low concentrations in urban stormwater); ii) pesticides (risk is greatly reduced if runoff is pretreated before entering an infiltration facility); iii) other organic compounds (risk is sharply reduced with adequate runoff pretreatment and soil percolation); iv) pathogens (risk is greatest in areas where sewage is mixed with stormwater); v) heavy metals (the risk is sharply reduced when runoff is pretreated and percolates through a soil layer); and vi) salts (can be a chronic risk because no method or pretreatment of percolation appears capable of reducing this potential).

Pitt et al. (1994) also suggest that residential areas pose the least risk of groundwater contamination, and therefore, infiltration practices can be located without extensive pretreatment. The use of grass buffer strips and other forms of pretreatment, however, are still advisable to prevent premature failure of the infiltration practice due to clogging.

With respect to groundwater conservation, the same document also states that: i) artificial groundwater recharge should be encouraged wherever practical to conserve groundwater, and ii) protection of areas with high infiltration rates is generally a good management practice. In evaluating proposals for development in significant infiltration areas, the effects on infiltration rates and the quality of the infiltrating water should be considered.

The minimum volume of water required for baseflow augmentation can be assumed to be equal to the volume of infiltration lost due to urbanization. As a guide the 1994 "Fish Habitat Protection Guidelines for Developing Areas" by the Ministry of Natural Resources suggests that the target for minimum levels of control for baseflow maintenance should be no runoff for a 5 mm storm (10 mm where soils are highly porous).

A useful table that summarizes the potential and effectiveness of various alternative drainage components to provide erosion control and groundwater recharge is available in the MOEE Stormwater Management Practices Planning and Design Manual and is presented below. The same table also provides a very good comparison between the potential of various BMP measures for water quality, flood control, mitigating temperature effects, and containing accidental spills.

Table 5.6: Stormwater Management Practice Potential

Stormwater Management Practice	Water Quality Control	Flooding	Erosion	Groundwater Recharge	Other	
					Temp.	Spills
Lot Grading	☒	☒	☒	■	☒	☐
Roof Leader Ponding	☒	☒	☒	■	☒	☐
Roof Leader Soakaway Pits	☒	☒	☒	■	■	☐
Pervious Pipes	■*	☒	☒	■	■	*
Pervious Catch-basins	■*	☒	☒	■	■	*
Wet Pond	■	■	■	☐	*	■
Dry Pond	☒	☐	■	☐	☐	■
Dry Pond with forebay	■	■	■	☐	☐	■
Wetland	■	☒	■	☐	*	■
Wetland with forebay	■	■	■	☐	*	■
Sand Filter	■	☒	☒	☐	☐	☒
Infiltration Trench	☒**	☒	☒	■	■	*
Infiltration Basin	☒**	☒	☒	■	■	*
Vegetated Filter Strip	■	☐	☒	☒	☒	☐
Buffer Strip	☒	☐	☒	☒	☒	☐
Oil/Grit Seperator (offline or bypass)	☒	☐	☐	☐	☐	■

Source: SWMP Planning & Design Manual, June 1994

■ highly effective (primary control) ☒ limited effectiveness (secondary control) ☐ not effective

* may have adverse effects

** effective pollutant removal (TSS, nutrients, metals, bacteria) but suspended solids removal reduces their longevity and hence effectiveness

5.4 Ability to Meet SWM Requirements

In general, all systems, if properly designed and constructed can meet ***quantity*** SWM requirements. As discussed in the section 4, if roadside ditches and swales are used to service limited drainage areas they can provide the same level of service as a conventional curb and gutter system.

The study has shown that alternative systems are capable of meeting *other* SWM requirements, including quality, erosion and groundwater recharge objectives, but their performance depends on many factors. A site specific assessment is necessary and can be assisted by the guidelines and tools developed as part of this study. It is also important to recognize and account for the cumulative effects of other stormwater management system components, such as lot level and end-of-pipe measures.

6.0 Assessment of Public Attitudes, Perceptions and Preferences

The knowledge and/or the understanding of public attitudes, their perceptions and preferences with respect to streetscape features can become a valuable asset in determining what type of alternative drainage systems could be acceptable or could become a resistance factor.

An assessment of public attitudes and perceptions was established based on the responses obtained for a series of relevant questions in our survey. Although separate surveys were prepared for municipal representatives and for the public, both surveys contained the same series of questions on Attitudes and Perceptions, and on Safety. Consequently, the responses from both groups were combined for the interpretation of the results. This provided a sample group of approximately 50.

In order to simplify the survey, most questions only made reference to three main types of drainage systems; i) typical roadside ditch, ii) grass swales, and iii) curb and gutter. These systems have predominant and unique features which most people are familiar with and can relate to. Direct references to infiltration trenches, perforated pipes, oil and grit separators (eg. Stormceptor units), raised culverts, etc. were not made because such alternative drainage features can usually be incorporated within at least one of the main types of drainage systems without necessarily changing its overall appearance.

The present section provides a detailed summary of the survey questions and responses which dealt with attitudes and perceptions with respect to: i) Streetscape aesthetics, ii) Safety, iii) Level of service, iv) Maintenance requirements, v) House market value, vi) Environmental impacts, and vii) Most appropriate system. When applicable the questions also inquired if the attitude or perception differed if the drainage system was in an urban or rural setting.

Public preferences with respect to: i) Presence and location of sidewalks, ii) Utility location, iii) Presence of curbs, iv) Street alignments, v) Parking on street, and vi) Municipal trees are also documented. These questions were only included in the survey for the real estate agents and developers.

It is emphasized that the results presented in this section were obtained from a limited number of survey responses and as such may not be a true representation of public opinions. Experience and evidence shows that public preferences can differ depending on location and specific neighbourhood characteristics.

6.1 Public Attitudes and Perceptions

6.1.1 Streetscape aesthetics

In order to address this issue, the survey asked how a ditch, a swale or a curb & gutter drainage system in an urban or rural area influenced the reader's perception of the overall aesthetics of a typical street. Figure 6.1 summarizes the combined responses from the municipal engineers and planners, and the real estate agents and developers.

The results of the survey indicate that over 80% of the respondents felt that a roadside ditch in an urban setting has a negative influence on the overall aesthetics of a typical street. For a rural setting, this negative perception towards a roadside ditch is significantly reduced to approximately 12%. While the majority indicated that a roadside ditch had no influence on the appearance of a typical street in a rural area, almost 30% felt that it had positive influence.

As compared to roadside ditches, the aesthetic perception of a grass swale in an urban setting is much better. Only 40% of respondents felt that grass swales in an urban setting have a negative influence on the aesthetics of a typical street and the majority felt that grass swales have either a positive or no influence. In a rural setting, grass swales are perceived to have the least negative influence.

In terms of aesthetics, the curb & gutter system rank the highest of all options when considered for an urban setting. In a rural setting the curb & gutter received the most negative responses when compared to roadside ditches and grass swales. However, the majority of respondents were evenly divided over whether curb & gutter system had a positive or no influence on the aesthetics of a typical street in a rural setting.

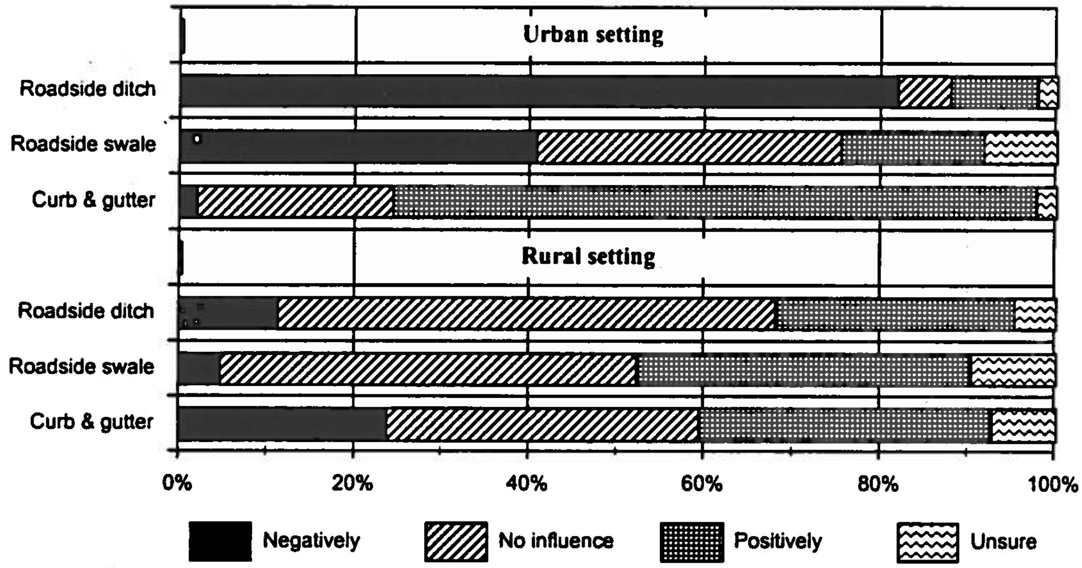


Figure 6.1: How does a ditch, swale or curb & gutter drainage system influence your perception of a typical streetscape? Does the opinion vary between an urban or rural setting?

6.1.2 Perception of safety

From our survey, the perception of safety was evaluated from the level of comfort which was expressed in terms of driving, walking or riding a bicycle along a roadway with ditches, swales or curbs & gutters. With respect to walking, the survey also inquired if the presence of sidewalks played a major role in providing a feeling of security.

The results shown in Figure 6.2a indicate that comfort levels for driving, walking or riding a bicycle are very high, and relatively the same for roads with swales or with curbs & gutters. For driving along a road with ditches, the comfort levels are slightly lower but are still acceptable. The most discomfort was expressed for walking or riding a bicycle along a roadside ditch.

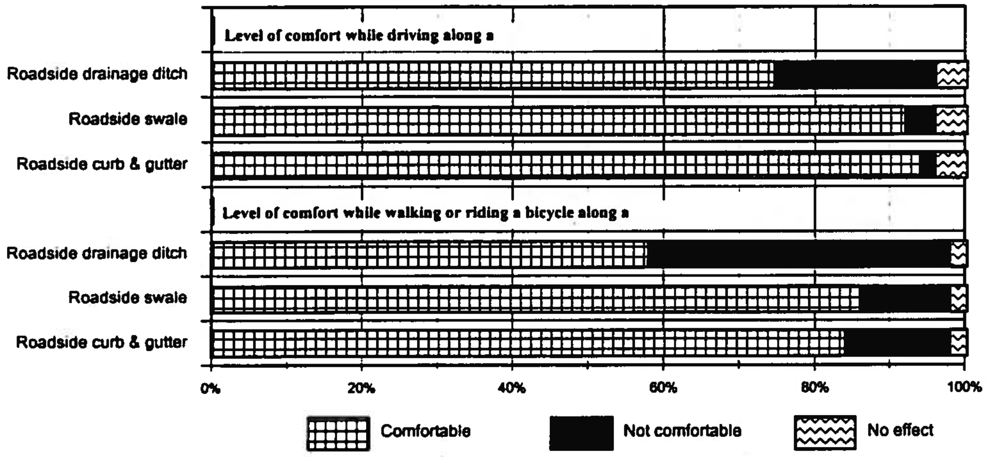


Figure 6.2a: How to do rate your level of comfort while driving, walking or riding a bicycle along a local roadway with a roadside ditch, a swale, or a curb & gutter drainage system?

Figure 6.2b indicates that the presence of sidewalks is a very important street feature in providing a feeling of security while walking along a local roadway. As such, over 60% of respondents are not comfortable walking along a roadway without a sidewalk.

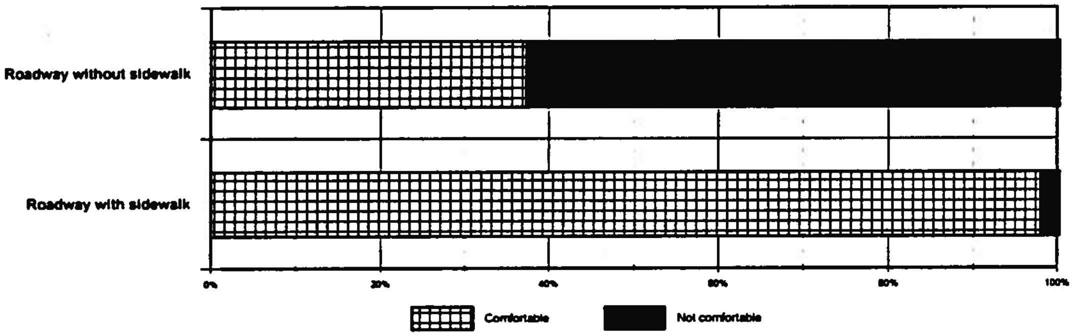


Figure 6.2b: How comfortable are you walking along a local roadway with or without a sidewalk?

Safety issues are further discussed in Section 8 of the report.

6.1.3 Level of service

As shown by the survey results presented in Figure 6.3a, the level of service provided by a curb & gutter drainage system is perceived to be the highest (~80% of respondents) in an urban setting. By comparison, almost 70% of respondents indicated that the level of service provided by roadside ditches in an urban setting was negatively perceived.

In a rural setting, the perception of service provided by any of the drainage systems was more or less the same with a slight preference for the curb & gutter.

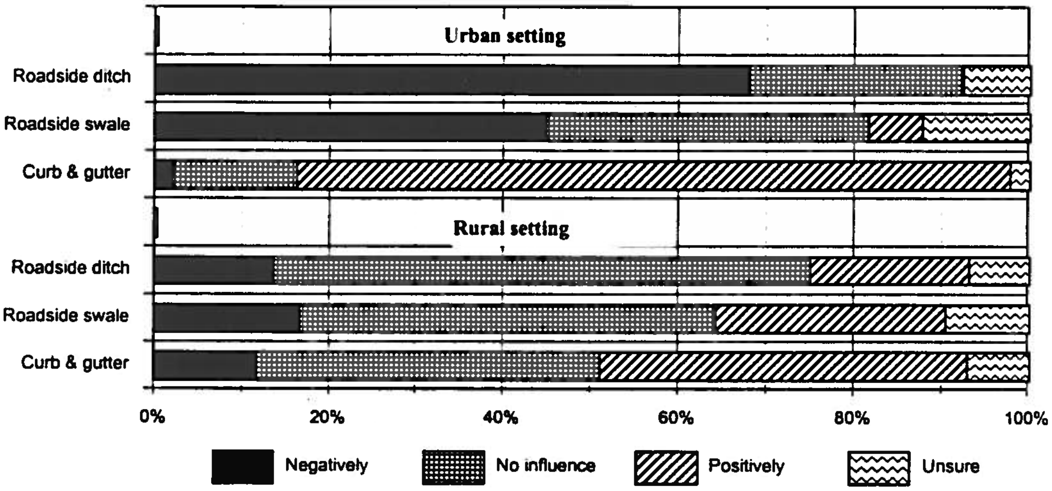


Figure 6.3a: How is the level of service provided by the various types of road drainage perceived when in an urban and rural setting?

The level of comfort with pooling of water during and after a heavy rainstorm may also be an indication of the perceived level of service. As such, the survey question and responses presented in Figure 6.3b show that the majority of respondents are not comfortable with the presence of pooling water on the street. Comfort levels were the highest when the pooling of stormwater is in a roadside ditch or swale.

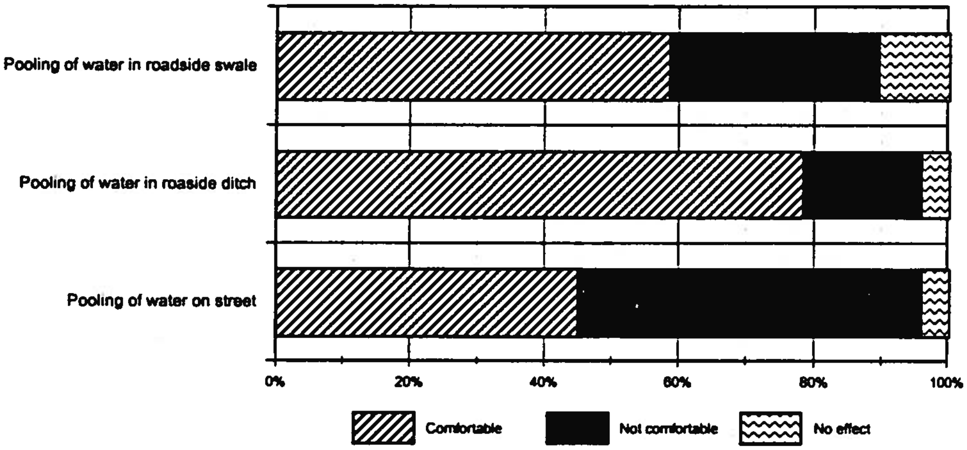


Figure 6.2b: How comfortable are you with the temporary pooling of water after a heavy rainstorm?

6.1.4 Maintenance requirements

Based on the survey results (see Figure 6.4), maintenance requirements by home owners were perceived to be the highest for roadside ditches and the lowest for the curb & gutter system. As such, 55% of respondents indicated that maintenance requirements for roadside ditches were high while approximately 8% and 6% indicated the same for grass swales and curb & gutter systems respectively. Only approximately 7% of the respondents indicated that maintenance requirements for roadside ditches were low as compared to 30% for grass swales and 85% for the curb & gutter system.

However, the survey did not identify what tasks or what expenses were thought to be necessary by home owners in order to maintain the various types of drainage systems.

It is further reminded that for the purpose of the survey, actual home owners were not interviewed and that a relatively small sample of developers and real estate agents answered the survey on behalf of their clients (the public).

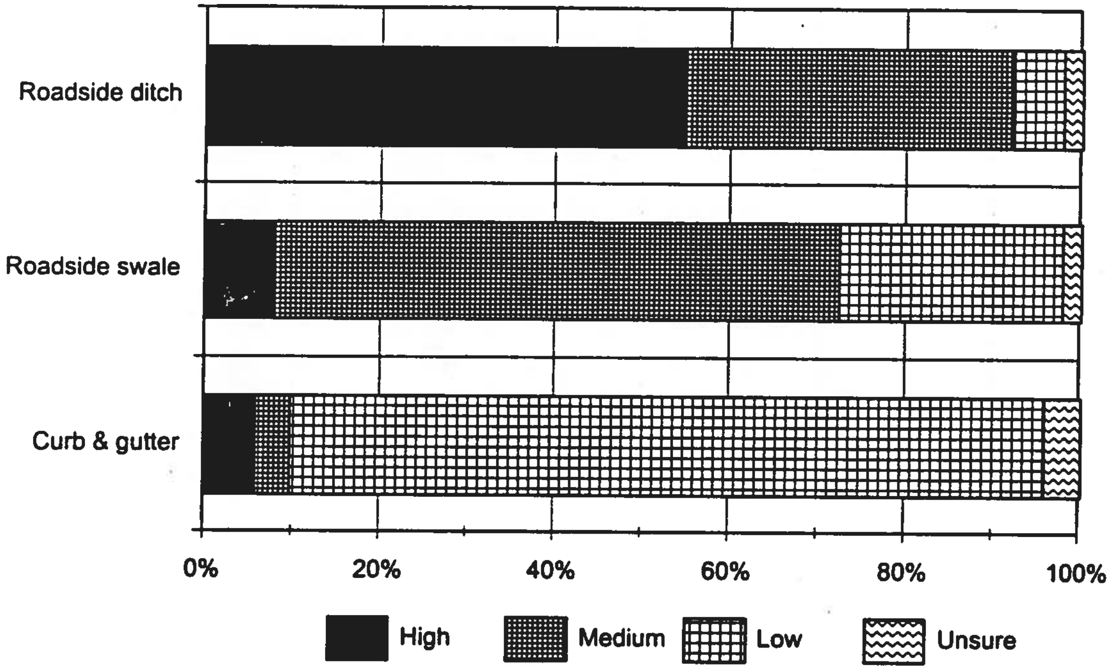


Figure 6.4: How is the level of maintenance required by home owners perceived for the different types of drainage systems?

6.1.5 House market value

According to the survey responses summarized in Figure 6.5, the market values of typical houses located in an urban setting were thought to be most positively influenced by the presence of a curb & gutter system. As such, and in an urban setting, over 65% of respondents felt that a curb & gutter system improved the market value of a house while almost the same percentage felt that a roadside ditch could reduce the value.

With respect to the use of grass swales in an urban setting, approximately 75% of respondents were almost evenly divided between a negative and no influence on the house market value, the majority of the remaining 25% were unsure.

In rural areas, the survey indicated that in general the type of drainage system did not appear to have an influence on the house market value except for the curb & gutter system where close to 85% of the responses were almost evenly divided between a positive and no influence. As compared to the responses for an urban setting, the percentage of those who felt that roadside ditches had a negative impact on the house value is reduced from approximately 65% to 15%. It is also noted that the percentage of negative responses for the curb & gutter system was higher for a rural setting than for an urban setting.

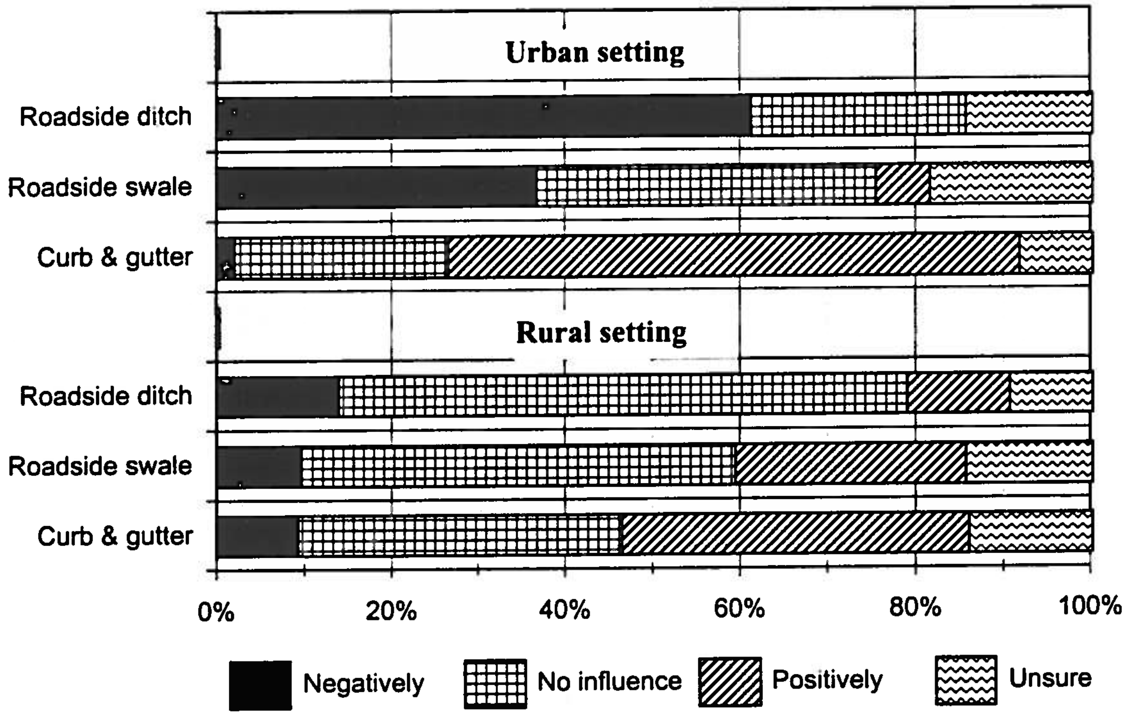


Figure 6.5: How does the type of drainage system influence the market value of a typical house? How does this perception change if the house is located in an urban or a rural setting?

6.1.6 Environmental impacts

The survey tried to identify if, in general, there was a perceived or known link between the type of drainage system and potential environmental impacts that could be caused by stormwater runoff. Based on a relevant question, the results presented in Figure 6.6 were obtained.

The survey results indicate that the general distribution of responses were somewhat similar for each type of drainage system whether they are installed in an urban or rural setting.

Based on the survey results, the overall perception is that the environmental impacts caused by roadside ditches and swales are perceived to be lower than for the curb & gutter drainage system. However, it should be noted that in all cases the majority of respondents were either unsure or indicated that the type of drainage system had no influence on the environment.

Furthermore, it is reminded that the results shown in Figure 6.6 represent the combined responses obtained from municipal representatives and the public. As compared to the other questions where both groups shared similar opinions, it can be noted that municipal representatives were the only ones for which the curb and gutter system was perceived to be more damaging to the environment as compared to roadside ditches and grass swales.

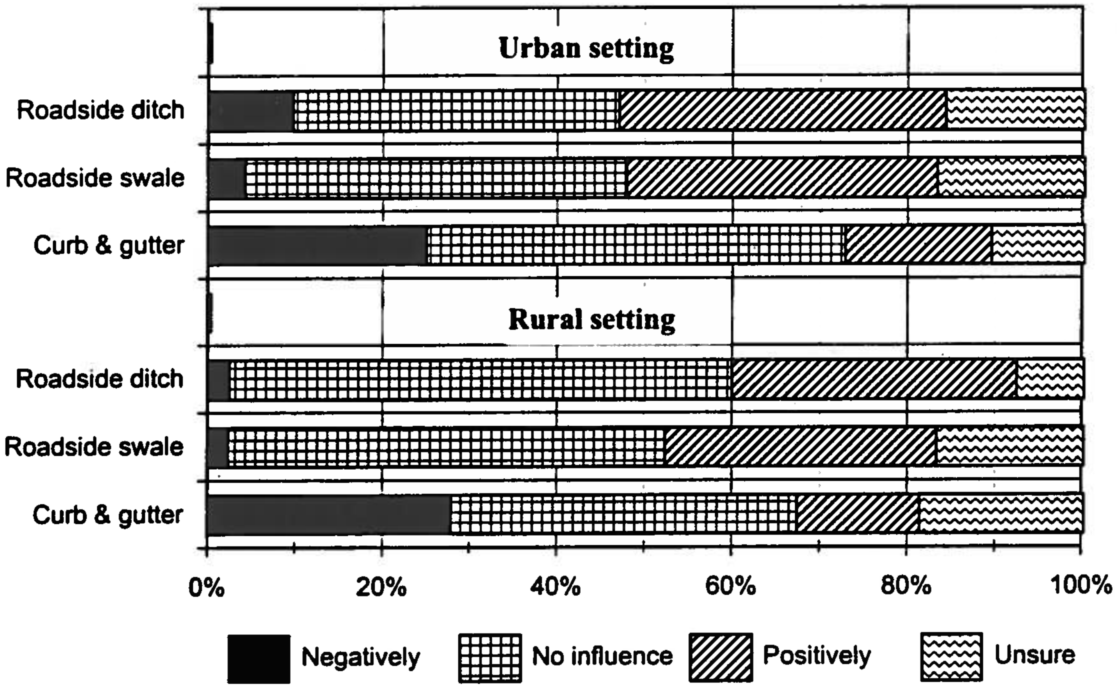


Figure 6.6: What influence does the type of drainage system have on the environment? Is the perception the same in a urban or rural setting?

6.1.7 Most appropriate type of drainage system

Finally, our survey asked the municipal representatives, based on an overall assessment of environmental, engineering, economic and public concerns, what type of drainage system was felt to be the most appropriate in an urban or rural setting. A similar question was asked to the public group based on a homeowner's perspective.

The responses from both groups were similar and the combined results are shown in Figure 6.7. As such, the curb & gutter is perceived by a large majority (almost 90%) to be the most appropriate drainage system in an urban setting. On the other hand, in a rural setting a smaller majority (close to 65%) indicated that the roadside ditch is the most appropriate drainage system followed by grass swales.

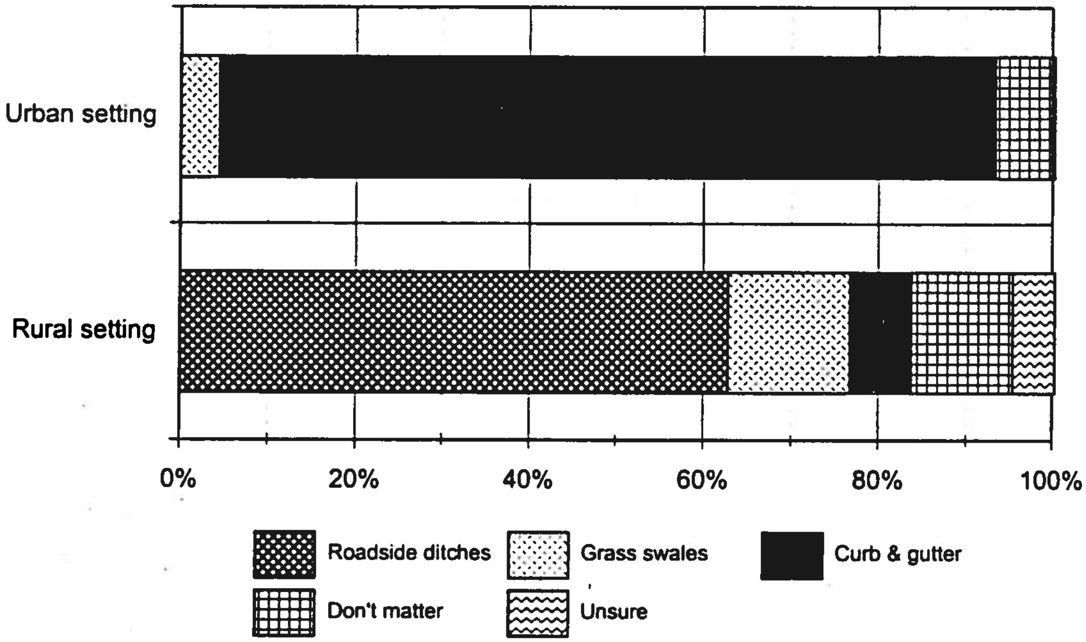


Figure 6.7: **Based on an overall assessment what type of drainage system do you feel is most appropriate in an urban and rural setting?**

6.2 Public Preferences

Within the survey which was sent to real estate agents and developers a specific series of questions was formulated in order to identify customer preferences related to sidewalks (their presence and location), the location of franchise utilities (above or below ground), street lighting, curbs, street layouts (straight or curved), parking on street, and municipal trees.

The following is a summary of the responses which were obtained from a limited sample group of 20. However, each individual was asked to answer for the public with whom they do business and not for themselves.

6.2.1 Sidewalks

Sidewalks do not have an important role in terms of drainage. However, their presence and their location may interfere with the use of alternative drainage systems. Therefore, the survey intended to identify if the public had any preferences with the presence and location of sidewalks.

The results presented in Figure 6.8a show that in urban areas the public prefers to have sidewalks while in rural area they prefer not to have any. From a perception of safety the presence of sidewalks is an important street feature for pedestrians.

When sidewalks are present, the majority of respondents indicated a preference to having only one as compared to two (see Figure 6.8b). The reason for this preference was not identified.

In terms of their location in an urban setting, most prefer to have the sidewalk away from the curb. In a rural area, the majority of respondents did not know what their preference would be. However, from those who knew, most preferred to have the sidewalk located away from the curb.

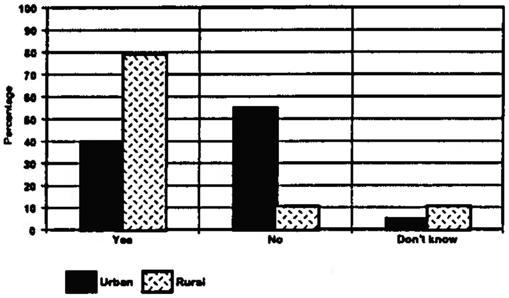


Figure 6.8a: Are streets without sidewalks preferred over streets with sidewalks?

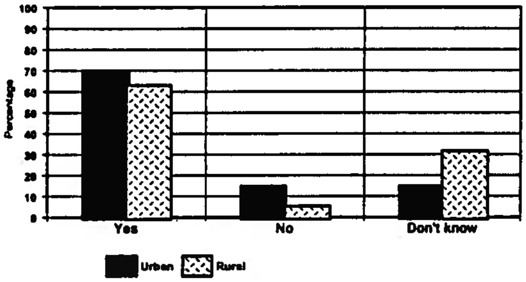


Figure 6.8b: Is a street with one sidewalk preferred over a street with two sidewalks?

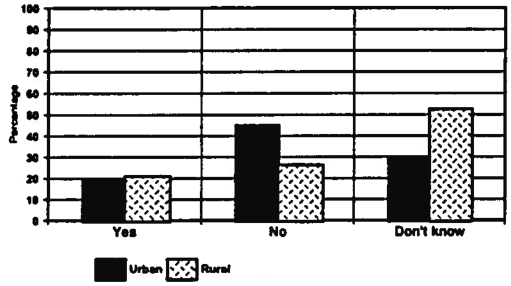


Figure 6.8c: Are sidewalks located next to curbs preferred over sidewalks located away from curbs?

6.2.2 Franchise utilities

As with sidewalks, franchise utilities provide no drainage functions but their presence and location may also interfere with the use of alternative drainage systems.

According to the survey results presented in Figure 6.9 and for urban areas, 100% of respondents prefer to have below ground utilities. By comparison, in rural areas, less than 50% indicated a preference of underground utilities while the majority was equally divided between "Don't know" and having above ground utilities.

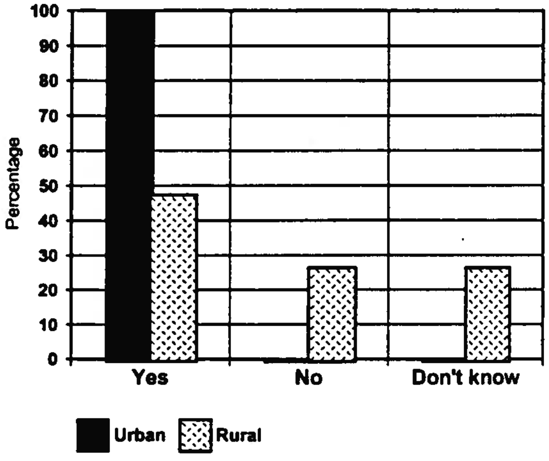


Figure 6.9: Are underground franchise utilities preferred over overhead utilities?

6.2.3 Street lighting

Light standards along streets may also interfere with the incorporation of alternative drainage systems.

According to our survey, the majority of respondents prefer to have street lighting on streets located in either urban or rural residential areas (see Figure 6.10).

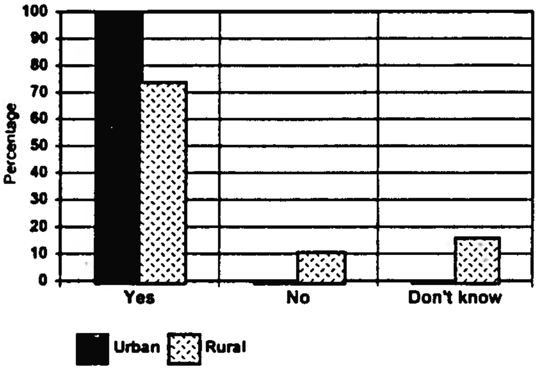


Figure 6.10: Are street with light standards preferred over streets without lights?

6.2.4 Streets with curbs

In a previous section of this report, issues related to safety were addressed in terms of expressed levels of comfort while driving, walking or riding a bicycle along a typical road with different types of drainage system. The survey determined that comfort levels were the highest and relatively the same for the curb & gutter system and grass swales. On the other hand the survey did not identify what system features increased or lowered the comfort levels.

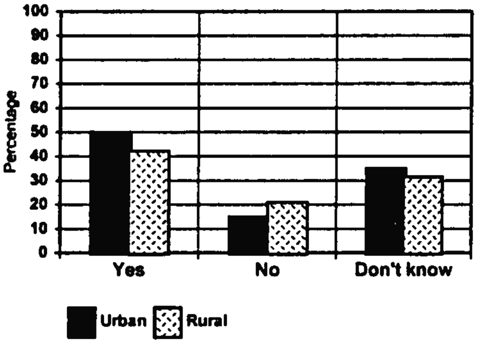


Figure 6.11: Are street with curbs safer than streets without curbs?

According to a different question (see Figure 6.11), most of the respondents felt that a curbed street is safer than a street without a curb. However, 50% and more either didn't know or did not agree.

6.2.5 Street alignments

Street alignments can play an important role in safety, and aesthetics.

Based on the survey (see Figure 6.12), the majority of respondents prefer to have curved street alignments in residential urban areas. For rural residential areas, the same preference still exists but the majority is somewhat evenly divided between Don't know and straight streets.

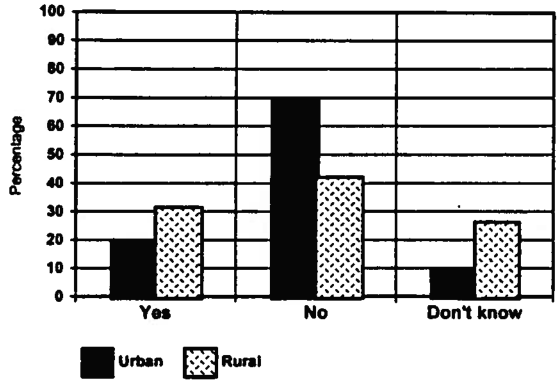


Figure 6.12: Are straight street layouts preferred over curved street alignments?

6.2.6 Parking on street

When parking on a street is permitted the road surface must be wide enough to accommodate both parked vehicles and moving traffic. In such conditions, and within a fixed Right of Way the available space for alternative drainage system features can become a limiting factor.

For residential areas within an urban setting our survey indicates in Figure 6.13 a strong preference (over 80%) to allow parking on streets while in a rural setting, although most (50%) still indicated a preference for parking on the street, more than 40% did not know.

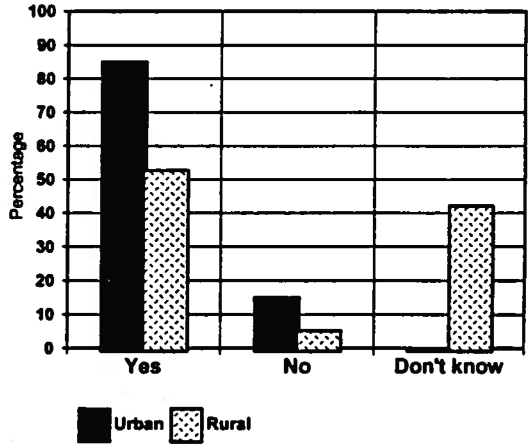


Figure 6.13: Are streets that allow parking preferred over streets where parking is not allowed?

6.2.7 Municipal trees

Municipal trees can be an important beautification asset to a residential area. Unfortunately, trees and their root systems can also interfere with the construction of an alternative drainage systems.

The survey results presented in Figure 6.14, indicate that the majority of respondents prefer streets with municipal trees over streets without trees.

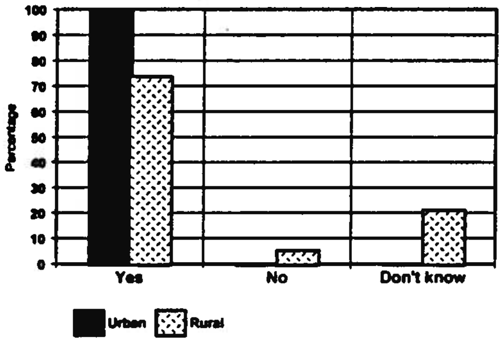


Figure 6.14: Are streets with municipal trees preferred over streets without municipal trees?

6.3 Summary of general public preferences

According to the survey and based on public attitudes, perceptions and preferences, the following is a summary of what characteristics a residential street in an urban and rural setting should have:

Urban Setting:

- A curb & gutter drainage system is somewhat expected, probably because this is the most commonly seen system in an urban setting.
- One sidewalk located next to or away from the curb.
- Franchise utilities should be installed underground.
- Street lighting should be available.
- Municipal trees should be planted.
- Curved street layouts are preferred.
- Parking on streets should be allowed.
- Pooling of water on street should not be allowed.

Rural Setting:

- Should be serviced by grass swales or roadside ditches.
- In terms of maintenance requirements and the perception of safety, grass swales are preferred over roadside ditches.
- The presence of sidewalks is not important.
- Franchise utilities can be installed above or below ground.
- Street lighting should be available.
- Municipal trees should be planted.
- Curved street layouts are somewhat preferred but not as much as in an urban setting.
- Parking on streets is not as important as in an urban setting.
- Pooling of water on street should not be allowed.

7.0 Assessment of Municipal Perspectives

The survey which was prepared for municipal representatives inquired if the use of alternative drainage systems would be considered in new urban or rural developments. If so, the survey further asked which system would be considered and what would be the reasons for not considering some of the alternatives. Similar questions were asked with respect to retrofit situations. The responses are summarized below.

7.1 New Developments

According to the survey results presented in Figure 7.1, the majority of the municipalities who responded indicated that they would consider the use of alternative drainage systems in a new development in either an urban or a rural setting. It is noted that the positive responses were significantly higher for rural developments.

The alternative drainage systems that would be most likely considered are presented in order of preference in Figure 7.2. In a rural area grass swales were the most popular while in an urban area grass swales with raised culverts were most often selected as a potential option. The least popular option was the grass swales with checked dams.

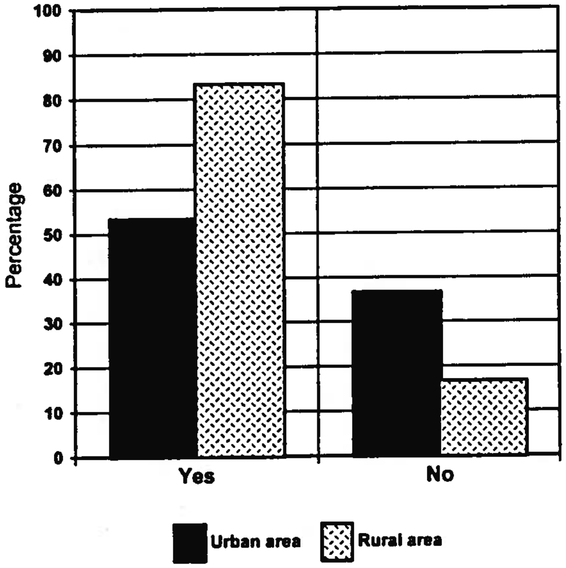


Figure 7.1: Would you consider using an alternative drainage system for a new subdivision in an urban or rural setting?

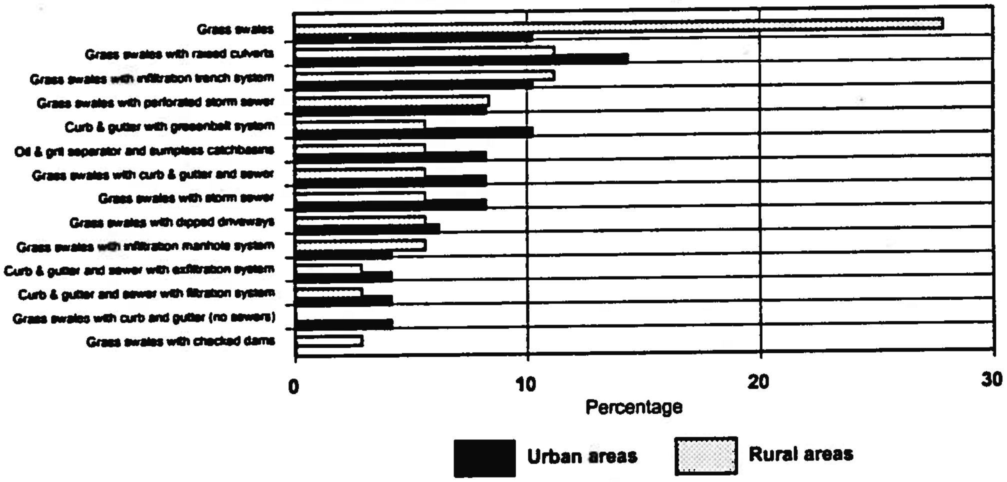


Figure 7.2: What alternative drainage systems could be considered in a new subdivision in an urban or rural setting?

The most common reasons for not considering the use of an alternative drainage system in a new development are presented in Figure 7.3. It can be seen that the main concern with the use of alternative drainage systems is with the potential additional maintenance costs. The aspect which is perceived to be the least affected by the potential use of alternative drainage systems is with the safety of drivers, cyclists and pedestrians.

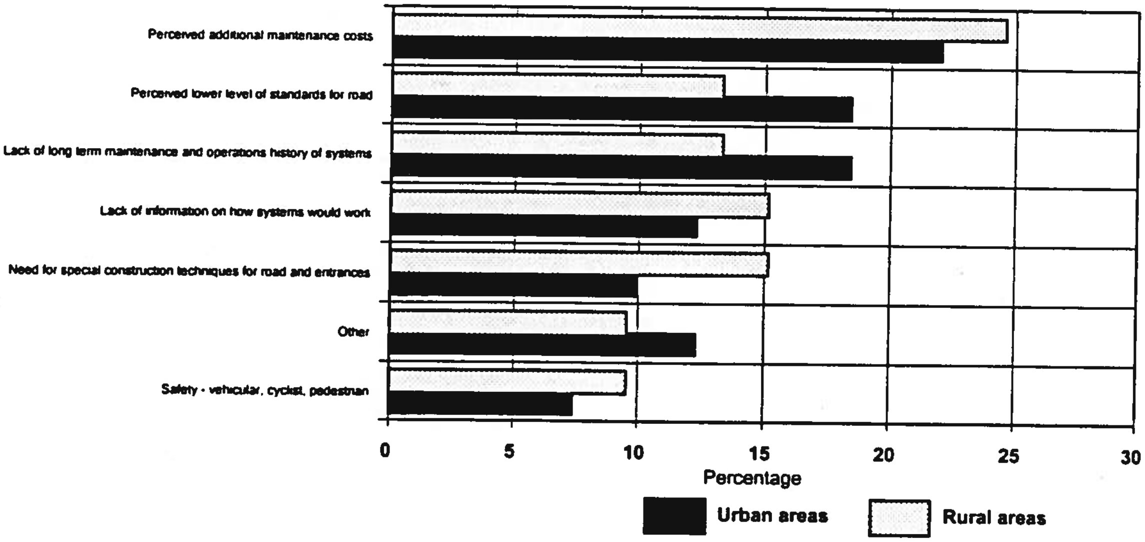


Figure 7.3: What are the reasons which would prevent you from considering the use of an alternative drainage system in a new subdivision located in an urban or rural setting?

7.2 Retrofit Situations

Over 90% of the municipalities who responded indicated that they would consider the use of an alternative drainage system in a retrofit situation (see Figure 7.4).

As with new developments, one of the alternative drainage systems that would be most likely considered are the grass swales with raised culverts and the least popular option were the grass swales with checked dams. The relative ranking of other options are presented in Figure 7.5.

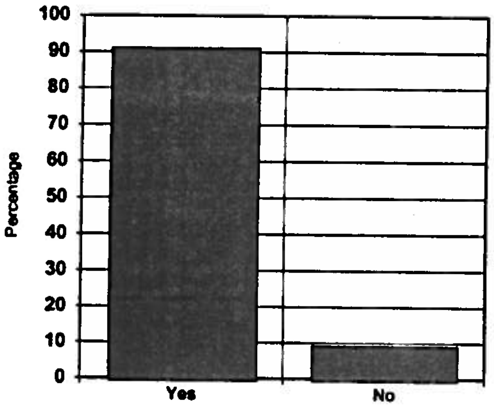


Figure 7.4: Would you consider the use of alternative drainage system for a retrofit of a conventional roadside ditch?

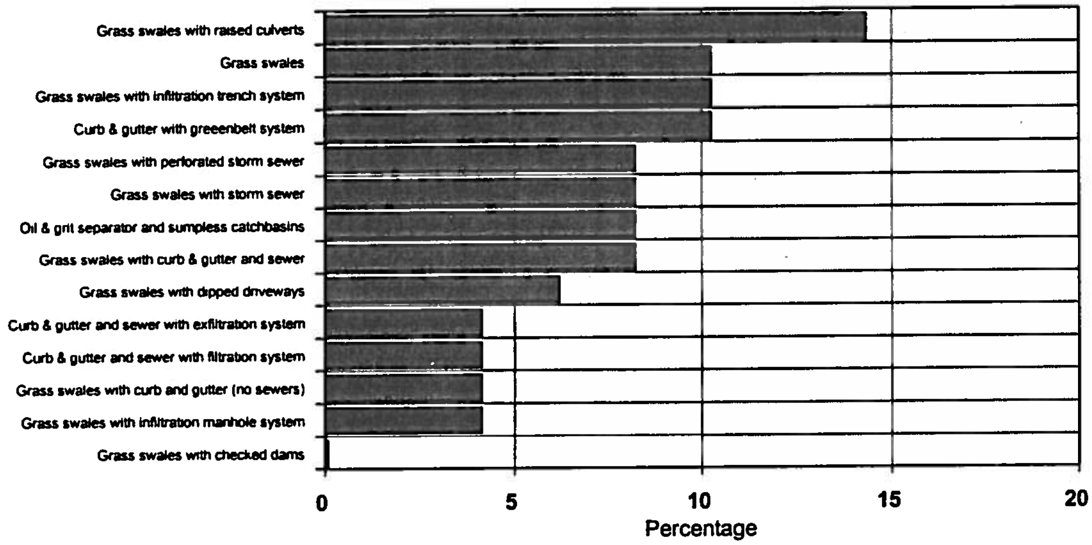


Figure 7.5: Which alternative drainage systems would you consider in a retrofit situation?

The most common reasons for not considering the use of an alternative drainage system in a retrofit situation are presented in Figure 7.6. Again, as with new developments, the main concern that would hinder the possible use alternative drainage measures is with the potential additional maintenance requirements and associated costs. Also, the aspect which is again perceived to be the least affected by the potential use of alternative drainage systems is the safety of drivers, cyclists and pedestrians.

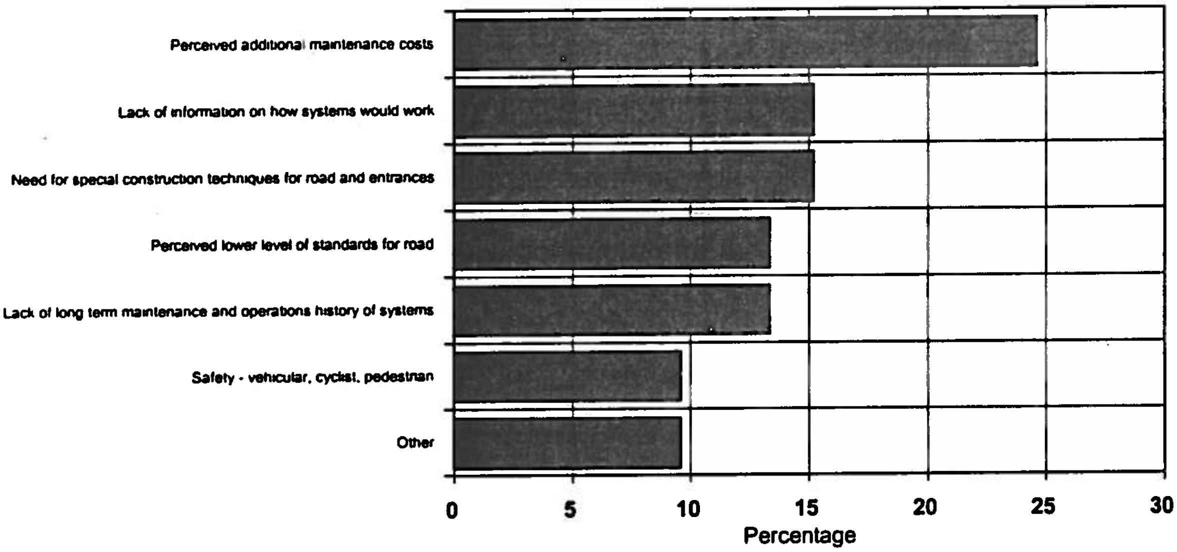


Figure 7.6: What are the reasons which would prevent you from considering the use of an alternative drainage system in a retrofit situation?

8.0 Safety Considerations

Safety issues can be related to motorists, pedestrians and cyclists. Drainage components which may have an influence on safety include: i) the presence of a curb, ii) the presence of ditches, iii) the presence of culverts, and iv) the presence of catch basins. Drainage functions which may influence the level of safety include: i) depth of water on street, ii) surface flow velocity, iii) system backups and basement flooding.

With respect to documented causes of accidents very little has been found during the course of this study to provide viable statistics on urban accidents or damages which may have been caused by drainage related features or functions. Inquiries with insurance companies have found that such information is not collected or analysed. Even basement flooding is not documented to determine if the cause was from the failure of a sump pump or a sewer backup.

However, the article discussed below describes statistics of highway accidents in which drainage structures were involved. It should be noted that drainage structures were secondary to the accident's cause and that other factors such as driver error or poor road conditions may have initiated the accident.

8.1 Vehicular Safety

With respect to motorists, the conclusion of an article on the magnitude and severity of drainage-structure-related highway accidents by D. Robertson states that, based on the findings of the National Accident Sampling System data analysis, drainage-structure-related accidents represent 8% to 9% of the total highway safety problems on Federal-aid roadways. These accidents are quite severe. In terms of all accidents, those involving curbs occur most frequently, while in terms of accident severity, hard embankments are the most dangerous. The review of scene photographs suggests that curb design improvements and, in some cases, curb removal would have reduced the severity, if not the occurrence, of many of the curb accidents reviewed.

The same publication also states that drainage-structure-related accidents occur in a higher proportion at night and in adverse weather compared to the same characteristics for all accidents. Based on the findings related to roadway characteristics, drainage-structure accidents are over represented in curves, on grades, and on wet surfaces.

The American Public Works Association's *Why Curb and Gutter,* states that; "... a curb contributes to safety by defining the edge of the street for drivers, pedestrians, and children. In contrast, ribbon paving (ie. roads without curbs) has no vertical barrier. Curbs show drivers where to drive, where to turn, and where to park. They also protect street lights, fire hydrants, signs and shoulders. Although the curb is not high enough to keep an out-of-control automobile from mounting it, even rolled curbs can give inattentive drivers an unpleasant reminder."

Based on our survey, when asked about the perception of safety provided by a curb and gutter, a swale or a roadside ditch, municipal and public representatives also indicated a preference towards the curb and gutter system for an urban environment. It should be noted that most respondents indicated that the swale made no difference (ie. was not better or worse than the curb and gutter). The breakdown of the survey responses are presented in Figures 8.1, 8.2 and 8.3 below.

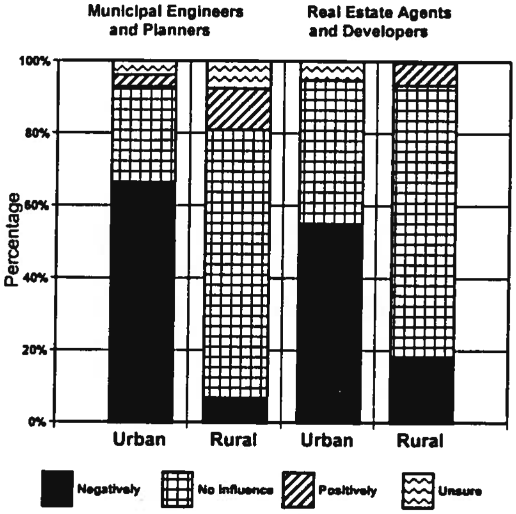


Figure 8.1: How does a ditch drainage system in an urban and rural area influence your perception/attitude towards safety?

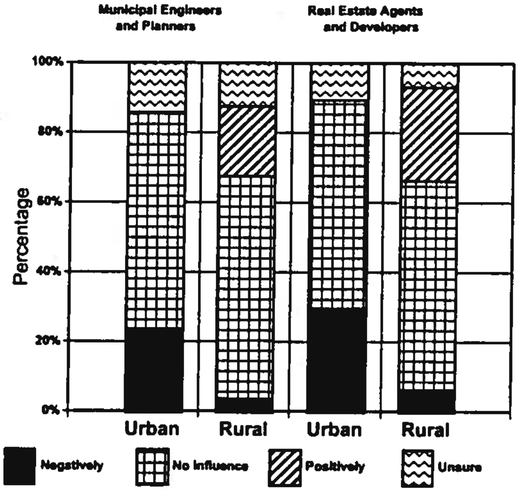


Figure 8.2: How does a swale drainage system in an urban and rural area influence your perception/attitude towards safety?

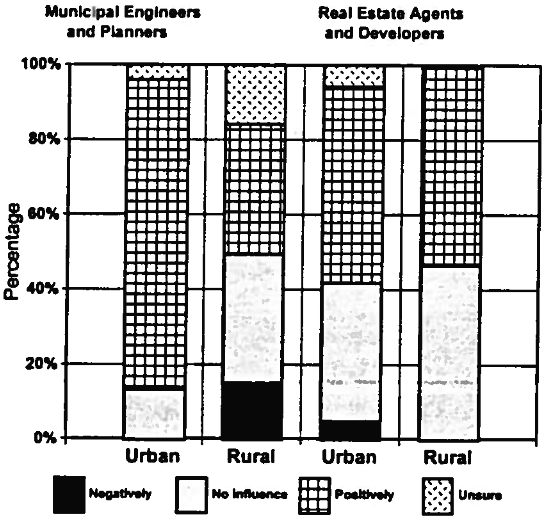


Figure 8.3: How does a curb and gutter drainage system in an urban and rural area influence your perception and attitude towards safety?

8.2 Pedestrian Safety

Although pedestrian safety can be affected by the functions of a drainage system, their safety seems to be a function of the volume and speed of traffic and the location of sidewalks.

For example, in 1968 pedestrians constituted 31% of the total killed in traffic accidents in New York State and 18% in the U.S.

Older people are more frequently involved. More than 83% of the deaths associated with crossing at the intersections involved people 45 years or older.

Pedestrians under 14 years of age accounted for over 45% of persons injured while standing or playing on the roadway and about 68% of those coming from behind parked cars.

8.3 Cyclist Safety

As with pedestrians, the safety of cyclists can also be influenced by the volume and speed of traffic. Catch basin grates and manhole covers which have settled can cause many cyclist to swerve towards the center of the road closer to fast moving automobiles.

8.4 Other Influencing Factors

8.4.1 Environmental factors

Though unfavourable weather or road conditions do have an influence on traffic accidents, the extent of such influence is yet to be determined. Total accident occurrences under various weather and road conditions in New York State for 1968 are given in Table 8.1 below. As can be seen from Table 8.1 the greatest number of accidents occurred on clear days, with dry conditions and on straight roads!

Table 8.1: Accident occurrences under various weather conditions in New York State for 1968
(% of Total Accident Occurrences)

Weather Conditions:	
Clear	78.2%
Rain, Snow, Sleet	20.6%
Fog	1.2%
Road Conditions:	
Dry	64.8%
Wet, Snowy	35.2%
Road Character:	
Straight	88.6%
Curve	11.4%

8.4.2 Urban-rural differences

The occurrence of traffic accidents varies greatly in urban and rural areas. As such approximately 1/2 of total urban accidents take place at intersections versus about 1/4 for rural accidents. There is a significantly higher proportion of pedestrian accidents in urban areas. Table 8.2 below gives a breakdown of the type and location of traffic accidents on a national (U.S.) basis for 1968.

Table 8.2 Type and location of traffic accidents on a national basis for 1968 in urban and rural areas

Type of Accident	Fatalities		Non-Fatal Injuries	
	Urban	Rural	Urban	Rural
Vehicle Collision with				
Pedestrian	6,400	3,400	125,000	25,000
Other vehicle	5,500	17,000	820,000	520,000
Fixed object	1,200	1,400	40,000	20,000
Bicycle	420	380	32,000	6,000
All other	480	1,220	3,000	9,000
Non collision	3,500	14,300	130,000	270,000

8.4.3 Roadside objects

Single vehicle accidents, or collision between a car and a bridge abutment, a lamppost, or some other roadside appurtenance, can account for as much as 32.3% of all accidents on the open road. In addition, such single vehicle accidents are generally more severe than other accident types: National Safety Council survey indicates that the 7.5% of urban accidents accounted for by such one-car accidents caused 21.3% of the deaths. In rural areas they increased to 32.3% of accidents and 39.6% of fatalities.

9.0 Considerations for Right-Of-Way, Road and Lot Planning

Planning issues related to right-of-way (ROW) widths, road widths, utility locations and lot sizes may inherently have an impact on the potential use of alternative drainage systems. This is especially true for alternatives which must be incorporated within the ROW but outside of the road allowance (eg. ditches and swales). Other development features which may interfere with the use of certain types of alternative drainage systems include reverse slope driveways, and tree planting.

Unfortunately, decisions related to the type of development and the layout of subdivision plans are often executed prior to the detailed assessment of stormwater management issues. It follows that, in some circumstances, the flexibility or the opportunity in proposing an alternative drainage system can become limited.

Furthermore, several municipalities have, over the years, developed detailed standards for road cross sections and for the location of public and franchise utilities. In the absence of such standards, many municipalities will refer to the Ontario Provincial Standards. In terms of drainage, most standards incorporate the curb & gutter system and others provide details for the typical roadside ditch but very few, if any, will provide details on how to incorporate alternative drainage features. The lack of such information can easily act as a detriment in trying to propose alternative drainage concepts.

Available standards are simple to follow and contractors are familiar with them. Any proposed deviations from such standards are often incorrectly perceived to be cost cutting measures benefiting the developer and potential future liabilities for the municipality. The lack of experience with new concepts raises valid concerns with long term maintenance requirements, traffic control, pedestrian movements, safety, economics and ROW planning. However, such concerns when properly addressed should not hinder the willingness to try new designs.

Based on the results of the survey with the municipal representatives, this section provides an overview of issues and concerns which should be considered when the use of alternative drainage systems are proposed in new developments or in retrofit situations. Issues related to ROW planning, road design and lot planning are discussed. Municipalities' willingness to try new concepts and the reasons to not consider potential drainage alternatives are also presented.

9.1 Right-of-Way Planning

Municipal right-of-way (ROW) widths can vary from approximately 17.0 m to 36.0 m while road surface widths can vary from approximately 6.7 m to over 15.0 m. There doesn't seem to be a direct relationship between ROW widths and road surface widths except for the fact that the ROW width should contain the road and any other public or franchise utilities. The road surface width is mainly determined by the type of development and its location with respect to traffic flow. The needs for public or franchise utilities will vary from location to location.

In terms of drainage, it is generally expected that the surface runoff be contained within the ROW width of a given road. The storage or the conveyance of stormwater over private properties is not usually accepted.

A series of existing design standards for various types of roads with different pavement widths and associated ROW widths were collected and are provided in the attached Appendix E. A review of existing ROW standards can help identify, based on geometry and available space, what type of alternative drainage systems could be accommodated with the least change to the existing standard. This particular aspect was considered in the stormwater conveyance section (Section 4).

9.1.1 The need for sidewalks

As indicated by our survey results on public attitudes and perceptions, streets with sidewalks are slightly preferred in urban areas (55% in favor, 40% against) while in rural areas almost 80% of respondents indicated a preference to have <u>no sidewalks</u>. When streets with sidewalks are considered, between 60% and 70% of the respondents indicated a preference to have the sidewalk on one side of street only. With respect to the location of sidewalks (next to road or away from road), most who had an opinion expressed a preference to have sidewalks away from the road.

The space required to incorporate sidewalks within the ROW can reduce the capacity to incorporate potential alternative drainage system components. Furthermore, when sidewalks are installed next to the road, they act as a curb and contain the runoff on the road surface. In such a case, the flow of water over sidewalks may not be acceptable due to safety reasons, and therefore the use of ditches or swales may not be an option.

It is noted that most municipal standards locate sidewalks away from the road edge with a 0.5 m to 1.0 m offset from the property line. If the sidewalks are 1.5 m wide then the space available for alternative drainage system features is reduced by 2 to 3 m on either side of the road. This reduction in space may not prevent the use of alternative drainage features but may reduce their capacities and effectiveness.

9.1.2 Planting of trees within the public road allowance

The presence of trees in the street boulevard may also interfere with the use of certain types of alternative drainage features. For example, the effectiveness and operation of perforated pipes and granular trenches can be affected by root intrusion. Although special measures such as the use of copper wires or copper mesh can be used to reduce this problem, they represent an additional cost and their effectiveness is not guaranteed.

Trees may also interfere with the flow in ditches and may create local erosion problems.

It is recalled from our survey with the public that 100% and almost 75% of respondents indicated that having municipal trees on each lot is the preferred choice in an urban and rural setting, respectively. When municipal engineers and planners were asked if the use of swales or roadside ditches could compromise the planting of trees, most (65%) said no for swales but the opinion was almost evenly divided between <u>Yes</u> and <u>No</u> for ditches (see Figure 9.1).

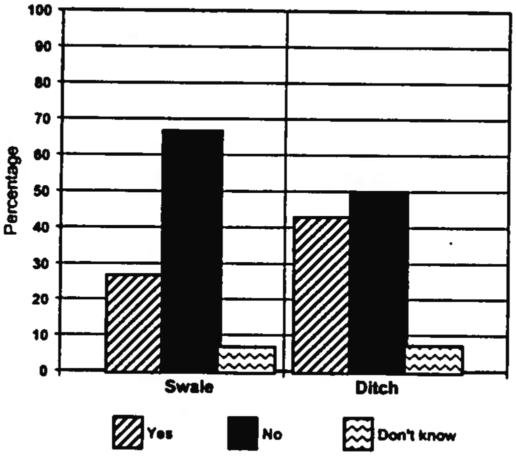


Figure 9.1 Can the use of swales or roadside ditches compromise the planting of trees in the public road allowance?

9.1.3 Type of landscape treatment in roadside ditches or swales

The type of landscape treatment in roadside ditches and swales can play an important role in terms of aesthetics, maintenance requirements, erosion control, stormwater conveyance and treatment. Types of landscape treatment can vary between grass, natural vegetation and hard surfaces.

With respect to aesthetics, the survey determined that the majority of respondents preferred to have grass covered swales and ditches (see Figure 9.2). This response is compatible with the needs for erosion control and stormwater conveyance.

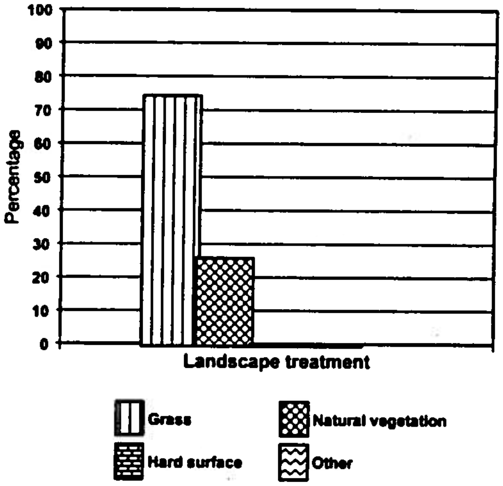


Figure 9.2. What type of landscape treatment do you feel is appropriate for a swale or conventional roadside ditch?

It should be noted that grassed ditches and swales can only be easily maintained if they have trapezoidal shapes with side slopes of 3:1 or less. Depending on the ROW and road width, these requirements may not always be met. However, in areas with steeper side slopes, alternative planting strategies (ie. taller grasses, wild flowers) may address aesthetic concerns, and if planned/designed for, can still accommodate conveyance requirements while providing other advantages such as treatment and erosion control.

9.1.4 Above or below ground utilities

For an urban setting, the survey indicated a unanimous preference (100% of respondents) to have below ground utilities. By comparison, for rural areas, less than 50% of the respondents expressed a preference to have below ground utilities while the others were evenly divided between the choice of above ground or undecided.

The survey to the municipal representatives also inquired if, in their opinion, a swale or conventional roadside ditch could be accommodated within a standard road allowance of (20 m) without compromising the allocation of other utilities. A summary of the responses is shown in Figure 9.3. The results indicate that most of the respondents felt that a grass swale could be constructed without interfering with other utilities. The opinions for roadside ditches were somewhat evenly divided between Yes, No, and Depends on site. When asked the same question but with a reduced ROW width (ie. less than 20 m), the majority indicated that neither the swale or roadside ditch could be accommodated without interfering with other utilities (see Figure 9.4).

As ditched roads are mostly found in rural areas where public utilities are not always available, typical standards for such roads do not always indicate where the possible alignments and locations for natural gas, electric, water services and cable t.v. can be located. The absence of such information is not an indication that below ground utilities are incompatible with the use of roadside ditches, swales or other alternative drainage features. As such, numerous examples of road standards showing the combined use of below ground utilities and roadside ditches or swales can be found in Appendix E.

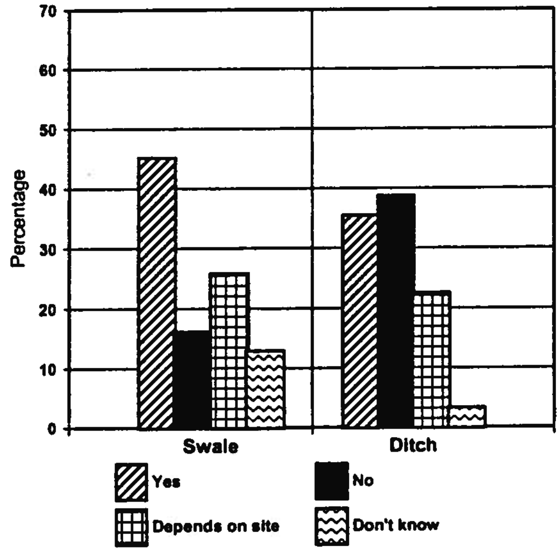
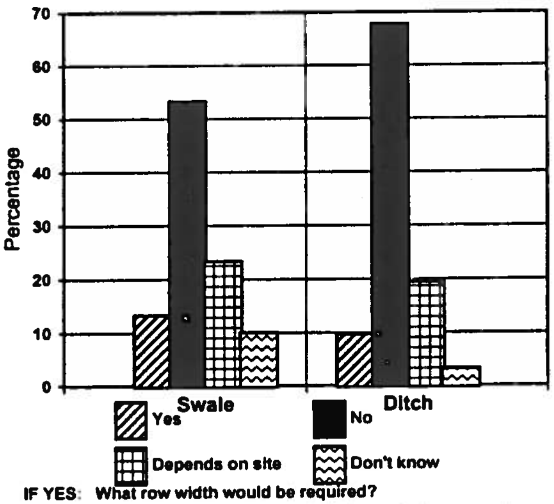


Figure 9.3: Can a swale or roadside ditch be accommodated within a standard road allowance of 20 meters without compromising the allocation of other utilities?



IF YES: What row width would be required?
Swale: 15, 18,18-20, 20, 26 m
Ditch: 18,18-20, 20, 26 m

Figure 9.4: Can a swale or roadside ditch be accommodated within a reduced road allowance of less than 20 meters without compromising the allocation of other utilities?

9.2 Road Designs

The design of a road and its drainage system are not independent of each other. Unlike other utilities such as sanitary sewers and watermains, the drainage system must service the road and its surrounding areas. Consequently, the design of the road must incorporate the necessary features to allow the drainage system to work. For example, a curbed street with ditches would require depressed curbs in strategic locations in order to direct the surface runoff from the road to the ditch.

It is recalled from the survey on public attitudes and perceptions that a large majority of respondents (almost 90%) indicated that the typical curb & gutter was perceived to be the most appropriate drainage system for a new urban subdivision. In rural areas, this perception is reduced to 10% where approximately 75% indicated that roadside ditches or grass swales are the most appropriate. These responses can also be interpreted as what is presently most commonly seen. In any case, it should be stressed that public opinion is only one factor to consider in the evaluation of road design alternatives. Furthermore, it should also be noted that a curb feature may be included within the road design, but there are alternatives to traditional sewer pipes (eg. perforated pipes, etc...)

Another important factor to consider in the design of a road is the drainage of the road base. It has been suggested that, in cold climate regions, the life of a road can be reduced by 50% if its base is not properly drained. Design features which are required to address this issue can be difficult to incorporate if the drainage system is made up of shallow swales and ditches without subdrains.

Road geometrics such as maximum and minimum slopes can also have an impact on the potential use of alternative drainage systems. It has been reported that the maximum preferred grade for an open ditch system is in the order of 3.5%. On the other hand, ditches with less than 1% grade can result in standing water that may be a nuisance depending on the adjacent land uses if the soils have low infiltration capacities. Roads with a one-sided cross fall can eliminate the need for two roadside ditches (or swales) but have been reported to cause icing problems during winter spring conditions when the snow bank on the higher side of the street melts and runs across the road surface.

9.3 Lot Planning

9.3.1 Lot widths

In a letter to the Lake Simcoe Region Conservation Authority (LSRCA) from Totten Sims Hubicki Associates (TSH, March 1994) on behalf of the Township of King it was suggested that a minimum lot width of 30 m should be considered for the proper integration of roadside ditches. This statement was partially made on the basis that, under the MTO Directive B-18, subsidies were not available for open ditch roadways in new plans of subdivisions in urban areas where the majority of lot frontages were less than 30 m.

However, with recent provincial downloading, such subsidies have been eliminated and should no longer be used as a determining factor to select the type of drainage system.

In any case, it is not necessarily the lot widths which should be considered as a potential constraint for the use of alternative drainage systems, but mainly the width and spacing of entrances and driveways. In the case of roadside ditches with culverts, the MOEE Stormwater Management Practices Planning and Design Manual suggests that their use is acceptable as long as the ditch/swale lengths are greater than the culvert lengths and longer than 5 meters.

Lot widths become even less of a concern when rear lanes are used to provide access to private dwellings. Rear lanes allow lots to be narrower and development to be more compact and eliminate the need for front entrances.

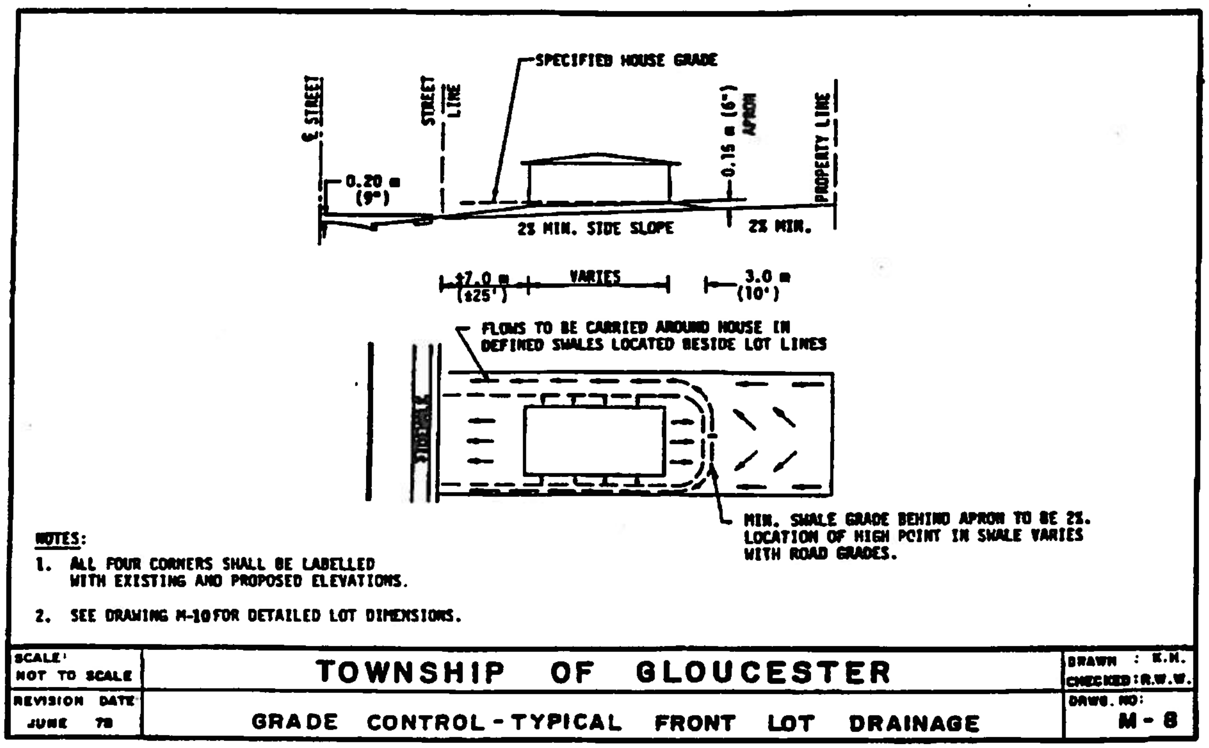
9.3.2 Lot drainage

Typically, the grading of a residential lot is as such to provide drainage from the back to front. However, in some cases it may be acceptable to have both front and rear lot drainage. Typical standards for both types of lot drainage are shown in Figure 9.5.

Rear lot drainage can be provided by means of grass swales underlain by a shallow storm sewer of a small diameter. Unless it is permitted to have surface drainage flow from property to property, one catchbasin per lot or per two lots (if installed at property line) is usually required. Some municipalities have found that the use of perforated pipes can enhance the drainage of backyard swales.

The use of rear lot drainage can significantly reduce stormwater peak flows and volumes to the road drainage system. In such cases, the effectiveness and longevity of various alternative drainage systems can be increased significantly.

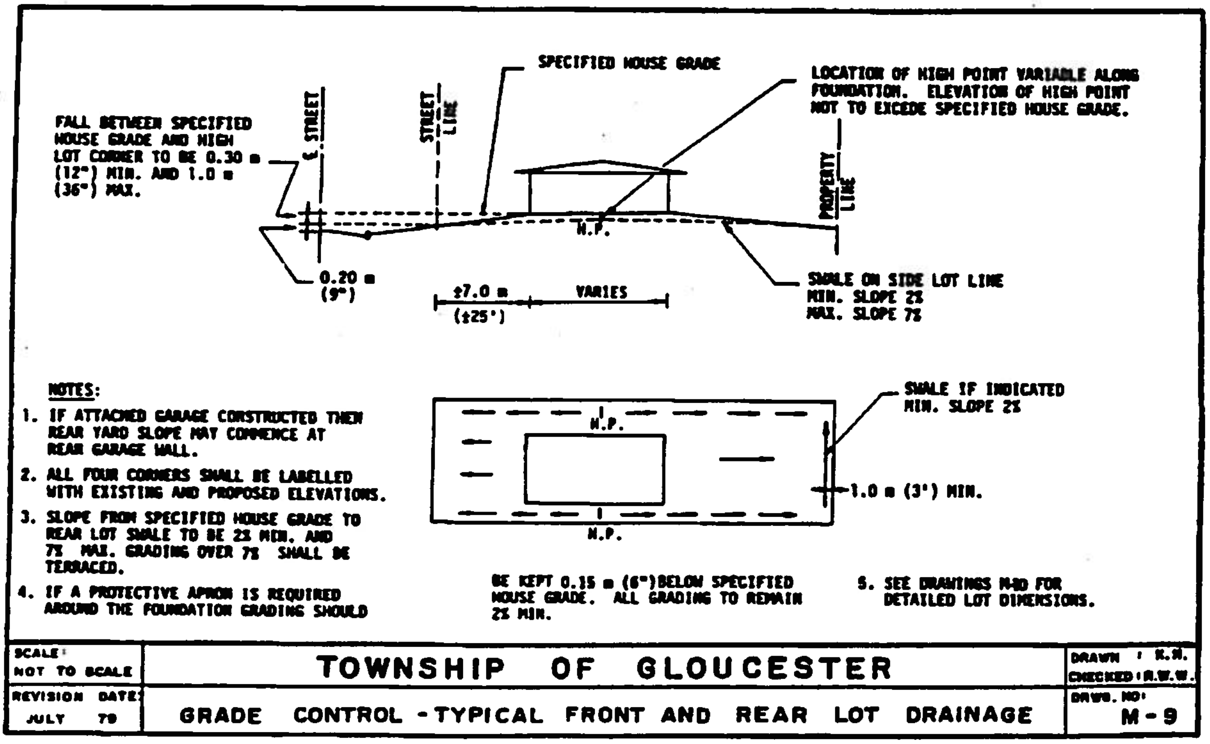
However, the use of backyard drainage is not always approved or encouraged by some municipalities. The main reasons for this are poor access and difficulty of maintenance. Numerous cases have been reported where uninformed home owners have interfered with the backyard drainage by regrading their lots or by covering catchbasins with sheds or other objects. Such problems could be reduced through adequate public education.



NOTES:

1. ALL FOUR CORNERS SHALL BE LABELLED WITH EXISTING AND PROPOSED ELEVATIONS.
2. SEE DRAWING M-10FOR DETAILED LOT DIMENSIONS.

SCALE: NOT TO SCALE	TOWNSHIP OF GLOUCESTER	DRAWN : K.H. CHECKED : R.W.W.
REVISION DATE JUNE 79	GRADE CONTROL - TYPICAL FRONT LOT DRAINAGE	DRWG. NO: M - 8



NOTES:

1. IF ATTACHED GARAGE CONSTRUCTED THEN REAR YARD SLOPE MAY COMMENCE AT REAR GARAGE WALL.
2. ALL FOUR CORNERS SHALL BE LABELLED WITH EXISTING AND PROPOSED ELEVATIONS.
3. SLOPE FROM SPECIFIED HOUSE GRADE TO REAR LOT SWALE TO BE 2% MIN. AND 7% MAX. GRADING OVER 7% SHALL BE TERRACED.
4. IF A PROTECTIVE APRON IS REQUIRED AROUND THE FOUNDATION GRADING SHOULD BE KEPT 0.15 m (6")BELOW SPECIFIED HOUSE GRADE. ALL GRADING TO REMAIN 2% MIN.
5. SEE DRAWINGS M-10 FOR DETAILED LOT DIMENSIONS.

SCALE: NOT TO SCALE	TOWNSHIP OF GLOUCESTER	DRAWN : K.H. CHECKED : R.W.W.
REVISION DATE: JULY 79	GRADE CONTROL - TYPICAL FRONT AND REAR LOT DRAINAGE	DRWG. NO: M - 9

Figure 9.5: Typical lot drainage and grade control
source, City of Gloucester Standards

9.3.3 Use of sump pumps

The use of sump pumps may be required in order to prevent the accumulation of water around basement foundations if ground water levels are high and if foundation drains cannot be directly connected to a deep storm sewer pipe. This condition most often exists in areas which are serviced by roadside ditches. However, in order to minimize the risk of basement flooding due to sewer surcharges, certain municipalities may impose the use of sump pumps even if a direct connection to a deep storm sewer is possible.

It has been reported that the continuous flows provided by the pumps which discharge to roadside ditches may increase erosion and icing problems during the winter and spring conditions.

In terms of public opinion, the survey found that according to almost 60% of respondents, sump pumps lowered the value of a house when it is located in an urban area. By comparison, when the house is located in a rural area, the same percentage of respondents felt that sump pumps had no influence on the value of the house (see Figure 9.6).

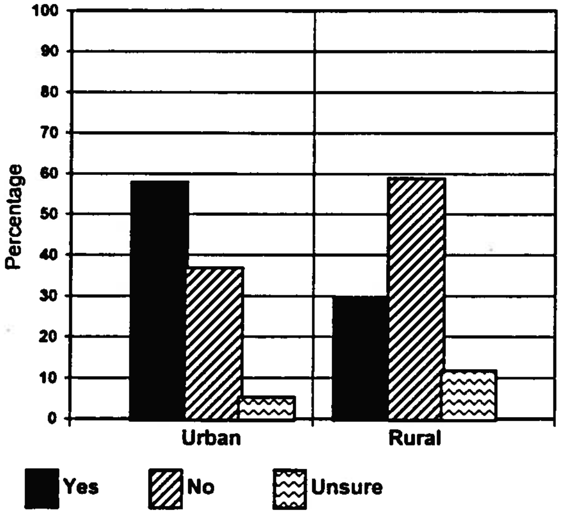


Figure 9.6 Does the use of sump pumps diminish the value of a house? How does the opinion vary between houses located in urban and rural areas?

9.3.4 Entrances and driveways

In general entrances and driveways should follow the road profile in order to not interfere with snow plowing operations. Entrances should not be excessively raised or depressed in order to prevent bottoming-out of cars entering and leaving the premises.

When culverts under driveways are required, their minimum sizes can vary between 300 mm to 450 mm with approximately 300 mm cover. The minimum size is required for maintenance purposes and the cover is required for structural reasons. These minimum dimensions can limit the use of shallow swales and ditches unless other drainage features such as perforated pipes are also incorporated.

10.0 Economic Considerations

The purpose of this section is to provide the necessary information to allow comparative cost analyses to be undertaken in the comparison of alternative drainage systems. However, the economic comparison should only be undertaken after the elimination of alternatives that are incompatible with site characteristics and development objectives.

The sources of information used to prepare this section include: City of Ajax, City of Oshawa, City of Etobicoke, York Region, Town of Richmond Hill, City of Nepean, City of Kanata, City of Vanier, City of Gatineau, Markborough Properties Inc., Sorbara Group (Vaughan), the MOEE Stormwater Management Practices Planning and Design Manual, the book "Techniques Alternatives en Assainissement Pluvial" by Azzout et al., and personal communications with several municipal engineers. Details of the collected information is provided in Appendix F.

It is noted that the information presented in this section represents an average of collected data and that capital and maintenance costs can vary from one municipality to another. In particular, maintenance costs can vary greatly with the frequency of the activities and should be adjusted based on individual needs. The digital spreadsheet copy of the selection tool provides this flexibility.

To simplify the cost comparison between various alternatives, Table 10.1 provides Capital, Maintenance and Total Present Value Costs for the construction and maintenance of various road drainage system components.

The Amortized Capital Costs (ACC) for the individual components were first computed with the following equation based on the provided construction or replacement cost, the annual discount rate and the life expectancy (longevity) of each component.

$$\text{Amortized Capital Cost } (ACC) = \frac{(CR \times i\%)}{1 - (1 + i\%)^{-L}} \qquad \textbf{(10.1)}$$

Where
CR= the construction or replacement cost
i%= the annual discount rate
L= the life expectancy (longevity) of the component

As an example, the construction or replacement cost of a manhole which is installed within the structure of a street was estimated at $3,300. With an annual discount rate of 7% and a life expectancy of 40 years, the ACC of the manhole can be computed as $247.53 using equation (1) as follows;

$$\frac{(\$3{,}300 \times 7\%)}{1 - (1 + 7\%)^{-40}} = \$247.53 \qquad \text{Example application of equation (10.1)}$$

Next, the present value of the capital and annual repair costs for each drainage component are calculated with the following equation based on the calculated amortized capital cost (equation 1), the annual discount rate, the selected life cycle and the estimated annual repair costs.

$$Present\ Value\ of\ (Capital + Annual\ Repairs) = TACC \times \frac{1 - (1 + i\%)^{-LC}}{i\%} \qquad \textbf{(10.2)}$$

Where TACC = Total of the Amortized Capital and the Annual Repair Costs
i% = the annual discount rate
LC = the Life Cycle being considered

As an example, the present value of a manhole installed within the structure of a street was computed at $3,691.04 based on annual discount rate of 7%, a life cycle of 80 years and an estimated annual repair cost of $12 per manhole. This can be computed by applying equation (2) as follows;

$$(\$247.53 + \$12.00) \times \frac{1 - (1 + 7\%)^{-80}}{7\%} = \$3{,}691.04 \qquad \text{Example application of equation (10.2)}$$

Similarly, the Present Value of the Amortized Annual Maintenance Activities (costs related to typical maintenance activities are provided in Table 10.2 and discussed below) can also be computed with the use of equation (2). The TOTAL Present Value Cost presented in Table 10.1 is thus the sum of the Present Value of the Capital and Repair Costs plus the Present Value of the Annual Maintenance Costs.

Various maintenance activities and related costs, which can be associated to various drainage components, are provided in Table 10.2. These unit maintenance costs refer mainly to cleaning activities. As with the capital costs, the provided unit maintenance costs represent average values obtained from several sources and should be verified against local cost information. It should also be noted that the provided maintenance costs are based on volume. For example, catch basin cleaning was estimated at $5/ea on the basis that a contractor would be required to clean several catch basins within the same work order.

The Amortized Annual Maintenance Costs of the various maintenance activities of Table 10.2 can be established based on the Average Unit Maintenance Cost and the proposed frequency. As such if the frequency of the maintenance activity is set to one or more times per year then the Amortized Annual Maintenance Cost is equal to the Average Unit Maintenance Cost multiplied by the frequency. For example, the Average Unit Maintenance Cost for street flushing was estimated at $0.10 / m. If street flushing is undertaken twice a year then the associated Amortized Annual Maintenance Cost is $0.20 (2 x $0.10).

However, if the frequency of the maintenance activity is less than once per year then the associated Amortized Annual Maintenance Cost (AMC) can be computed with the help of equation (1), but modified in order to not double count certain maintenance activities when the drainage component is actually replaced. The modified equation is as follows;

$$\text{Amortized Annual Maintenance Cost } (AAMC) = \frac{\left(\dfrac{AMUC}{(1 + i\%)^{(1/FREQ)}} \times i\%\right)}{1 - (1 + i\%)^{-(LONG \times (\frac{LONG}{(1/FREQ)} - 1)^{-1})}} \qquad \textbf{(10.3)}$$

Where
AMUC = the Average Maintenance Unit Cost
i% = the annual discount rate
FREQ = the Frequency of maintenance activity (0.2 = once in 5 years)
LONG = the Longevity of the associated drainage component

A simple example as to why the modified equation (3) is needed, is with Item # 5 (Ditch regrading and cleaning) which is scheduled to occur every 10 years. However, since the longevity of the ditch is set to 20 years (Table 10.1) a ditch would in fact be cleaned only every 20 years. Using a 10 year cycle in the original equation (1) would double count the costs associated with the ditch regrading and cleaning.

For each drainage system component and the selected maintenance activities, the individual AMC of the Average Unit Maintenance Costs are summed up and transferred to the appropriate column in Table 10.1. The Present Value of the total AMC are then computed and added to the Present Value of the Capital and Repair Costs to give the TOTAL Present Value COST associated with each drainage system component.

It is noted that because of the potentially large variability from one area to another, the cost of land and losses in tax revenues were not included in the overall cost of end of pipe facilities.

With the digital Excel spreadsheet copy of the cost tables, the user can enter, modify and adjust the following parameters;

i) construction or replacement costs
ii) life expectancy (longevity)
iii) discount rate
iv) lifecyle
v) up to four maintenance activities associated with each component
vi) average costs associated with each maintenance activity
vii) frequency of maintenance activities

The use of the Excel spreadsheet will provide the flexibility to designers and engineers to easily evaluate and compare the total Present Value of various potential alternative drainage systems.

10.1 Example Cost Comparison

As an example, Table 10.3 compares the cost for four typical drainage systems where System #1 is a conventional curb and gutter system with concrete pipes and an end of pipe facility for quality and erosion control; System #2 is similar to System # 1 but an Oil and Grit Separator unit is used to provide some quality control; System #3 is a conventional ditch system with an end of pipe facility for quality and erosion control; and System #4 is a grass swale system with perforated pipes and infiltration trenches capable of retaining and infiltrating the runoff of a 25 mm storm. It is assumed that the various designs will provide at least a 1:5 yr level of service with quality and erosion control based on a 25 mm storm. The type of development used in the example consists of a 10 ha area with 40% imperviousness, 20 m ROW, and 20 x 40 m lots.

Based on the costs provided in Table 10.1 and Table 10.2 and the design assumptions presented in Table 10.3, it is found that the least costly alternative is the conventional ditch system with an end of pipe facility for erosion control. The second least expensive system is the grass swale with perforated pipe system and exfiltration trenches capable of retaining and exfiltrating the runoff of a 25 mm storm.

When compared to the conventional curb and gutter system the total present value costs of the conventional ditch system and grass swale with perforated pipe system represent 60% and 74% of the present value costs associated with the conventional curb and gutter system. The conventional curb and gutter system with an Oil and Grit Separator is approximately 3% more expensive.

The Excel Spreadsheet of Tables 10.1 and 10.2 provide the means to conduct quick cost comparisons for various other alternative drainage systems.

However, in view of the potential variability in unit cost between municipalities, it is strongly recommended that further assessment of cost be conducted through site specific case examples.

Table 10.1: Capital, Annualized and Total Present Value Costs

(assumes that rock excavation is not required)

Discounted Rate = 7% Life cycle (yrs) 80

Road Drainage System Components		Capital costs Construction / Replacement					Maintenance activities and related cost					TOTAL PRESENT VALUE COST
		Construction or replacement cost	Longevity (yrs)	Amortized capital cost	Annual repair costs	Present Value capital and repair costs	Activity (refer to Table 10.2 for descriptions)			Total Annual maintenance cost	Present Value annual maint. cost	
Road Surfaces$^{(+)}$	with curbs	$311.00 /m	40	$23.33 /m	n/a	$331.77 /m	1	2		$0.55 /m	$7.82	$339.59 /m
(with curbs, w = 8.5 m)	with ditches or swales (w/o subdrains)	$346.00 /m	20	$32.66 /m	n/a	$464.49 /m	1	3		$0.60 /m	$8.53	$473.02 /m
(others, w = 7.5 m + shldr)	with ditches or swales (w/ subdrains)	$346.00 /m	40	$25.95 /m	n/a	$369.11 /m	1	3		$0.60 /m	$8.53	$377.64 /m
Subdrains 100mm diam		$20.00 /m	40	$1.50 /m	n/a	$21.34 /m	n/a			$0.00 /m	$0.00	$21.34 /m
Curbs (one side only)		$45.00 /m	20	$4.25 /m	$0.27 /m	$64.25 /m	n/a			$0.00 /m	$0.00	$64.25 /m
Cubs and gutter (one side only)		$60.00 /m	20	$5.66 /m	$0.27 /m	$84.39 /m	n/a			$0.00 /m	$0.00	$84.39 /m
Manholes	installed on street	$3,300.00 /ea	40	$247.53 /ea	$12.00 /ea	$3,691.04 /ea	8a			$5.00 /ea	$71.11	$3,762.15 /ea
	installed off traffic areas	$3,300.00 /ea	80	$232.03 /ea	$3.00 /ea	$3,342.67 /ea	8b			$2.36 /ea	$33.55	$3,376.22 /ea
Regular Catch Basins	installed on street	$1,400.00 /ea	40	$105.01 /ea	$12.00 /ea	$1,664.16 /ea	8a			$5.00 /ea	$71.11	$1,735.27 /ea
	installed off traffic areas	$1,400.00 /ea	80	$98.44 /ea	$3.00 /ea	$1,442.67 /ea	8b			$2.36 /ea	$33.55	$1,476.22 /ea
Corrugated steel catch basins with 12" grate		$550.00 /ea	40	$41.26 /ea	n/a	$586.73 /ea	8b			$2.30 /ea	$32.75	$619.48 /ea
Storm sewers	(typ 450mm)	$480.00 /m	40	$36.00 /m	$0.27 /m	$515.89 /m	n/a			$0.00 /m	$0.00	$515.89 /m
Multiple pipe exfiltration system		$1,000.00 /m	40	$75.01 /m	$0.14 /m	$1,068.77 /m	15b			$0.31 /m	$4.43	$1,073.20 /m
Ditches	(one side of road)	$45.00 /m	20	$4.25 /m	n/a	$60.41 /m	5			$0.29 /m	$4.09	$64.51 /m
Grass swales	(one side of road)	$36.00 /m	20	$3.40 /m	n/a	$48.33 /m	4			$0.30 /m	$4.27	$52.60 /m
Roadside topsoil and grass	(one side of road)	$36.00 /m	20	$3.40 /m	n/a	$48.33 /m	n/a			$0.00 /m	$0.00	$48.33 /m
Culverts	(typ 450mm)	$700.00 /ea	20	$66.08 /ea	$3.80 /ea	$993.76 /ea	7			$5.00 /ea	$71.11	$1,064.87 /ea
Check dams		$300.00 /ea	10	$42.71 /ea	n/a	$607.47 /ea	??			$0.00 /ea	$0.00	$607.47 /ea
Perforated pipes (including granular material and geotextile)	no pre-treatment	$175.00 /m	40	$13.13 /m	$0.14 /m	$188.68 /m	15b			$0.31 /m	$4.43	$193.10 /m
	with pre-treatment	$175.00 /m	40	$13.13 /m	$0.14 /m	$188.68 /m	15d			$0.06 /m	$0.90	$189.58 /m
House sump pumps		$200.00 /ea	10	$28.48 /ea	n/a	$404.98 /ea	n/a			$0.00 /ea	$0.00	$404.98 /ea
Outfall and Erosion control		$10,000.00 /ea	20	$943.93 /ea	n/a	$13,424.57 /ea	10a			$500.00 /ea	$7,111.00	$7,111.00 /ea
							(if at end of curb & gutter)					
							10b			$134.50 /ea	$1,912.82	$1,912.82 /ea
							(if at end of ditch or swale)					
							10c			$68.74 /ea	$977.57	$977.57 /ea
							(if system retains 25mm runoff)					
Dry ponds	40% imperviousness	$20,000.00 /10 ha	40	$150.02 /1 ha *$1.50 /m*	n/a	$2,133.56 /1 ha *$21.34 /m*	12	13		$336.28 /1 ha *$3.36 /m*	$4,782.51	$6,916.07 /1 ha* *$69.16 /m*
Wet ponds	40% imperviousness	$30,000.00 /10 ha	40	$225.03 /1 ha *$2.25 /m*	n/a	$3,200.34 /1 ha *$32.00 /m*	11	13		$396.28 /1 ha *$3.96 /m*	$5,635.83	$8,836.17 /1 ha* *$88.36 /m*
Artificial wetlands	40% imperviousness	$35,000.00 /10 ha	40	$262.53 /1 ha *$2.63 /m*	n/a	$3,733.73 /1 ha *$37.34 /m*	11	13		$396.28 /1 ha *$3.96 /m*	$5,635.83	$9,369.56 /1 ha* *$93.70 /m*
Infiltration Basin	40% imperviousness	$25,000.00 /10 ha	40	$187.52 /1 ha *$1.88 /m*	n/a	$2,666.95 /1 ha *$26.67 /m*	12	13	14	$400.75 /1 ha *$4.01 /m*	$5,699.48	$8,366.43 /1 ha* *$83.66 /m*
Water quality inlets: Oil and grit separators**	40% imperviousness	$5,520.00 /1 ha *($13,800 /ha imp)*	40	$414.05 /1 ha *$4.14 /m*	$4.80 /1 ha *($12/unit/ha imp)*	$5,956.89 /1 ha *$59.57 /m*	9			$500.00 /1 ha *$5.00 /m*	$7,111.00	$13,067.90 /1 ha *$130.68 /m*
Infiltration trenches	40% imperviousness	$20,000.00 /1 ha	10	$2,847.55 /1 ha *$28.48 /m*	n/a	$40,497.87 /1 ha *$404.98 /m*	16			$277.50 /m²	$3,946.61	$44,444.48 /1 ha
Exfiltration wells	40% imperviousness	$62,500.00 /1 ha	10	$8,898.59 /1 ha *$88.99 /m*	n/a	$126,555.85 /1 ha *$1,265.56 /m*	17			$3,100.00 /1 ha	$44,088.22	$170,644.07 /1 ha

Notes:

Conversions from (ha) to (m) are based on the assumption of a typical street ROW of 20 m and 40 m deep lots.
*) Total amortized cost does not include land value and potential losses in tax revenues
**) Costing information provided by *Stormceptor*
+) Does not include the cost of the curbs or subdrains.
Costs are in 1998 dollars and represent averages. Actual costs may vary between municipalities
Amortized capital cost is at the given discounted rate (7%) over the longevity period
Present Value calculation all done over the given life cycle (80 years) at the shown discounted rate.

- Annual costs for activities done less than once per year have been determined by a two step calculation
  1. Present value at the discounted rate is determined over the maintenance period
  2. Amortized cost are then calculated over the maintenance period at discount rate of 7%
  3. For activities which are done only once in the lifetime of the device, the cost is amortized over the entire life = 2X the maintenance period

Table 10.2: Maintenance Activities and Associated Costs

Item	Maintenance Activity			Average Cost per unit	Frequency per year
1	Street Flushing (both sides)			$0.10 /m	2
2	Street sweeping (only for roads with curbs) (both sides)			$0.07 /m	5
3	Shoulder and edge treatment (both sides)			$0.20 /m	2
4	Grass cutting and repairs			$0.30 /m	1
5	Ditch regrading and cleaning (both sides)			$6.00 /m	0.1
6	Swale regrading, sod and topsoil			/m	
7	Culvert thawing and winter drainage ($500 per 100 units)			$5.00 /ea	1
8a	Catch basin cleaning	installed on street		$5.00 /ea	1
8b		installed off street (w/ pre-treatment)		$5.00 /ea	0.5
9	Oil and grit separator cleaning ($250) + disposal ($250) actual cost depends on the number of units being cleaned out at a given time.			$500.00 /ea	1
10a	Outfall maintenance	from conventional C&G system		$500.00 /ea	1
10b		from ditch or grass swale system		$500.00 /ea	0.33
10c		if system retains 25mm rainfall		$500.00 /ea	0.2
11	Wet pond maintenance	grass cutting, litter pickup, weed control, re-planting		$390.00 /1 ha drainage area	1
12	Dry pond maintenance	grass cutting, litter pickup, weed control, re-planting		$330.00 /1 ha drainage area	1
13	Sediment removal from end of pipe facilities including disposal	40 % imperviousness (Annual Loading = 0.925m^3/ha)		$323.75 /1 ha	0.05
14	Infiltration basin maintenance	tiling and re-vegitation		$140.00 /1 ha drainage area	0.5
15a	Pervious pipe maintenance	no pre-treatment	flushing	$1.00 /m	0.2
15b			radial washing	$2.00 /m	0.2
15c	Pervious pipe maintenance	with pre-treatment	flushing	$1.00 /m	0.07
15d			radial washing	$2.00 /m	0.07
16	Infiltration trench maintenance (1.5 m deep, control runoff from 25mm runoff @ 40% imp)			$277.50 /1 ha	1
17	Exfiltration wells (assume 3.2 exfiltration wells per hectare for 40% imperviousness)			$3,100.00 /1 ha	1
18	**User Defined Maintenance Activity**				
19	**User Defined Maintenance Activity**				
20	**User Defined Maintenance Activity**				

Notes:
- Conversions from (ha) to (m) are based on the assumption of a typical street ROW of 20 m and 40 m deep lots.
- Costs are in 1996 dollars and represent averages of collected information.
- Actual unit costs may vary between municipalities.
- Frequency of maintenance activities should also be adjusted accordingly.

Table 10.3: Cost comparison between four typical systems

(New system)

System objectives: Designed to provide at least a 1:5 yr level of service with quality and erosion control based on a 25 mm storm. Use 7% annual discount rate and 80 year lifecycle.

Development: 10 ha area at 40% imperviousness, with a 1000 m x 8.5 m roadway and a 20 m ROW with 20 x 40 m lots.

System components	TOTAL Present Value COSTS , ( ) represents number of units			
	System #1 **Conventional curb and gutter system with concrete pipes and an end of pipe facility for quality and erosion control.**	**System #2** **Like System #1 but with Oil & Grit Separator units for source control and an end of pipe facility for additional quality and erosion control.**	**System #3** **Conventional ditch system with an end of pipe facility for quality and erosion control. Road has no subdrains.**	**System #4** **Grass swale system with perforated pipe system and infiltration trenches capable of retaining and infiltrating the runoff of a 25 mm storm.**
Roads	$339,590.80	$339,590.80	$473,023.22(1	$377,639.22
Subdrains	$42,671.22	$42,671.22	0	0
Curbs and gutter	$168,774.69	$168,774.69	0	0
Manholes	(10 on street) $37,621.49	(9 on street) $33,859.34	0	(5 on street, 5 off street) $35,691.84
Catch basins	(32 regular) $55,528.53	(32 regular) $55,528.53	0	(100 corrugated steel off road) $61,947.82
Sewers	(1000 m) $515,894.52	(1000 m) $515,894.52	0	(2000 m, perforated with pre-treatment) $379,152.96
Ditches	0	0	(2000 m) $129,010.13	0
Swales or roadside grass	(2000 m) $96,656.88	(2000 m) $96,656.88	0	(2000 m) $108,190.09
Culverts	0	0	(100) $106,487.33	0
Sump pumps	0	0	(100) $40,497.87	(100) $40,497.87
Outfall and end of pipe erosion control	$7,111.00	$7,111.00	$1,912.82	$977.57
End of pipe facility (wet pond)	$88,434.10 + land + losses in tax revenues	$70,747.28(2 + land + losses in tax revenues	$70,747.28(3 + land + losses in tax revenues	0
Oil & Grit Separator(4	0	(5 units) $65,339.48	0	0
Total present value cost (per 10 ha of drainage area or 1000 m of roadway)	**$1,352,283.24***	**$1,396,173.75***	**$821,678.66***	**$1,001,097.36**

Notes: *) Cost for land required by end of pipe facility or losses in tax revenues are not included due to large variability.

1) Cost of road can be reduced by $95,384 if subdrains can be installed. For subdrains add $42,671.

2) Assumes Oil & Grit Separators are 50% efficient and therefore includes a 50% credit on cost for sediment removal from end of pipe facility.

3) Cost assumes that ditches are 50% efficient at removing sediments. If properly constructed, ditched roads may not require an end of pipe facility in which case the cost can be reduced by ($70,747.28 + land + losses in tax revenues).

4) Prices reflect the use of Stormceptor units for which the cost information was available from the manufacturer.

General) Total annual costs are based on "average" total costs and individual costs may vary between municipalities.

11.0 Overall Comparison of Alternative Drainage Components

Based on the literature review, the findings from the survey and additional considerations identified in sections 4 through 10, this section represents a brief comparative summary of the major alternative drainage system components which can be part of an alternative drainage system. That is, instead of comparing actual drainage systems, the various drainage components are compared in terms of advantages, disadvantages, design features, and operational and maintenance considerations.

11.1 Curbs and Gutters

Although curbs and gutters may also provide other services, they are one of the most recognisable drainage features in urban areas. Rainfall runoff from the road and adjacent lands is conveyed along a gutter formed by the roadside curb and the edge of the road until it is captured by a catch basin inlet. Once in the catch basin, the water is then directed to an underground pipe system which in turn discharges to a receiving water body or to a stormwater management facility.

Advantages:

- Li, Orland, Hogenbirk (1995) point out that curbs are said to promote safety for both motorists and pedestrians by offering a physical and visible barrier boundary between them.
- the curb and gutter protects the road edge and roadbase from erosion and reduces sod damage associated with snowploughing activities.
- can usually be constructed deep enough to also drain the weeping tiles of adjacent houses and buildings.
- roads constructed with curb and gutters can be designed to create low points where excess stormwater can be retained.

Disadvantages:

- lack of water quality treatment capability thus requiring some end of pipe facility.
- reduction of ground water recharge and stream baseflow.
- can increase downstream channel erosion if end of pipe flow is not controlled.
- slippery conditions on roads due to clogging of catchbasins.
- water ponding during large storms or blockage of inlet by ice or debris can create conditions for hydroplaning.
- car splashing can release more pollutants to the environment by washing off the underside of the vehicles.
- cyclist often go around inlets and manhole covers and thus increase the risk of accidents.

Design features and considerations:

- requires a deep outlet

Capital costs:

- depends on the various components used (see section 11)

Operational and maintenance considerations:

- Curb and gutter systems require a wide range of maintenance activities

Longevity:

- 20-50 yrs.

11.2 Roadside Ditch with or without Culverts

The roadside ditch is also a very common type of drainage system. This type of drainage system is usually seen along highways and in rural areas where private lots are larger than in urban centres.

Advantages:

- increases the time of concentration of surface runoff and therefore design flows are lower.
- lower peak flows require smaller downstream infrastructure which can represent substantial savings.
- lower peak flows provide some erosion control benefits.
- grass bottom ditches provide some filtration of stormwater and an opportunity for infiltration.
- available storage volume within the ditch can provide some quantity control benefits.
- during intense storms, water is less likely to pond on the surface of the road.
- some cities offer a leaf pick up program in the fall during which time residents can rake their leaves into the roadside ditch where they will be picked up.

Disadvantages:

- to some, a roadside ditch may become an eye sore if not properly maintained.
- local flooding during spring snowmelt is often associated with culvert blockages.
- may be limited to small drainage areas based on system characteristics (eg. slopes, presence of culverts, culvert sizes and spacing).
- does not provide the means for foundation drain connections.
- culvert heaving at private entrances can become chronic problems for some home owners.
- stagnant water in improperly graded ditches may become breeding grounds for mosquitoes.
- can be difficult to maintain if side slopes are too steep and if ditches retain water.

Design features and considerations:

- vegetated waterways may be built in three shapes or cross-sections: parabolic, trapezoid, or "V" shaped. Poland (1975) notes that the parabolic design is the most satisfactory, and is ordinarily the shape found in nature.
- although the ODS allows for ditch side slopes of 2:1, these should be reduced where possible to make the maintenance of the ditch easier. As such it was suggested that where mowing or other maintenance is planned, side slopes should not exceed 4:1 (Amimoto 1978; Tourbier et al. 1980b).
- sharp turns should be avoided as they are potential problem areas for erosion or debris jams.
- cost-effectiveness of driveway slope for roadside safety improvement was evaluated by Post (1978) to be 8:1.
- erosion control may be provided with the use of check dams. MNR (1990) recommends that check dams should not be located where the drainage area exceeds 4 ha (10 ac). Furthermore, the maximum height of a check dam should be less than 600 mm and the centre should be at least 150 mm lower than the outer edges. Frequent clean-out is needed for best performance. Unless properly designed and installed, a washout of the dam may cause more sedimentation downstream than would have occurred if the check dam had not been used. Approximate cost for check dams is $300.
- brush barriers can be used where sediment in surface water requires filtering. The maximum slope length upstream of a barrier should be no more than 30 m. Design and construction information for brush barriers is available in the MNR-Environmental Guidelines for Access Roads and Water Crossings Manual, 1990. Approximate cost for brush barriers is $3.15/m.

Operational and maintenance considerations:

- ditches are often perceived to require a high level of maintenance

Longevity:

- 10-20 yrs.

11.3 Grass Swales

Swales are vegetated channels that allow conveyance and infiltration of storm runoff. In general, swales have shallower side slopes than ditches.

Advantages:

- grass swales are essentially living filters and are thought to be an ideal practice for treating the quality of stormwater runoff.
- usually less expensive than the curb and gutter alternative and easy to maintain.
- does not require a deep outlet.
- does provide some control of peak discharges by increasing the time of concentration.
- can significantly reduce requirements on downstream drainage infrastructures (see section 4).
- provides some filtration of stormwater and an opportunity for infiltration and groundwater recharge.
- Yousef (1985) indicated that swales were quite effective in removing total metals in urban runoff.
- removal rates exceeding 80% of suspended solids were suggested by Whalen and Callum (1988) and observed by Sabourin et. al (1995).
- lower flows provide some erosion control benefits.
- easily maintained by home owners and are aesthetically pleasing by providing a country type streetscape.
- possibility of integration within parks and playgrounds.

Disadvantages:

- limited capacity to accept runoff from large design storms or from large drainage areas.
- not generally capable of removing soluble pollutants such as nutrients, Yousef (1995).
- if not deep enough, swales may not provide an appropriate road base drainage unless perforated drains are used.
- requires the use of sump pumps for foundation drains.
- infiltrating surfaces may clog over time.
- potential for groundwater contamination.
- depending on size and width, land requirements may become important.

Design features and considerations:

- depth of flow should be minimized as much as possible. The flatter the slopes, the better.
- side slopes should be no greater than 3:1 (h:v) and longitudinal slopes preferably less than 3.0%
- more typically, pollutant removal rates are not that high unless the soils have high infiltration rates and flow velocities are less than 0.15 m/s.
- key design features to increase swale efficiency (in terms of pollutant removal) include techniques to promote greater infiltration such as incorporating sand trenches, perforated underdrains, check dams, broader bottom widths and greater lengths.
- dense cover of water tolerant, and erosion resistant grass must be established. In areas where deicing agents are used, some care should further be taken in selecting the type of grass cover.
- underlying soils should have infiltration rates greater than 13 mm/hr.
- the use of check dams in swales can be limited due to their relatively shallow depths.
- for protection against erosion, maximum permissible flow velocities range from 0.6 m/s to 1.6 m/s.

Capital costs:

- for a 4.5 m wide, 3:1 side slope swale, the cost for excavation and shaping plus (i) seeding/straw mulching is approximately $20/m, while for (ii) sodding/stapling it is approximately $36/m.
- culverts at private entrances can be estimated at $700.

Operational and maintenance considerations:

- a dense vegetative cover should be maintained. If necessary, routine seeding may have to be done.
- if clogging of soil pores becomes a problem the removal of sediment may be necessary.
- it is noted that grass swales combined with perforated pipes have been installed over the last 12 years by the City of Nepean (Ontario) and that maintenance requirements for both the swales and the pipes have been next to nil. Only a few square metres of grass have been replaced due to snowploughs and brownouts where the infiltration capacity of the swale was too high.

Longevity:

- 10 - 20 yrs

11.4 Percolation / Exfiltration Trenches

Percolation / exfiltration trenches are stone filled trenches that allow rainwater to fill the stone voids and then to infiltrate into the surrounding soil column. For soils with inadequate permeability, a perforated pipe may be installed in the infiltration trench to carry the water to a drainage system. Filter fabric is commonly placed around all sides of the trench to prevent clogging of the voids. Infiltration basins, infiltration wells or dry wells, and infiltration pits are variations of the infiltration trench design.

Advantages:

- can be quite effective for small storms and therefore useful for controlling water quality.
- although Schueler et al. (1991) reported that about 50% of percolation trenches constructed in the eastern United States have failed, when properly operating, percolation trenches can remove up to 99% of particulate.
- excellent alternative for ground water recharge.
- cheap to construct.
- easy to integrate into existing landscape.
- does not require an outlet.

Disadvantages:

- limited flood-peak reduction benefit.
- clogging by solids has been found to be of concern.
- potential for ground water contamination
- not very effective on steep slopes

Design features and considerations:

- sizing rules for storing .5 inches (13 mm) or 1.0 inches (25 mm) of runoff per impervious hectare have been recommended (Schueler, 1987).
- they typically serve impervious tributary areas of 2 ha or less.
- if the groundwater table is near the bottom of the trench, groundwater mounding can develop under the trench which may in turn increase the potential for contamination.
- groundwater table should be at least 1 m below the bottom of the trench.
- 15-30 m^3 of storage per impervious hectare is presently recommended in Germany (Grotehusmann, 1994)
- trench depth is usually between 1 to 4 m and 1 to 2 m wide. Filter fabric is placed around all sides of the trench to prevent clogging and soil fines from leaching into the stone reservoir.
- buffer strips should be placed between the runoff producing area and the trench for solids removal.
- according to Duchene et al. (1993); (i) approximately three-quarters of the infiltration occurs through the bottom of the trench, (ii) the impact of sediment clogging the bottom of the trench is important but limited, and, (iii) the infiltration rates calculated using a simple Darcy model is consistently lower than those of a finite element simulation, hence the use of a Darcy model will develop conservative values.
- an elaborate storm sewer system with perforated pipes placed in granular trenches was constructed by the City of Etobicoke in 1993. The system is said to capture and treat the runoff of 15 mm storm events (City of Etobicoke, 1994). Although monitoring of the system is still underway, it is expected that all particles above the 50-100 micron range will be removed; bacteria will die off in the soil environment; fertilizers and other nutrients will likely be taken up by the trees in the area; groundwater will be recharged. However, chemicals, such as herbicides, pesticides or de-icing salts will not be removed.

Capital costs:

- estimated at $75/$m^3$ (Azzout et al., 1994).

Operational and maintenance considerations:

- surface maintenance to prevent clogging, $1.25/$m^2$, (Azzout et al., 1994).

Longevity:

- 5-10 yrs.

11.5 Porous Pavements

The porous pavement concept, which includes open-graded friction courses, is not a new concept. Porous pavement uses the natural infiltration capacity of the underlaying soil to absorb rain water after storing it in the porous base consisting of sand or large diameter open-graded gravel. If infiltration into the soil is undesirable or if soil permeability is low, a perforated pipe can be provided to transport the rainwater to a drainage system.

Advantages:

- peak flow reduction and lower risk of flooding downstream.
- lower flows can significantly reduce the requirements on the stormwater drainage infrastructure downstream.
- does not require additional space.
- lower risk of hydroplaning and less splashing.
- lower risk of black ice.
- can be designed to store up to several inches of rainwater to delay runoff from the site and to attenuate peak discharge to an acceptable level.
- estimates of pollutant removals for modular (paver blocks) porous pavement range from 0 to 95%, depending on the pollutant and on the site conditions.

Disadvantages:

- clogging of permeable surfaces can be a problem.
- regular maintenance is required.
- can be affected by frost.
- higher cost.
- requires public education to reduce risk of clogging.
- can represent a higher risk of ground water contamination.

Design features and considerations:

- usually recommended for low-traffic roads or parking lots.
- requires that the ground water elevation be at least 0.6 to 1.0 m below road base.
- Yu (1993) suggests that to avoid structural problems associated with wet pavement foundations, porous pavements may be suitable for parking lots only, in warm (never freezing) climates with sandy substrates.
- sources in the literature indicate that porous pavements have been used in Scandinavia for almost 20 years without much problem.
- the use of permeable pavement in conjunction with infiltration trenches and infiltration inlets has been implemented since 1981 in congested urban areas of Tokyo (Fujita, 1993). Because of the high clogging potential of permeable pavements (Schueler et al., 1991), a cleaning device has successfully been developed.
- typically, the depth of the stone reservoir below the porous pavement structure should be designed to detain, as a minimum, the first 13 mm of runoff for no longer than 72 hours.

Operational and Maintenance considerations:

- routine cleaning by vacuum sweeping or spray wash is necessary.
- pressure wash required at least once every 5 years.

Longevity:

- varies based on maintenance efforts.

11.6 Water Quality Inlet: *(eg. Stormceptor)*

The Stormceptor is a patented water quality inlet that takes the place of a conventional manhole in a storm drain system. Because of its special design the device can remove free oil and suspended solids from stormwater during low flows. During high flows, a patented by-pass device prevents the scour or resuspension of settled material.

Advantages:

- can be implemented as part of a treatment train.
- prevents groundwater contamination and extends the maintenance period for other stormwater quality measures.
- Excellent spill control device for commercial and industrial developments.
- simple to design and specify.

Disadvantages:

- cannot be used as a storm drain inlet.

Design features and considerations:

- although initial versions of these devices were shown to have poor performance, newer and improved models are now providing much better results. Such a model, Stormceptor, has been reported to remove 50 to 80% of the total sediment load when properly applied as a source control for small areas (eg. 5.0 ha or less).
- must have at least 1 metre of cover above the obvert of the pipe.

Capital costs:

- prices are based on the size of the unit and can vary between $ 8,250 to $ 25,000 excluding delivery and installation. An average cost of a unit for 1 ha of impervious area can be in the order of $ 13,800.
- a regular installation can cost from $ 6,000 to $ 10,000 and may vary depending on whether the application is in a new development or a retrofit setting (and from contractor to contractor).
- taking an average unit cost and installation cost the total cost per hectare of impervious area can be approximated between $ 20,000 to $ 30,000.

Operational and Maintenance costs:

- based on field monitoring, an annual clean out would be sufficient based on the estimated annual sediment removal rates.
- typical per unit cleaning cost (equipment and personnel) is estimated to be approximately $ 250 exclusive of the disposal costs. Disposal costs are estimated to be in the order of $ 300 to $ 500 plus any laboratory costs.

Longevity:

- 20-50 yrs. (based on experience with concrete; as most types of water quality inlets have not been in operation for this length of time, a true test is not available).

12.0 Alternative Drainage System Selection Tool

Design guidelines for the construction of alternative drainage systems can be found in various literature. Their potential advantages and disadvantages with respect to stormwater management functions are also well documented. However, it is often the selection of the most appropriate alternative(s) which can become complicated and may require a detailed assessment. Unfortunately, such assessments are most often conducted on a qualitative basis with a lack of objectivity and can, consequently, lead to arguable results.

To improve the assessment for the potential use of various alternative drainage techniques it is necessary to know and consider as many quantifiable aspects as possible. Such aspects should be easily obtainable.

In order to properly assess the potential use of various alternative drainage systems, the following aspects should be considered:

i) Compatibility with physical site characteristics.
ii) Compatibility with planning objectives (or existing development in the case of a retrofit situation) and ease of integration.
iii) Ability to meet stormwater management objectives.
iv) Economics.
v) Public acceptance / Safety.

In this section of the report, a systematic procedure to help determine which types of alternative drainage systems (see Table 12.1 for list of features and description) could be used within a specific project is developed and presented. In its initial steps, the procedure uses the process of elimination to identify which drainage features are compatible with the physical site characteristics and/or with the type of development. Based on the potential use of various drainage features, conceptual drainage systems can then be evaluated in terms of their ability to meet stormwater management objectives, costs (capital and maintenance, refer to Section 10), and public expectations.

The procedure which makes use of various tables can be used for new developments or retrofit situations. The step by step approach which is described in the following sections can be visualized by the flowchart presented in Figure 12.1.

The use of the Tables which are presented in this section have been programmed into a user interactive Excel Spreadsheet application which also includes the costing information presented in Section 10. The User's guide for the Excel Spreadsheet program is provided in Appendix H with a sample application. Additional "real life" applications of the Selection Tool are presented in a separate document entitled "Demonstration of a Conveyance System Selection Tool in Urban Road Projects" by Totten Sims Hubicki Associates and Donald G. Weatherbe Associates.

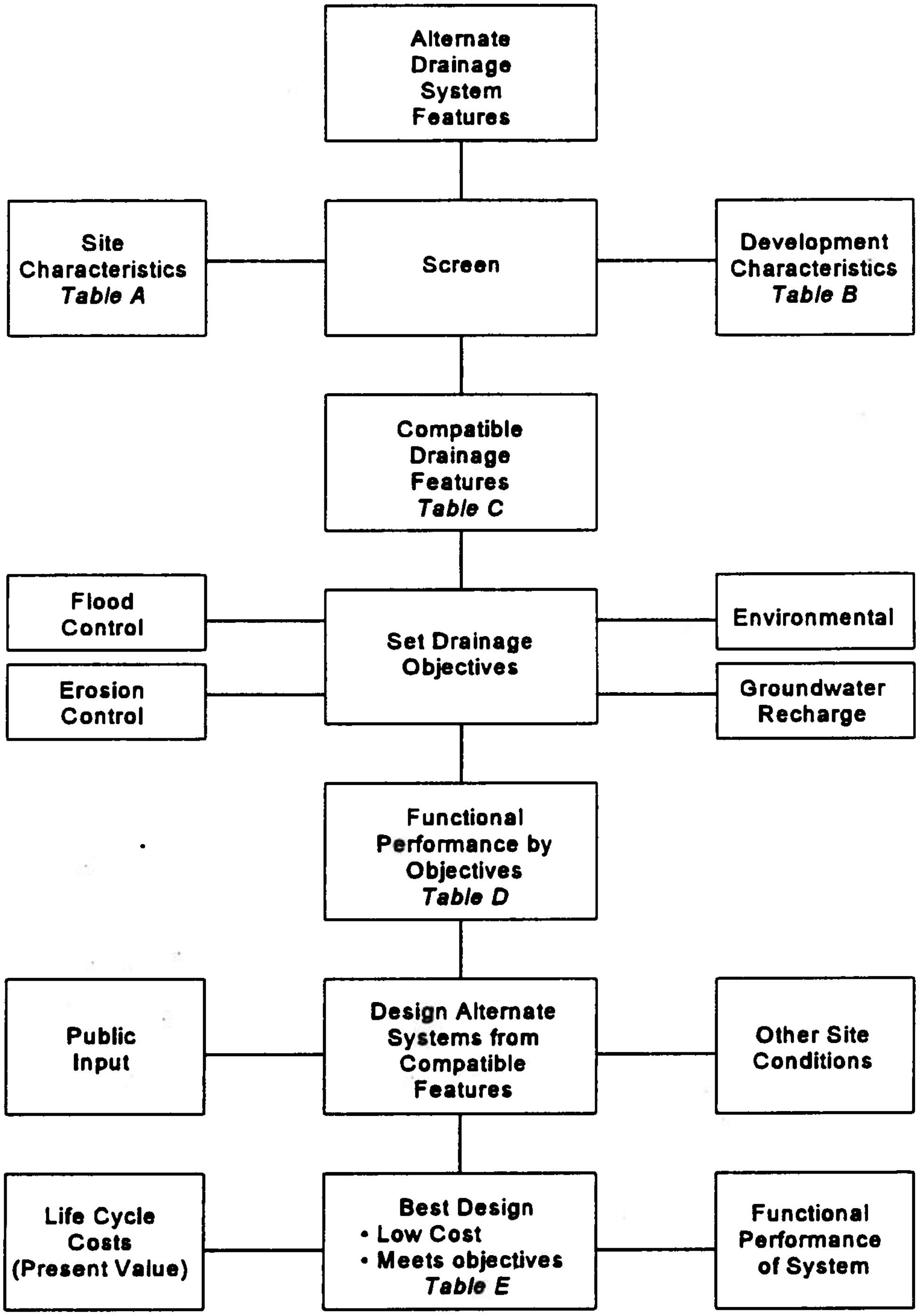


Figure 12.1: Steps in Application of Selection Tool

(see Table 12.2 for a list and description of various alternative drainage features)

Table 12.1: Description of Drainage Features

	Drainage Features and Description
1	**Street curbs** A raised concrete, asphalt or stone edging along the side of a road to form part of a gutter. Figures 1.1a and 1.1b show typical cross-sections of standard curbs while Figure 1.4 shows a typical road section with curbs. By themselves, street curbs can provide some on-site flood control but little environmental benefits. Curbs can sometimes be viewed as more socially acceptable and found to provide a sense of security. No site or development characteristics were found to prevent the use of street curbs.
2	**Roads with one-sided cross slopes** A road built without a centre crown so that the runoff is directed to one side of the street only. This allows for fewer catchbasins or the need to only have one drainage ditch/swale. Except for some economical benefits, one-sided cross slope streets provide no valuable SWM benefits. In some areas, where snow accumulation is a factor, one-sided cross slope streets may be discouraged to prevent snowmelt from freezing across the road surface.
3	**Porous pavement with storage structure** A pavement structure which by design and construction allows some surface runoff to flow through and stored in a clear stone granular base. The stored water can then be released slowly to another drainage feature such as storm sewers through sub-base drains. A typical section of a porous pavement structure is shown in Figure 1.2. When designed properly, such structures could provide some erosion and water quality control benefits. However, the use of porous pavements should be discouraged where the ground surface can freeze for extended periods and should be prohibited in areas where surface sediments are abundant (eg. where local soils are highly susceptible to erosion or in industrial areas).
4	**Porous pavement with exfiltration system** Similar to Feature #3 but in this case the water which is retained within the porous pavement structure is released (exfiltrated) slowly to the surrounding soils. When designed properly, such structures could retain and exfiltrate sufficient runoff to provide groundwater recharge, erosion and quality control benefits. However, exfiltrating water to the surrounding soils should only be considered if the underlaying soils are compatible with the presence of water, and if the groundwater quality is not at risk, and when the subsurface infiltration rates are at least 2.5 mm/hr, and when the depth of groundwater or bedrock is at least 1.5 m from the surface. Furthermore, the use of porous pavements should be prohibited in areas where surface sediments are abundant (eg. where local soils are highly susceptible to erosion or in industrial areas) or where toxic chemicals are transported or stored (eg. gas stations). Finally special care may be required where below ground franchise utilities are found or where surface slopes exceed 5%.
5	**Storm sewers with foundation drain connections** This is the typical storm sewer system normally found in conventional urban developments. The storm sewer must be installed at a sufficient depth (usually more than 2 m) in order to allow a gravity connection from the nearby building foundation drains. Consequently, such systems also require sufficiently deep outlets. While storms sewers can be designed to provide adequate on-site flood control and possibly off-site flood control (if the major system is retained on the street and catchbasins are equipped with inlet control devices), they cannot, by themselves, provide any groundwater recharge, erosion control or water quality control benefits. Storms sewers can, however, provide some thermal impact reduction.
6	**Shallow storm sewers with sump pumps** This system is simular to the one described under Feature #5 except that the depth of the storm sewer is mainly governed by frost protection requirements since water collected by foundation drains is removed by sump pumps. While storms sewers with sump pumps can be designed to provide adequate on-site flood control and possibly off-site flood control if the major system is retained on the street and catchbasins are equipped with inlet control devices, they cannot, by themselves, provide much SWM benefits. If the sump pumps discharge to a grass surface area, some groundwater recharge may be achieved. Furthermore, storms sewers can also provide some thermal impact reduction.
7	**Roadside ditches with culverts** This is the typical roadway drainage system usually found in low density urban areas and rural areas. Figure 1.9 shows a typical cross-section of a roadside ditch drainage system. The depth of a ditch can usually vary between 0.6 m to 1.5 m, however, in order to maintain a sufficient culvert cover, ditches should be at least 1.0 m deep. The perviousness of roadside ditches can provide some groundwater recharge benefits while the less than smooth surface of a ditch can reduce flow velocities and provide some erosion control benefits. The vegetative cover along ditches can provide adequate sediment removal and some nutrient uptake and thermal impact reduction. In addition, the storage volume of some ditches can further provide on-site and off-site flood control. However, the use of roadside ditches with culverts should be implemented with additional considerations where the surface slopes are less than 1% or more than 5%. Available space (i.e. within the road right-of-way and between private driveways) can also represent an important limitation for the use of roadside ditches with culverts. As such, a single ditch requires at least 2.5 m within the ROW and should at least have 5.0 m in length between driveways. Other factors which may affect the use of ditches are; i) climate, ii) type of soils, iii) type of development, and iv) location of sidewalks.

	Drainage Features and Description
8	**Shallow ditches or swales (no culverts)** Unlike roadside ditches with culverts (Feature #7), shallow ditches or swales are normally only a few centimetres deep (10 to 25 cm) and the vegetative surface of a swale is continuous with the landscaping of the adjoining lot. A typical cross-section of a grass swale is shown in Figure 1.12 while a true life picture can be seen in the Factsheet of Section 14. Like the typical roadside ditch, shallow ditches or swales can provide some groundwater recharge, erosion control, sediment removal, nutrient uptake, bacteria die-off and oil and grease removal benefits. However, unlike typical ditches and because of the lack of culverts, grass swales cannot provide, by themselves, adequate on-site and off-site flood control. Factors which may affect the use of shallow ditches or swales include; i) surface infiltration rates to prevent excessive surface ponding, ii) surface slopes, iii) type of soil, iv) available space within the road right-of-way, and v) location of sidewalks.
9	**Shallow perforated pipe exfiltration system** Usually consists of a shallow perforated pipe system installed within a granular trench of clear stone surrounded by a filter cloth. Surface stormwater can be directed to such a system by means of catchbasins and/or from the ground surface by infiltration. Once in the pipe, water can exfiltrate (out of the pipe) to the surrounding granular trench and soils. If the pipe is continuous then any excess water can be conveyed to a downstream outlet (eg. standard storm sewer or ditch). Shallow perforated pipes are usually installed next to the roadway underneath shallow ditches or grass swales. An example of such a system is shown in Figure 1.12. When properly designed and constructed, shallow perforated pipe exfiltration systems can provide a wide range of SWM. benefits including; groundwater recharge, erosion and quality control, thermal reduction, and flood control. However, such systems should not be considered where local soils are incompatible with the presence of water or where the groundwater quality is at risk. Similarly, such systems should not be considered where the sub-surface infiltration rates (hydraulic conductivity) are less than 2.5 mm/hr or if the groundwater levels (or bedrock) are less than 1.5 m from the bottom of the granular trench. Additionaly, special considerations may be required if the following site and development characteristics exist; i) shallow outlet, ii) surface slopes greater than 5%, iii) surface soils suspectible to erosion, iv) industrial land use or high imperviousness, v) limited space within the road right-of-way, vi) sidewalks next to road, vii) trees within the road right-of-way, and viii) presence of below ground franchise utilities.
10	**Deep perforated pipe exfiltration system** Similar to the shallow perforated pipe exfiltration system except for the fact that the perforated pipe is installed at lower depths. However, because the pipes are deep, surface runoff must be directed to the system with the use of catchbasins. Once in the pipe, water can exfiltrate (out of the pipe) to the surrounding granular trench and soils. If the pipe is continuous then any excess water can be conveyed to a downstream outlet (eg. standard storm sewer). Deep perforated pipes have been installed under the roadway as standard storm sewers. An example of a drainage system incorporating a deep perforated pipe was constructed in the City of Etobicoke is shown in Figure 1.5. When properly designed and constructed, deep perforated pipe exfiltration systems can provide a wide range of SWM. benefits including; groundwater recharge, erosion and quality control, thermal reduction, and flood control. However, the use of such systems should not be considered where local soils are incompatible with the presence of water or where the groundwater quality is at risk (unless adequate pre-treatment is provided). Similarly, such systems should not be considered where the sub-surface infiltration rates (hydraulic conductivity) are less than 2.5 mm/hr or if the groundwater levels (or bedrock) are less than 1.5 m from the bottom of the granular trench. Additionally, special considerations may be required if the following site and development characteristics exist; i) shallow outlet, ii) surface slopes greater than 5%, iii) surface soils susceptible to erosion, and iv) industrial land use or high imperviousness.
11	**Deep perforated pipe filtration system** Unlike the shallow and deep perforated pipe exfiltration systems, the deep perforated pipe filtration system can be used where the soils are impervious or with low infiltration rates. The system requires at least two perforated pipes; one deeper than the other. Typically, the surface runoff captured by a catchbasin would be directed to the shallower perforated pipe from which water could exfiltrate to a filtrating sand layer below which another perforated pipe would re-collect the exfiltrated water. A drainage system incorporating a deep perforated pipe filtration system was installed in the City of Etobicoke (see Figure 1.6). When properly designed and constructed, deep perforated pipe filtration systems can provide some groundwater recharge (limited), erosion and water quality control, and thermal reduction. When constructed in combination with standard storm sewers as shown in Figure 1.6, this drainage system can also provide some flood control benefits. However, the use of such systems are not applicable where a sufficient deep outlet is not available and furthermore, the system may require special attention where the local groundwater levels are high.
12	**Raised culverts** Raised culverts would normally be used with roadside ditches (feature #7) except that the culverts are installed in such a way that their inverts are slightly higher than the ditch bottom elevation. Depending on the difference in elevation between the culvert invert and ditch bottom, and the width and slope of the ditch, raised culverts can create conditions which provided some the erosion, quality and groundwater recharge control benefits. Figure 1.10 shows a typical roadside ditch with raised culvert. The application of raised culverts should not be considered to increase surface infiltration when the local soils are incompatible with the presence of water or when the groundwater quality is at risk. Similarly, the use of raised culverts should not be considered if the surface infiltration rates are too low (eg. less than 13 mm/hr) as this may create excessive periods of surface ponding. Other considerations for the use of raised culverts are similar to the ones for the Roadside ditches with culverts (Feature # 7).

	Drainage Features and Description
13	**Dipped driveways** As the name implies, the concept with dipped driveways is that rather than having to install culverts, the driveways are dipped to allow their overtopping during major runoff events. By having the driveways slightly higher than the bottom of the ditch/swale will provide some opportunity for storage and water infiltration. The benefits and limitations of using dipped driveways in shallow ditches/swale are similar to the ones of using raised culverts. However, dipped driveways will not provide much in terms of flood control.
14	**Check dams** Check dams would normally be used with roadside ditches (Feature #7) with a similar objective as using raised culverts except that check dams can be constructed anywhere along the ditch to increase local water retention and infiltration. Depending on the height of a check dam, the width and slope of the ditch along which it is constructed, check dams provide some the erosion, quality and groundwater recharge control benefits. Figure 1.3 shows a typical log check dam while Figure 1.11 shows a typical roadside ditch with a check dam. The limitations of using check dams are similar to those of using raised culverts (Feature #12) and dipped driveways (Feature #13).
15	**Oil and Grit separators** Oil and Grit separators (O&Gs) are devices which cannot be used by themselves to create a drainage system. Usually their use is combined with the use of conventional storm sewers such as depicted in Figure 1.7. O&Gs are large manhole structures consisting of separate chambers (usually 3) through which stormwater travels in order to remove coarse sediments (grit), oils and other floatable pollutants. The only real site constraint in using O&Gs is with the depth of the drainage outlet which has to be sufficiently deep to accommodate the device's physical requirements. In terms of SWM benefits, O&Gs can provide some quality control (sediments, phosphorus, oil and grease). In fact O&Gs are one of few SWM features that can effectively remove (retain) oil and grease from stormwater.
16	**Greenbelts and backyard swales** Greenbelts and backyard swales are typically shallow vegetated channels that provide a means to convey and infiltrate storm water runoff. Examples of backyard swales are sometimes found along the back property line residential developments where split drainage is allowed. Sometimes, rear lot catchbasins and /or perforated pipes are also used in combination with such swales to enhance backyard drainage. As shown in Figure 1.8, deep swales within greenbelts can also be used in combination with conventional storm sewers. When properly constructed, greenbelts and backyard swales can provide significant groundwater recharge, erosion and quality control benefits as well as some thermal reduction and on-site flood control. However, in order to prevent nuisance ponding, the use of greenbelts or backyard swales should probably not be considered if surface infiltration rates are less than 13 mm/hr. Furthermore, additional limitations may be imposed if the local groundwater quality is at risk, surface slopes, and erodibility of surface soils.
17	**Horizontal infiltration / exfiltration trenches** Horizontal infiltration / exfiltration trenches are stone filled trenches in which surface runoff can infiltrate and then exfiltrate to the surrounding soils. Filter fabrics are commonly placed around all sides of the trench to prevent clogging of the stone voids. When properly constructed, horizontal infiltration / exfiltration trenches can provide significant groundwater recharge, erosion and water quality control benefits as well as thermal impact reduction. However, the application of such drainage features are not recommended in areas where the soils are incompatible with the presence of water or where the sub-surface infiltration rates are less than 2.5 mm/hr or where the depth of the groundwater table (or bedrock) is within 1.0 m from the expected bottom of the trench. Other aspects to consider include; i) quality of water to be infiltrated, ii) surface slopes, iii) surrounding landuse, iv) space constraints, v) location of trees, and vi) presence of nearby below ground franchise utilities.
18	**Vertical exfiltration wells and perforated catchbasins** Exfiltration wells and perforated catchbasins consist of semi-deep narrow vertical stone filled trenches from which surface runoff can exfiltrate to the surrounding soils. Filter fabrics are commonly placed around all sides of the trench to prevent clogging of the stone voids. When properly constructed and maintained, vertical exfiltration wells and perforated catchbasins can provide significant groundwater recharge, erosion and water quality control benefits as well as thermal impact reduction. As with the horizontal infiltration / exfiltration trenches, the application of such drainage features are not recommended in areas where the soils are incompatible with the presence of water or where the sub-surface infiltration rates are less than 2.5 mm/hr or where the depth of the groundwater table (or bedrock) is within 1.0 m from the expected bottom of the well. Other aspects to consider before making use of vertical exfiltration wells and perforated catchbasins include; i) quality of water to be infiltrated, ii) surface slopes, iii) surrounding landuse, iv) location of trees, and v) presence of nearby below ground franchise utilities.
19	**Infiltration basins** Infiltration basins are a type of end-of-pipe SWM facilities which can usually be considered for drainage areas of at least 5.0 ha. When properly constructed they can provide adequate groundwater recharge, erosion and water quality control benefits, and thermal impact reduction. Site and development characteristics which may prevent the use of wet ponds include; i) incompatibility of soils with water, ii) groundwater quality at risk, iii) low surface infiltration rates (eg. less than 60 mm/hr), iv) depth of groundwater table (or bedrock), v) erodibility of surface soils, vi) expected of inflowing water quality, and lack of available space.

	Drainage Features and Description
20	**Wet ponds (extended detention)** Wet ponds are a type of end-of-pipe SWM facilities which can be considered for drainage areas of at least 5.0 ha. When properly constructed they can provide adequate erosion and water quality control benefits, and possibly some off-site flood control. Site and development characteristics which may prevent the use of wet ponds include; i) inability to maintain a permanent pool of water, ii) depth of outlet, and iii) lack of available space.
21	**Dry ponds** Dry ponds are a type of end-of-pipe SWM facilities which can be considered for drainage areas of at least 5.0 ha. When properly constructed they can provide adequate erosion and water quality control benefits, and possibly some off-site flood control. Site and development characteristics which may prevent the use of wet ponds include; i) depth of outlet, ii) expected quality of inflowing stormwater, and iv) lack of available space.
22	**Artificial wetlands** Artificial wetlands are a type of end-of-pipe SWM facilities which can be considered for drainage areas of at least 5.0 ha. When properly constructed they can provide some erosion and water quality control benefits, and possibly some off-site flood control. Site and development characteristics which may prevent the use of artificial wetlands include; i) inability to maintain a permanent pool of water, ii) reduced effectiveness during winters, iii) expected quality of inflowing stormwater, and iv) lack of available space.

12.1 Selection of Drainage Features Based on Site Characteristics (Table A)

Most physical characteristics of a given site are unlikely to change even after its development. Therefore, such characteristics can be used to quickly identify and eliminate incompatible drainage features. Important site characteristics which should be considered include the following:

Incompatibility of soils with water: Some soils are incompatible or react to the presence of water. For example, soils with a high gypsum content should not be considered for use with concentrated infiltration measures because such soils are susceptible to dissolution and could represent a risk for cave-ins. In other cases, the soil composition may have a tendency to swell when wet and shrink when dry. Such changes in volume may create problems to surrounding structures. The assessment of such characteristics requires the expertise of a qualified soil engineer, geologist or hydrogeologist.

The use of infiltration BMPs is not recommended when an incompatibility of soils with water has been established.

Groundwater quality at risk: This may be a concern when the project is located within or near an area where groundwater is a source of potable water or baseflow to a nearby stream with sensitive aquatic habitat. Safe distances or buffer zones will depend on various factors such as existing groundwater quality, soil types, presence of open-jointed rocks, location of aquifers, and speed of groundwater flow. To quantify the risk associated with the potential contamination of groundwater requires discussions with local authorities and the expertise of a qualified hydrogeologist.

The use of infiltration BMPs is not recommended when a risk associated with groundwater contamination as been established.

Soil types and infiltration rates: The types of soils and their corresponding capacities for infiltration are of prime concern for all types of alternative drainage systems which incorporate an infiltration function. Reasons for this concern are to prevent the potential for nuisance ponding of stormwater and to ensure that any storage volume provided by the drainage feature can be regained before the next rainfall event. In general surface infiltration rates should be in the order of 13 mm/hr as to prevent lengthy accumulation of standing water; and similarly subsurface infiltration rates should be at least 2.5 mm/hr so that storage volumes may be replenished in time for the next possible storm. However, for surface infiltration basins it is often recommended that the soil infiltration rates be at least 60 mm/hr. Standard infiltration or percolation tests can be conducted to identify the soils' infiltration capacities.

Table 12.2 provides typical textbook values of hydraulic conductivities for various USDA Soil-Texture Classes.

Table 12.2: Average Hydraulic Conductivities for Various Soil-textures

USDA Soil-Texture Class	Hydraulic Conductivity, K	
	in/hr	mm/hr
Sand	4.74	120.4
Loamy Sand	1.18	30.0
Sandy Loam	0.43	10.9
Loam	0.13	3.3
Silt Loam	0.26	6.6
Sandy Clay Loam	0.06	1.5
Clay Loam	0.04	1.0
Silty Clay Loam	0.04	1.0
Sandy Clay	0.02	0.5
Silty Clay	0.02	0.5
Clay	0.01	0.3

Source: Design and Construction of Urban Stormwater Management Systems,
ASCE Manuals and Reports of Engineering Practice No. 77, WEF Manual of Practice FD-20

Depth of groundwater table or bedrock: The depth of bedrock or the highest seasonal groundwater level is an important consideration for the following reasons; i) the vertical space which can be available for underground storage may be limited, and ii) a high groundwater table can easily be contaminated by chronic or accidental pollution if filtration through soils is not adequately provided. In general, the seasonally high groundwater level or bedrock should be at least 1 m below any drainage feature which uses infiltration. Standard geotechnical site investigations can provide this information.

Source of continuous flow: For the use of wet detention ponds or wetlands it may be necessary to maintain a given water level for the livelihood of an ecosystem. In this case a source of a continuous flow would have to be available.

Depth of drainage outlet: The depth of the anticipated drainage outlet, whether to an existing man made structure (eg. ditches, storm sewers) or to a natural feature can be a significant physical constraint in selecting potential stormwater conveyance systems. For example, if a shallow municipal drain is the only possible outlet to a proposed rural subdivision, then the use of deep storm sewers with water quality inlets could not be an option. A simple site visit or the review of existing topographic maps or municipal drawings can easily provide this information.

Surface slopes: Ground surface slopes can also represent physical constraints for some types of conveyance systems and infiltration measures. It is important to note however that the average slope of the site is not necessarily the determining factor unless it is relatively flat (ie. less than 1%). Where the average slopes are in the order of 5% and over, it is more important to try to consider the slope of the ultimate drainage infrastructure. Information on surface slopes can be obtained from topographic maps, areal photos and/or site investigations.

Climate: The climate is not always considered a factor in selecting potential alternative drainage system components. However, the climate should be given some special consideration in areas where snow and freezing temperatures are expected. For example, the construction of a single cross slope street may be acceptable in south Florida where the freezing or snowmelt running across the road surface is not a concern.

Highly Erodible soils: Areas where surface vegetation is sparse or which are in proximity of construction or farming activities can represent conditions which may not be compatible with infiltration techniques if adequate erosion and sediment controls cannot be provided. Under such conditions the use of effective pre-treatment measures must be incorporated to prevent the premature clogging of infiltration surfaces.

Size of drainage area: The size of the total drainage area is only a constraint if it is smaller than approximately 5 ha. For such areas the use of large end of pipe facilities is not practical. On the other hand it is noted that, in some cases, large drainage areas could be serviced only in part by some types of drainage features. For example, roadside ditches or swales have limited hydraulic capacities and as such their use could be restricted to upstream reaches. The extent of this constraint will depend on the layout of the development and, as demonstrated in the Section 4, on the physical characteristics of the conveyance system.

12.2 Selection of Drainage Features Based on Development Characteristics (Table B)

Constraints imposed by development features can be rigid if the site is already developed and the assessment is for a retrofit system. On the other hand if the site is being considered for development then the potential constraints can become flexible if the assessment is made in the early planning stages. In either case, development characteristics which may become constraints to the potential use of alternative drainage systems include the following:

Type of landuse: The type of landuse may limit the use of certain alternative drainage measures. For example, in industrial areas where the transportation or storage of dangerous chemicals is likely, the use of any infiltration techniques would not be acceptable unless sufficient pre-treatment components are incorporated in their designs. It should also be noted that commercial areas with gas stations represent a similar risk. In general, residential types of developments are the most compatible with any type of alternative drainage systems.

ROW planning: The main ROW planning issues which may interfere with the use of certain types of alternative drainage features include: i) available space (which can be defined as the ROW width less the road surface width and less the total width of sidewalks), ii) presence and location of sidewalks, iii) planting of trees within the road boulevard, and iv) the presence and location of underground utilities. Issues related to ROW planning were discussed in Section 9.

Lot planning: Features at the lot level which may further reduce the potential use of alternative drainage features include: i) lot widths or more precisely the spacing between entrances, ii) imperviousness, iii) type of lot drainage (ie. back to front or split), iv) presence of reverse slope driveways. Issues related to ROW planning were discussed in Section 9.

12.3 Selection of Drainage Features Based on Ability to Meet SWM Objectives (Table D)

SWM requirements can vary from site to site based on local and downstream conditions. In general SWM objectives can be determined by general guidelines, local authorities or based on the results of an overall watershed/subwatershed plan. The most important SWM objectives which may have to be considered include the following:

Groundwater recharge: Groundwater recharge may be important for the maintenance of baseflows in streams and rivers as well as to replenish the source of drinking water for those who depend on wells. As a general rule and in order to meet this requirement, the runoff of a 5 to 10 mm storm (see Section 5.3) should be retained and infiltrated, unless local studies specify an alternative recharge target. Special attention must be taken when both groundwater recharge and the risk of contamination are important.

Erosion control: Erosion control may or may not be a requirement and depends on the conditions of the receiving water body. However, if erosion control is an issue it can be provided, in general, by controlling the runoff of a 25 mm storm (See section 5.2). (NOTE: a higher level of control may be required depending on site specific studies). The control can be provided through the combination of retention and infiltration.

Quality control: Quality control requirements can differ from location to location and will vary based on the type of receiving water body (eg. lake or river), its size, its potential use, and the type of fish habitat which may or could exist. In general stormwater quality control objectives may be achieved by the removal of; i) suspended sediments, ii) nutrients such as phosphorous, iii) bacteria and iv) oil and grease. Refer to Section 5.1 for additional information and guidelines.

Thermal impact reduction: Thermal impacts can be an important consideration for receiving water bodies with cold water stream ecosystems. In such cases, the effects from stormwater are predominant when surface runoff is conveyed or retained at ground level and exposed to warm air and sunlight for some time. Refer to Section 5.1.1.7 for additional information and guidelines.

Flood control and level of service: Flood control could be a requirement within the site and/or off site. That is, the operation of the drainage system should not inundate surrounding properties and should not convey stormwater in such a way as to increase the potential of downstream flooding. In new developments such controls can usually be achieved while in retrofit situations it may be difficult. The level of service can be defined as the capacity of the system in relation to a design event (ie. 1 in 5 yrs). Another element to consider is whether or not a major system outlet is present or if can be incorporated within the development. Although this latter element can greatly depend on the final grading and configuration of the site, it should nonetheless be considered in the derivation of alternatives. Refer to Section 5 for additional information and limitations of alternative stormwater conveyance systems.

12.4 The Selection Tool

As described at the beginning of this section, the main purpose of the Selection Tool is to: i) help determine which types of alternative drainage features could be used within a specific site, and ii) help compare potential conceptual drainage systems. This can be achieved through the use of the detailed tables described in this section.

Tables A and B present the elements described in Sections 12.1 and 12.2 respectively. That is, Table A can be used to eliminate specific drainage features which are incompatible with the local site characteristics while Table B can be used to eliminate options which are incompatible with existing or potential development characteristics. Table C can be used to summarize the results obtained from the use of Tables A and B, and to identify which drainage features could be incorporated in a conceptual system.

Table CD was recently added to the Tool and derived from the work done by D.G. Weatherbe and Associates and Totten Sims Hubicki. The table can be used to summarise the stormwater management objectives and target performance for the drainage system being considered. The table can also be used to assign variable priorities to the various SWM objectives which are to be met.

Table D is used as a reference and compares the potential SWM functions (benefits) of the various alternative drainage features.

Finally, Table E can be used to describe and evaluate possible conceptual drainage systems. The evaluation can be based on potential SWM performance, specific design objectives (eg. foundation drain connections), and costs. It is noted that conceptual drainage systems must be established from the designer's experience and knowhow.

The following sections describe how to use the various tables. An example application follows in Section 12.5.

12.4.1 How to use Table A - site characteristics

Based on a preliminary assessment of site conditions, the designer checks (✓) all of the applicable site conditions which are listed in the table. Any (✗) which appears below a checked site characteristic eliminates the potential use of the alternative drainage feature on that line. For any (O) which appears below a checked characteristic the designer must refer to the numbered comment for Table A to determine if there is a valid concern.

The alternatives which are not eliminated receive a score of '1' in the appropriate column of Table C while alternatives for which an unresolved (O) remains is given a score of '0.5'.

12.4.2 How to use Table B - development characteristics

Based on the known or anticipated development characteristics of the site, the designer checks (✓) all of the applicable characteristics which are listed in the table. Any (✗) which appears below a checked characteristic eliminates the potential use of the alternative drainage feature on that line. For any (O) which appears below a checked characteristic the designer must refer to the corresponding numbered comment for Table B and determine if there is a valid concern.

The alternatives which are not eliminated receive a score of '1' in the appropriate column of Table C while alternatives for which an unresolved (O) remains is given a score of '0.5'.

12.4.3 How to use Table C - identification of compatible features

Table C is used to summarize the results obtained from Tables A and B, and to identify which drainage features could be used within a given study area. The score of any alternative drainage feature is obtained by multiplying the results from Tables A and B.

Since the results from Tables A and B can only be '0', '0.5' or '1' it then follows that any feature which was found to be incompatible (ie. value of '0') with either the site or development characteristics will be eliminated and as such could not be used within the study area. Features which end up with a final score of '1' are fully compatible with both site characteristics and development characteristics.

Features with a final score of '0.5' or '0.25' are potentially incompatible with either or both site characteristics and development characteristics. A review of the notes for Tables A and B should help determine if such features should be considered or not.

12.4.4 How to use Table D - comparison of SWM functions

Table D was prepared for reference purposes only and provides an indication of how well a particular drainage feature can respond to a particular SWM objective. SWM objectives were divided into 5 groups; i) groundwater recharge, ii) erosion control, iii) quality control, iv) flood control, and v) thermal reduction. The water quality control objective was further divided into 4 subgroups; i) sediment removal, ii) nutrient removal, iii) bacterial die-off, and iv) oil and grease removal.

The numbers provided in Table D are referred to as "Stormwater Management Function Potential (SWM-FP) values". SWM-FP values can vary from '0' to '1'. A value of '0' indicates that the corresponding drainage feature provides no valuable benefit (0%) towards the respective SWM target objective. By comparison, a SWM-FP value of '1' (100%) would indicate that the corresponding drainage feature could, if designed and constructed properly, achieve 100% of the targeted SWM objective.

Examples for SWM-FP values could be: i) a simple curb & gutter (no pipes) does not, as a drainage feature, provide any benefits for groundwater recharge and is therefore given a corresponding SWM-FP value of '0', ii) roadside ditches and swales (if properly constructed and well vegetated) could remove up to 80% of sediments and therefore are given a corresponding SWM-FP values of '0.8' , and iii) an oil and grit separator (if properly sized and maintained) can remove, on average, approximately 60% of sediments and therefore was given SWM-FP values of 0.60.

The SWM-FP values provided in Table D are further used in the comparison of conceptual drainage systems (see Section 12.4.5). Note, however, that SWM-FP values are intended to assist in relatively comparing alternative drainage systems and, until further monitored data is available, should not be expected to estimate actual performance.

It is further noted that SWM-FP values can be modified or updated as new information on the SWM function effectiveness of the various drainage features becomes available. Furthermore, the values currently presented in Table D are based on the assumption that each drainage feature is optimally designed to service the entire area. Consequently, in the final comparison (Section 12.4.5), SWM-FP values should be reduced for drainage features which will only be used for certain parts of the site.

12.4.5 How to use Table E - comparison of conceptual drainage systems

Based on the results obtained in Table C (identification of site and development compatible drainage features) it may be possible, based on design experience, to conceive various alternative drainage systems which may include some or all of the potential drainage features. To further compare each alternative it is necessary to evaluate the cost of each system and how well it can meet the objectives of the project. As can be anticipated, some drainage features may only address some specific objectives and therefore the evaluation must consider the system as a whole and not simply its individual components.

Once a conceptual drainage system is defined it can be further evaluated with the use of Table E. (Examples of alternative drainage systems and drainage features are discussed in Sections 1 and 11). This is done by first listing the system's individual components in the first column of Table E and entering the system's objectives in the columns under the heading of "Drainage System Objectives and Compliance". System objectives may include SWM objectives as well as other specific requirements which may have been requested by the public (eg. elimination of sump pumps and direct connection to storm sewers). For each drainage feature and based on Table D, SWM-FP values are then selected and entered in the corresponding columns of Table E (the Excel Spreadsheet does this automatically). SWM-FP values for features which will only be used in parts of the system could be adjusted based on drainage area accordingly. The total cost for each feature can also be calculated and entered in the last column.

To identify whether or not the proposed drainage system could meet the SWM objectives the Selection Tool Excel Spreadsheet offers two methods to evaluate the overall SWM-FP of the system.

With the first method, a simple sum of SWM-FP values could be used to provide a comparative evaluation of the system's potential performance.

The second method is somewhat more sophisticated as it accounts for the fact that the effective performance of SWM features which work in series can not be evaluated by the simple sum of individual performances but rather by their product summation. This can be applied with the multi-efficiency model presented in a paper by J.Li et al in which the cumulative performance of groundwater recharge, TSS, TP and Bacteria removal functions of a series of SWM features can be evaluated with the use of equation (12.1).

$$\text{Overall SWM-FP} = \left[1 - \prod_{i}^{n} (1-\eta)\right] \times 100\% \qquad \textbf{(12.1)}$$

Where i = is the i^{th} feature being considered
n = is the total number of features with the system
Π = is the product summation of $(1-\eta)$
η = the runoff volume reduction or the sediment reduction efficiency of a specific feature

With either method, the resulting score of the overall SWM-FP for each system objectives will indicate if the system could meet the individual requirements. In general, a score of '1' or more would indicate that the system could meet the objective. Anything less than '1' would indicate a potential deficiency and the need to re-evaluate the system.

If more than one alternative drainage system is being considered, then the overall effectiveness of each system and their costs can be used in the final selection.

Table A: Selection of alternative drainage features based on site characteristics

FEATURE	TABLE A	TABLE B	Drainage Features	Site Characteristics															
				Soils are incompatible with the presence of water	Ground water quality is at risk	Soil Infiltration Rates			Depth of groundwater or bedrock (m)		No source of continuous flow	Depth of drainage outlet (m)			Surface Slopes (%)		Climate is vulnerable to cold and snowy winters	Surface soils are highly susceptible to erosion	Drainage area is less than 5.0 ha or space is limited
						Surface inf < 13 mm/hr	Surface inf < 60 mm/hr	Sub-surf inf < 2.5 mm/hr	< 1.5	1.5 - 4.0		< 1.0	1.0 - 2.0	> 2.0	< 1.0	> 5.0			
				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1	1	1	Street curbs																
2	1	1	Roads with one-sided cross slopes														O_8		
3	1	1	Porous pavement with storage structure														O_8	X	
4	1	1	Porous pavement with exfiltration system	X	X			X	X							O_6	O_{14}	X	
5	1	1	Storm sewers with foundation drain connections									X	X						
6	1	1	Shallow storm sewers with sump pumps									X	O_{17}						
7	1	1	Roadside ditches with culverts									O_4	O_3		O_5	O_6	O_7	O_{10}	
8	1	1	Shallow ditches or swales (no culverts)			O_{18}										O_6		O_{10}	
9	1	1	Shallow perforated pipe exfiltration system	X	X			X	X	O_1		O_{15}	O_{15}			O_6		O_{10}	
10	1	1	Deep perforated pipe exfiltration system	X	O_{16}			X	X	O_1		O_{15}	O_{15}			O_6		O_{10}	
11	1	1	Deep perforated pipe filtration system						X	O_1		X	X						
12	1	1	Raised culverts	O_{11}	X	X						X	O_4			O_6	O_8	O_{10}	
13	1	1	Dipped driveways	O_{11}	X	X										O_6	O_8		
14	1	1	Check dams	O_{11}	X	X										O_6	O_8	O_{10}	
15	1	1	Oil and Grit separators									X	X						
16	1	1	Greenbelts and backyard swales		O_{12}										O_5	O_6		O_{10}	
17	1	1	Horizontal infiltration / exfiltration trenches	X	O_{16}			X	X	O_1						O_6		O_{10}	
18	1	1	Vertical exfiltration wells and perforated catchbasins	X	O_{16}			X	X	X								O_{10}	
19	1	1	Infiltration basins	X	O_{16}	X	X		X	X		X	O_{20}				O_9	O_{10}	X
20	1	1	Wet ponds								O_2	X	O_{20}					O_{10}	X
21	1	1	Dry Ponds		O_{13}							O_{19}	O_{20}					O_{10}	X
22	1	1	Artificial wetlands								O_2						O_9		X
23	1	1	User Defined Feature (ex: Lot level ctls)																
24	1	1	User Defined Feature (ex: Major System)																
25	1	1	User Defined Feature																

Blank - Compatible alternative, gives a score of '1' in Table C

X - Not compatible, gives a score of '0' in Table C

O - May or may not be compatible, gives a score of '0.5' in Table C (see notes for Table A)

Table A Notes

To be used to further evaluate the compatibility of drainage features with site characteristics.

Note #	Check Caution	Override Caution	Notes for Table A
1		☐	Not recommended when the distance between the bottom of the infiltration structure and the groundwater table (or bedrock) is less than 1.0 m.
2		☐	Not recommended if a minimum permanent pool cannot be maintained.
3		☐	Not recommended for situations where water table is less than depth of ditch or where the infiltration rate of surface soils is less than 13 mm/hr.
4		☐	Not recommended if in order to maintain the proper culvert cover, the level of entrances or driveways have to be raised in such a way as to negatively affect the comfort of driving.
5		☐	Should only be considered if surface infiltration rates are greater than 13 mm/hr in order to prevent nuisance surface ponding.
6		☐	The average surface slope should not be the determining factor but rather the slope of the expected structure. For example, even if the average surface slope is above 5%, roads and ditches may be constructed at a less accentuated cross slope. In the case of ditches and swales, such high slopes may easily create conditions for erosion due to high flow velocities. In the case of raised culverts or check dams these would have to be high and frequent to have any positive influence. In the case of infiltration trenches the use of vertical flow barriers may be required to maximize the use of storage.
7		☐	Not recommended if ditch is too shallow (< 0.60 m) and poorly drained (slope < 1% or surface infiltration < 13 mm/hr) or if culverts are too small (< 450 mm). The first condition is prone to culvert heaving and the second to ice or snow clogging.
8		☐	Not recommended if located in areas where ground surface can freeze for extended periods.
9		☐	Not recommended if pollutant removal effectiveness is also required during the winter season.
10		☐	The presence of highly erodible soils or high contents of suspended solids in surface runoff require that pretreatment measures be used to ensure the longevity of any infiltration technique and/or to minimize maintenance requirements.
11		☐	Not recommended if designed amounts of infiltrated runoff exceeds natural conditions.
12		☐	Not recommended if contaminated runoff is expected. Only use in backyards.
13		☐	Not recommended unless bottom of facility is impermeable.
14		☐	Not recommended unless roadbase is free draining and not affected by frost.
15		☐	Not recommended if system is to be connected to an outlet which is shallower than the perforated pipe system.
16		☐	Not recommended unless sufficient pre-treatment can be provided (eg. with oil and grit separators).
17		☐	Not recommended unless sufficient depth cover can be provided for frost protection.
18		☐	Not recommended unless used jointly with another feature that allows proper drainage.
19		☐	Not recommended unless used for major system storage only.
20		☐	May not be feasible is used jointly with conventional storm sewers with foundation drain connections.

Table B: Selection of alternative drainage features based on development characteristics

FEATURE	TABLE A	TABLE B	Drainage Features	Development characteristics											
				Type of landuse			ROW planning					Lot Planning			
				Residential	Commercial	Industrial	[ROW width] - [Road surface Width] - [Sidewalk Width] (m)		Sidewalks next to road	Trees within ROW	Below ground franchise utilities	Spacing between entrances < 5.0 m	Imperviousness > 75%	Back to front drainage	Reverse slope driveways
							< 2.5	2.5 - 5.0							
				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1	1	1	Street curbs												
2	1	1	Roads with one-sided cross slopes		X	X									
3	1	1	Porous pavement with storage structure			X									
4	1	1	Porous pavement with exfiltration system		O_{1}	X					O_{8}				
5	1	1	Storm sewers with foundation drain connections												
6	1	1	Shallow storm sewers with sump pumps												X
7	1	1	Roadside ditches with culverts		O_{2}		X	O_{5}	O_{11}			X	O_{9}		X
8	1	1	Shallow ditches or swales (no culverts)				O_{5}		O_{11}						
9	1	1	Shallow perforated pipe exfiltration system			O_{3}	O_{5}		O_{11}	O_{7}	O_{8}		O_{9}		
10	1	1	Deep perforated pipe exfiltration system			O_{3}									
11	1	1	Deep perforated pipe filtration system												
12	1	1	Raised culverts			O_{3}	X		O_{11}			X	O_{9}		X
13	1	1	Dipped driveways			X			O_{11}						X
14	1	1	Check dams			O_{3}	X		O_{11}			X	O_{9}		X
15	1	1	Oil and Grit separators												
16	1	1	Greenbelts and backyard swales			O_{3}			O_{6}				O_{9}	O_{10}	
17	1	1	Horizontal infiltration / exfiltration trenches			O_{3}	O_{4}		O_{6}	O_{7}	O_{8}		O_{9}		
18	1	1	Vertical exfiltration wells and perforated catchbasins			O_{3}				O_{7}	O_{8}				
19	1	1	Infiltration basins			O_{3}									
20	1	1	Wet ponds			O_{12}									
21	1	1	Dry Ponds												
22	1	1	Artificial wetlands			O_{12}									
23	1	1	User Defined Feature (ex: Lot level ctls)												
24	1	1	User Defined Feature (ex: Major System)												
25	1	1	User Defined Feature												

Blank - Compatible alternative, gives a score of '1' in Table C

X - Not compatible, gives a score of '0' in Table C

O - May or may not be compatible, gives a score of '0.5' in Table C (see notes for Table B)

Table B Notes

To be used to further evaluate the compatibility of drainage features with development characteristics.

Note #	Check Caution	Override Caution	Notes for Table B
1		☐	Not recommended if area includes gas stations or other types of activities where toxic chemicals are transported or stored.
2		☐	May not be aesthetically pleasing in highly developed areas.
3		☐	Any infiltration techniques used within an industrial area should be done with extreme care. Gas stations and storage areas for toxic chemicals should not be considered if such techniques are anticipated. Not recommended for use in roadside ditches or swales with extremely permeable soils.
4		☐	Not recommended if sufficient available space is not available to also include buffer strips or adequate pretreatment.
5		☐	Can only be installed on one side of the street.
6		☐	Difficult to incorporate within ROW. Could only be used as lot level control.
7		☐	Not recommended unless special techniques such as the use of copper mesh installed around the infiltration structure in order to prevent damage from tree roots. The appropriate selection of trees or adequate distances between planting and infiltration structures may also reduce this potential problem.
8		☐	Not recommended if the presence of underground utilities interferes with the use of underground infiltration structures. Proper planning and discussions with the local utilities may address this problem. However, in the case of a retrofit situation, the use of infiltration techniques within the ROW may be more difficult.
9		☐	Not recommended if the the availability of contiguous open space is very limited.
10		☐	Backyard swales cannot be used.
11		☐	Cannot be used if two sidewalks are constructed. If only one sidewalk is constructed then could be used on side without sidewalk.
12		☐	Not recommended unless it is demonstrated that bioaccumulation of pollutants will not create adverse environmental effects.

Table C: Identification of compatible drainage features
(use to compile results from Tables A and B, optional)

Feature	Drainage system features	Compatibility checks (refer to Tables A and B)		
		(A) Site characteristics	(B) Development characteristics	Overall Score (A) x (B)
1	Street curbs	1	1	1
2	Roads with one-sided cross slopes	1	1	1
3	Porous pavement with storage structure	1	1	1
4	Porous pavement with exfiltration system	1	1	1
5	Storm sewers with foundation drain connections	1	1	1
6	Shallow storm sewers with sump pumps	1	1	1
7	Roadside ditches with culverts	1	1	1
8	Shallow ditches or swales (no culverts)	1	1	1
9	Shallow perforated pipe exfiltration system	1	1	1
10	Deep perforated pipe exfiltration system	1	1	1
11	Deep perforated pipe filtration system	1	1	1
12	Raised culverts	1	1	1
13	Dipped driveways	1	1	1
14	Check dams	1	1	1
15	Oil and Grit separators	1	1	1
16	Greenbelts and backyard swales	1	1	1
17	Horizontal infiltration trenches	1	1	1
18	Vertical exfiltration wells and perforated catchbasins	1	1	1
19	Infiltration basins	1	1	1
20	Wet ponds	1	1	1
21	Dry Ponds	1	1	1
22	Artificial wetlands	1	1	1
23	**User Defined Feature (ex: Lot level ctls)**	1	1	1
24	**User Defined Feature (ex: Major System)**	1	1	1
25	**User Defined Feature**	1	1	1

Notes on Overall Score values

Score	Suggestion
1	This drainage feature is potentially compatible with both site and development characteristics
0.5	This drainage feature may be compatible, however a cautionary note was generated for Table A or Table B -- See Table A Notes and Table B Notes
0.25	This drainage feature may be compatible, however a cautionary note exists for both Table A and Table B -- See Table A Notes and Table B Notes
0	This drainage feature is potentially not compatible with both site and development characteristics

Table CD: Stormwater Management Objectives

Function	Objective Narrative Target	Target (10) Performance	Importance to Project (11)	
			Text	Weight
Groundwater recharge (1) (Infiltration of runoff from a 10 mm storm)	**Infiltrate or reduce flows**	**100%**	High	3
Erosion control (Control or infiltration of runoff from a 25 mm strom)	**Rate of runoff control for downstream erosion control**	**100%**	High	3
Suspended solids (2)	**Reduce load**	**100%**	High	3
Phosphorus removal	**Reduce load**	**100%**	High	3
Bacteria uptake (3)	**Reduce load**	**100%**	High	3
Oil and grease (4)	**Control**	**100%**	High	3
Thermal reduction (5)	**Control**	**100%**	High	3
Flood control (on-site) (6)	**Minor system performance to design storm**	**100%**	High	3
Flood control (off-site) (7)	**Rate of runoff control for downstream flood control**	**100%**	N/A	0
Major system (8)	**Major system to be considered in design**	**100%**	High	3
Source Controls (9)	**Source controls to be considered in design**	**100%**	N/A	0

Notes:

1) Infiltrate or reduce annual flow volumes.
2) Use 50 to 80% depending on use in the receiving water.
3) Reduce numbers in discharge.
4) Percent flow through measure.
5) Percent flow through measure.
6) Always assumed as basis for design of all elements.
7) Control of 25 mm storm assumed to control both erosion flooding. Target is percent control for system.
8) Only if needed to be added at additional cost - set weight as 1.
9) Only if performance and cost know - set weight as 1.
10) Numbers shown are for illustration purposes. The user must set targets for each analysis based on subwatershed uses.
11) Importance and and weights (see Config sheet to modify).

Table D: Comparison of SWM Function Potentials

FEATUR	TABLEC	SCEN.1	SCEN.2	SCEN.3	Drainage Features	SWM Function Potentials										
						Ground water recharge (5 (Infiltration of runoff from a to 10 mm storm)	Erosion control (Control or infiltration of runoff from a 25 mm storm)	Quality control				Thermal reduction	Flood control		Major System (3	Social Values (3
								Suspended Solids (1	Phosphorus Removal (1	Bacteria die-off	Oil and grease (2		On-site	Off-site		
1	1	☐	☐	☐	Street curbs	0	0	0	0	0	0	0	1	0		
2	1	☐	☐	☐	Roads with one-sided cross slopes	0	0	0	0	0	0	0	0	0		
3	1	☐	☐	☐	Porous pavement with storage structure	0	0.5	0.8	0.53	0	0	0	0	0		
4	1	☐	☐	☐	Porous pavement with exfiltration system	0.95	1	0.9	0.86	0.76	0	1	0	0		
5	1	☐	☐	☐	Storm sewers with foundation drain connections	0	0	0	0	0	0	1	1	1 (*		
6	1	☐	☐	☐	Shallow storm sewers with sump pumps	0.1 (-	0	0.08	0.08	0.08	0	1	1	1 (*		
7	1	☐	☐	☐	Roadside ditches with culverts	0.4	0.25	0.86	0.68	0.32	0	0.25	1	1 (:		
8	1	☐	☐	☐	Shallow ditches or swales (no culverts)	0.8	0.5	0.93	0.83	0.64	0	0	0	0		
9	1	☐	☐	☐	Shallow perforated pipe exfiltration system	0.95	1	0.95	0.89	0.76	0	1	1	1 (*		
10	1	☐	☐	☐	Deep perforated pipe exfiltration system	0.95	1	0.81	0.79	0.76	0	1	1	1 (*		
11	1	☐	☐	☐	Deep perforated pipe filtration system	0.1	0.5	0.45	0.33	0.08	0	1	1	1 (*		
12	1	☐	☐	☐	Raised culverts	0.1	0.05	0.36	0.26	0.08	0	0	1	1 (:		
13	1	☐	☐	☐	Dipped driveways	0.1	0.05	0.22	0.17	0.08	0	0	0	0		
14	1	☐	☐	☐	Check dams	0.15	0.1	0.38	0.3	0.12	0	0	0	0		
15	1	☐	☐	☐	Oil and Grit seperators	0	0	0.6	0.4	0	1	0	0	0		
16	1	☐	☐	☐	Greenbelts and backyard swales	0.8	0.5	0.86	0.78	0.64	0	0.5	0.5	0		
17	1	☐	☐	☐	Horizontal infiltration trenches	0.8	1	0.86	0.78	0.64	0	1	0	0		
18	1	☐	☐	☐	Vertical exfiltration wells and perforated catchbasins	0.8	1	0.86	0.78	0.64	0	1	0	0		
19	1	☐	☐	☐	Infiltration basins	0.8	0.5	0.82	0.76	0.64	0	0.5	0	0		
20	1	☐	☐	☐	Wet ponds	0	1	0.75	0.5	0.75	1 (+	0	0	1		
21	1	☐	☐	☐	Dry Ponds	0	1	0.5	0.33	0.7	0	0	0	1		
22	1	☐	☐	☐	Artificial wetlands	0	0.75	0.4	0.4	0.5	0	0	0	1		
23	1	☐	☐	☐	User Defined Feature (ex: Lot level ctls)											
24	1	☐	☐	☐	User Defined Feature (ex: Major System)											
25	1	☐	☐	☐	User Defined Feature											

Notes: +) If equipped with appropriate booms.

-) Only if pumps discharge to backyards or onto a grass area.

*) Only if system has inlet control devices and storage on street is permitted.

:) Only if ditches / swales are deep enough to provide adequate storage.

1) Values shown are combined efficiency of removal from infiltration and other processes such as sedimentation.

2) While most devices will remove some oil and grease, only those with specific design features for this have been given values.

3) Values for "Major System" and "Social" benefits must be entered by user.

4) Values for "User Defined Features" must be entered by user if applied.

5) Groundwater recharge values shown in relation to infiltration of 10 mm storms or less, which represents approximately 80% of annual volume.
Total performance for measures with infiltration has been adjusted to reflect annual performance due to infiltration.

Table E: Comparison of conceptual drainage systems - Scenario 1
(working table)

Total drainage area (ha):	10	Cost of this system	$0.00 (from "Cost Comparisons" table)
Total Percentage of Impervious Area:	40.0%		

Description of potential alternative drainage system: ____________________

Selected Drainage Features		Area (1 serviced by feature (ha)	Drainage System Objectives and Compliance (refer to Table D)									
☐ Use multi-efficiency model **System Efficiency**		→										
Target Performance (from Table CD)		→										
'System Compliance		→										
Objectives Priority Weighting (from Table CD)		→										
Weighted Compliance as per SWM Priorities		→										

Total Feature Benefit Index	0.00	The sum of each Drainage Feature Benefit Index
Average System Compliance	0.00	The average of each objective's System Compliance
Overall Score	0.00	The sum of Weighted Compliance as per SWM Priorities

NOTES: 1) Areas associated to any feature must be less than or equal to the Total Drainage area.
2) The System Compliance must be recalculated when the areas associated to Drainage Feature are modified.
To do this, "click" twice on the "Use multi-efficiency model" CheckBox next.

13.0 Conclusions and Recommendations

This study undertook a comprehensive evaluation of road drainage systems by carefully analyzing the various components and features of the road right-of-way according to engineering, environmental, economic and social considerations. The study found that a range of alternative drainage systems can be used to meet environmental objectives, and these systems can be compatible with traditionally desired road features (eg. swales/perforated pipes and curbed edge roads). However, site specific assessments are necessary and can be assisted by the guidelines and tools developed as part of this study. It is also important to recognize and account for the cumulative effects of other stormwater management system components, such as lot level and end-of-pipe measures.

Literature review

- Over 200 relevant references were collected and reviewed.
- Over 60% of the collected references have been published within the last five years.
- Alternative drainage techniques are being used around the world. Some countries have been doing so for the last twenty years.
- Literature shows a trend toward the emergence of new approaches to SWM and initial testing to determine advantages/disadvantages.
- Data on reported construction and maintenance cost are somewhat limited.
- Literature is weak in areas of maintenance requirements, pollutant removal efficiencies, and public preferences.

Questionnaires/surveys

- Two separate questionnaires and surveys were prepared; one for municipal engineers and planners and a second for real estate agents and developers. The latter survey was prepared to gauge public opinions and expectations. A total of 197 surveys were distributed and 52 were returned.
- The questionnaire survey with municipal engineers and planners identified a strong willingness to try alternative drainage systems. However, reasons for not wanting to try new types of drainage systems were highly focused on the <u>perception</u> that such systems are in general more expensive construct and maintain. Our review of the cost information obtained from various municipalities has demonstrated that the conventional curb & gutter system with storm sewers can often be more expensive to maintain than a conventional roadside ditch system.
- Public preferences for road right-of way features will vary from neighborhood to neighborhood and may be influenced by what the public expects to see there (based on what has been commonly seen). Therefore, local public preferences should be assessed for each case (especially in retrofit situations). Use of computer enhanced photographs showing options is effective. Opportunities to increase public awareness and participation in SWM should be pursued.
- It is recommended that more detailed public surveys be conducted to truly identify their perceptions and attitudes towards SWM and alternative drainage systems.

Conveyance and storage functions of surface drainage systems

- A systematic procedure was developed to evaluate the conveyance capacities of various surface drainage systems.
- It was found that given the limited available space within standard ROW widths of 20 m and 27 m, the conventional V-Shaped ditch with 2:1 side slopes was the most hydraulicly efficient when compared to ditches and swales with shallower side slopes.
- A comparison of conveyance capacities between roadside drainage alternatives (ie. ditches / swales without the interference of culverts) with the maximum allowable flows on roads with curbs demonstrated that roadside systems can contain and convey as much as twice the flow of roads with curbs.
- In areas where the longitudinal slopes are 1% and above, a vegetation height of 10 cm to 30 cm in roadside ditches can reduce flow velocities below critical values for erosion and allow an increase in flow depth. For example, the maximum allowable flow in a typical V-Shaped ditch with 2:1 side slopes constructed within a ROW of 20 m (no sidewalks) with a longitudinal slope of 2.5% is limited to 0.43 m^3/s to guard against erosion if the grass cover is maintained to a height of 50 mm. For the same ditch and longitudinal slope, the maximum flow can be increased by more than four times (to 1.78 m^3/s, limited by the depth of the ditch) if the height of the vegetation is maintained at 30 cm.
- Culvert sizes and their spacing can significantly reduce the maximum flows which can be conveyed in ditches and swales.
- However, it was also found that the combined effect of culverts and lower flow velocities in shallower and wider ditches/swales increased the time of concentration and reduced the design peak flows by as much as 2% to 38% as compared to the flows from a conventional curb/gutter system with storm sewers. Hence, the conclusion of the analysis ultimately demonstrated that for a given peak flow, more area can be serviced by shallower and wider ditches/swales than by a curb/gutter system.
- The use of check dams and raised culverts can reduce the volume requirements in end of pipe facilities and can locally increase groundwater recharge. However, their use along roadside ditches/swales can only be significant where the longitudinal slopes are low (eg. < 1.0%) and/or where the maximum depths of retained water are important (eg. >200 mm). On the other hand, any retained water should be infiltrated within a reasonable time (eg. < 6 hours) and based on average surface infiltration rates of grass covered soils this would limit the depth to approximately 50 mm.
- It is recommended that further work be done to evaluate how the findings of the study can be integrated in our usual hydrologic and hydraulic computational procedures. For example, how does one quantify the reduction for the requirements of an end of pipe facility if an alternative drainage system such as grass swales with perforated pipes and oil and grit separators is proposed.

Stormwater quality, erosion control and groundwater recharge of alternative drainage systems

- As continuous modelling is becoming the preferred approach in evaluating the overall effectiveness of BMPs, there is a need to further develop the required analytical tools to assess a variety of BMPs (not just end of pipe facilities).
- Many authors have adopted to present measured pollutant removal efficiencies in percentages rather than in absolute concentrations. This approach can be misleading when the inflow concentrations are lower than the usual average concentrations. As this will be more the case when numerous lot and conveyance controls are implemented, it is suggested that a more useful presentation of data is to compare outflow concentrations with target concentrations in terms of ratios.
- Erosion controls should not only be related to the receiving body of water but also upland areas and the conveyance system especially if this one is comprised of ditches and swales.
- More work is required to better document how urban stormwater pollutants migrate into the ground and groundwater when infiltration BMPs are used.

Cost comparison of alternative drainage systems

- A procedure to conduct a detailed cost analysis was developed order to effectively compare various alternative drainage systems.
- An economic comparison of alternative drainage systems found that the capital and maintenance costs ranged from $31,447/yr/1000 m or roadway for a grass swale/perforated pipe system to $45,028/yr/1000 m for a conventional curb/gutter system with oil and grit separators and an end of pipe facility. While these costs are significant, regardless of the system, further economic evaluation of the less tangible cost/benefits that proper stormwater management can provide toward the environment and recreational values is warranted.
- Additional economic evaluations are required to further substantiate the costs identified in this report. This could be accomplished through site specific case examples.

Safety considerations

- Except for one article which summarized the statistics of U.S. highway accidents in which drainage structures were involved, little other information was found quantifying safety issues which may related to alternative drainage systems.
- However, our limited survey indicated that the public and municipal representatives feel that urban roadways with curbs provide a higher level of safety than roadways with ditches. In rural areas, roadways with ditches were found to be more acceptable than roadways with curbs.
- Grass swales were found acceptable in both urban and rural areas.

Considerations for Right-Of-Way, road and lot planning

- There is a need to develop new additional ROW standards which show how to incorporate various types of drainage alternative features. The absence of such standards is often the reason for not allowing new types of systems to be used.
- Further discussions are required with the various types of public and private utilities in order to promote coordination and the understanding of potential concerns with the use of alternative drainage components.
- Design standards for the use of alternative drainage systems should be included in the Ontario Provincial Standards for Roads and Municipal Services.
- Where narrow lots are proposed and where the potential culvert spacing is a major constraint, the use double driveways at the property line could double the culvert spacing.
- The use of rear lanes in high density residential areas could increase the opportunities to use alternative road drainage concepts

Selection tool

- A simple but yet effective approach was developed to help in the process of selecting the most appropriate type of alternative drainage system. In its initial assessment, the approach uses site and development characteristics to eliminate incompatible features. In its final stage, the method allows the designer to consider the SWM objectives, the costs and public expectations in order to make a final decision.
- Monitoring results for the various types of drainage alternatives should continue to be collected in order to update the SWM Potential Function Table used by the Selection Tool.
- The selection tool which was developed in this study needs to be tested in real case scenarios. Such exercises may identify the need to refine the method.

Use of roadside ditches

- In general, all systems, if properly designed and constructed can meet ***quantity*** SWM requirements. As discussed in the section 4, if roadside ditches and swales are used to service limited drainage areas they can provide the same level of service as a conventional curb and gutter system.
- Ditches / swales should be considered where technically feasible and where they provide some environmental benefits.
- Where possible ditches should be constructed with shallower cross slopes.
- Some of the municipalities which were surveyed during the course of this study have indicated that in their jurisdiction, the maintenance of roadside ditches and culverts is the responsibility of the homeowner.
- The maintenance of roadside ditches can be facilitated if the side slopes are not steeper than 3:1.
- In general, all systems, if properly designed and constructed can meet ***quantity*** SWM requirements. As discussed in the section 4, if roadside ditches and swales

are used to service limited drainage areas they can provide the same level of service as a conventional curb and gutter system.

Public Education and Feedback

- As the use of stormwater management BMP's moves closer to the source so they are to the public. Many European communities are promoting what they call "gutter education" as part of a non structural BMP. Such efforts can also be used to reinforce the need to pick up after our pets
- Public education should be emphasized to promote the purpose, use and potential benefits of using alternative drainage system components including the use of lot level controls.
- Developers who promote the use of alternative drainage systems should educate future home buyers where such alternative standards may entail a higher risk of occasional inconvenience (eg. Ponding at the back of the lots). When possible, local authorities should provide assistance to such endeavors
- Public perception on maintenance requirements for alternative drainage systems should be further evaluated .

APPENDIX A

Terms of Reference

TERMS OF REFERENCE

FOR

AN EVALUATION OF ROADSIDE DITCHES AND OTHER RELATED STORMWATER MANAGEMENT PRACTICES

February 5, 1996

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TERMS OF REFERENCE

AN EVALUATION OF ROADSIDE DITCHES AND OTHER RELATED STORMWATER MANAGEMENT PRACTICES

1.0 INTRODUCTION

The field of stormwater management has evolved substantially from the days when efficient conveyance channels and end-of-pipe techniques were employed to meet the single purpose objective of flood control. Now, an integrated "treatment train" approach addresses a complex range of watershed management objectives. This approach involves a combination of stormwater management practices at the lot level, along the conveyance system, and at the end-of-pipe. Together these practices help maintain or restore a more natural cycling of water by encouraging infiltration, reducing runoff volumes and velocities, and filtering pollutants carried by the stormwater. These functions are important in:

- managing flood flows;
- mitigating erosion;
- promoting infiltration to groundwater; and
- protecting water quality, habitat, and other watershed values.

Although there have been recent local studies, which have documented or begun to document the technical performance and overall acceptance of some of the lot level and end-of-pipe techniques, there remain many questions associated with the use of certain conveyance systems. In particular, the traditional practice of roadside ditches (i.e. rural cross-section) may offer advantages over a curb-gutter-sewer system (i.e. urban cross-section) by providing some level of stormwater quality and quantity management. However, when considering the use of roadside ditches as a stormwater management measure in new urban developments; maintenance of existing ditches; or conversion of ditches to an urban cross-section, in older neighbourhoods, designers and reviewers are faced with many opposing opinions over their merits. A recent paper (Li *et al.*, 1995 draft) describes a broad range of perspectives regarding the application of alternative road drainage systems. This initial research points to the need for further study of the environmental performance, social considerations, and costs associated with various road drainage designs.

2.0 PURPOSE

The purpose of this study is to investigate and report on environmental, engineering, social, and economic issues (both positive and negative) associated with the use of roadside ditches and alternative road drainage systems.

Consulting services are being sought to review and document experience from other jurisdictions as reported in the literature; survey public attitudes; and compare capital, operations and maintenance costs associated with various road drainage systems. The consultant is expected to build upon the initial work completed by Ryerson University and the Lake Simcoe Region Conservation Authority (LSRCA), which is referenced in Appendix A.

3.0 OBJECTIVES

1. To evaluate "roadside ditches" according to the following criteria:

    - water conveyance (flow velocity, volume, timing)
    - water quality treatment (e.g. removal rates for: sediment, nutrients, bacteria, oils and grease, metals, other)
    - infiltration to groundwater (e.g. recharge, contamination potential)
    - ability to meet typical stormwater management requirements
    - safety (e.g. vehicular, pedestrian)
    - right-of-way planning and design considerations (e.g. utility location)
    - road planning and design considerations (e.g. traffic conveyance, parking, drainage of the road base)
    - lot planning and design considerations (e.g. driveway design, sidewalks, landscaping, lot width)
    - public attitudes and perceptions
    - aesthetics
    - real estate values
    - routine and long term maintenance requirements and longevity
    - economics (i.e. capital, operations and maintenance costs)
    - seasonal considerations associated with any of the above-noted criteria (e.g. compatibility with snow removal operations)
    - other criteria, as deemed appropriate

2. To compare different roadside ditch designs (i.e. channel lining, vegetation type, soil type, slope, presence of check dams or other design modifications, etc.) according to the above-noted criteria, where differences exist.

3. To compare roadside ditches to other types of conveyance systems, including curb/gutter/sewer, perforated pipes, and different conveyance systems with catchbasin exfiltration or stormceptor-type units, according to the above-noted criteria.

4. To recommend a procedure for selecting the appropriate road drainage alternative according to various site characteristics.

5. To recommend modifications to traditional roadside ditch designs that would address any concerns identified.

6. To recommend a strategy for the improved management and maintenance of existing roadside ditches with potential implementation roles for municipalities, agencies, and homeowners.

4.0 SPECIFIC TASKS

In order to meet the objectives of this study the consultant shall:

1. Update and expand upon the available literature review, including a review of published papers and technical reports. Literature may be drawn from Canadian and international sources, but information should be applicable/transferrable to the Greater Toronto Area. Copies of publications referenced in the paper "Environmental Drainage Designs - Alternatives to the Curb-Gutter-Sewer Systems" (see Appendix A) can be made available to the consultant.

2. Administer questionnaire/surveys to and/or conduct interviews with local residents and real estate agents as a means of assessing public attitudes, experiences and costs associated with roadside ditches, traditional curb-gutter-sewer systems, and other road drainage systems. The consultant may propose an alternative approach for obtaining this information.

3. Administer questionnaire/surveys to and/or conduct interviews with selected municipal officials (public works) as a means of:

    a) establishing a standard method of calculating per unit capital, operations and maintenance costs associated with roadside ditches, traditional curb-gutter-sewer systems, and other road drainage systems; and

    b) compiling specific cost data.

    The consultant may propose an alternative approach for obtaining this information.

4. Based on the information collected, evaluate and compare alternative road drainage systems according to the criteria defined in section 3.0 (Objectives).

5. Review the "Rational Approach" for the selection of road drainage systems (see Appendix A), proposed by Ryerson University and the LSRCA, and based on the results of this study, recommend any modifications necessary to develop a simple and effective assessment/selection tool.

6. Attend at least three review committee meetings as further specified under sections 5.0 and 6.0.

7. Prepare interim, draft and final reports and factsheets, based on input provided by the review committee and as further specified under section 5.0 (Deliverables).

5.0 DELIVERABLES

1. **Proposed workplan and draft survey and/or interview questions**

2. **Interim report** (i.e. 5-10 pages, point form) containing preliminary results of the literature review, public attitudes and cost components of the study; proposed outline of the draft report and factsheet; and approach to developing recommendations.

3. **Study Report** (draft and final versions)* documenting the study approach, findings, and recommendations. The report shall address all study objectives stated in section 3.0, report on tasks #1-4 described in section 4.0, and identify areas in need of further investigation. The report shall provide appropriate recognition of the contributions of all participants in this research.

4. **Factsheet** (draft and final versions)* summarizing and illustrating the main study findings and recommendations for distribution to other municipalities and interested individuals. The factsheet shall be designed with consideration for cost and ease of reprinting (e.g. one colour, maximum 11 X 17" double-sided, including graphics).

5. **One copy of each key reference** collected during the literature review. The consultant shall limit the cost of this deliverable to $100.

6. **Attendance at three review committee meeetings:**
    (1) start-up
    (2) presentation and discussion of interim report
    (3) presentation and discussion of draft report

*The consultant shall submit reports to MTRCA in the form of one bound copy and one unbound copy suitable for photocopying for broader distribution to Review Committee members. In addition, the final report and factsheet shall be submitted on disk in a form acceptable to the MTRCA.

6.0 SUGGESTED SCHEDULE

Week of	**Milestone**
March 8	Award of Contract
March 18	Review Committee Meeting #1 (Start up and presentation of proposed study approach, schedule, and draft survey/interview questions)
May 6	Submission of Interim Report
May 20	Review Committee Meeting #2 (discussion of interim report)
June 10	Submission of Draft Report and Factsheet

June 24	Review Committee Meeting #3 (discussion of draft report)
July 29	Submission of Final Report and Factsheet

7.0 COST

An upset limit has been set for this study at $20,000 including GST.

8.0 CONSULTANT SELECTION PROCESS

Proposal Requirements

The proposal should be no more than 10 pages in length and should include the following:

- relevant experience
- identification of key participant(s)
- proposed approach, including detail sufficient to describe the level of effort (e.g. mechanisms for researching literature, prospective survey respondent groups and sample sizes, etc.)
- cost (total and a breakdown based on person-hours and tasks)

Corporate information may be appended.

Proposal Deadline

Proposals must be directed to:

Ms. Sonya Meek
Coordinator, Environmental Projects
MTRCA
5 Shoreham Drive
Downsview, Ontario
M3N 1S4

Proposals must be received by 12:00 noon on February 19, 1996.

Selection Criteria

Proposals will be evaluated according to the following criteria:

- understanding of stormwater management objectives and practices
- past experience
- qualifications of primary researcher(s)
- approach
- quality of proposal
- cost

APPENDIX A: BACKGROUND PAPERS BY RYERSON UNIVERSITY AND THE LAKE SIMCOE REGION CONSERVATION AUTHORITY

Abstracts of two relevant background papers are included within this Appendix. Full copies of the papers could not be reprinted at this time, as they are in the process of being published. However, one full copy of each draft paper will be available at the MTRCA Head Office reception desk (5 Shoreham Drive, Downsview; Hours of Operation - 8:30 am to 4:30 pm) for review by consultants wishing to bid on this project. Consultants interested in viewing these papers are encouraged to contact Angela Parisi at (416) 661-6600 ext. 295 or Sonya Meek at ext. 253 to reserve an appointment time.

DRAFT

ENVIRONMENTAL DRAINAGE DESIGNS
ALTERNATIVES TO THE CURB-GUTTER-SEWER SYSTEM

James Li[1], Robert Orland[2], and Tom Hogenbirk[2]

Abstract: For many years, road and lot drainage systems have been designed to convey stormwater runoff away as quickly as possible in order to reduce localized ponding. To serve this purpose, the curb-gutter-sewer system has been generally used in urban centres which eventually discharges to the receiving waters or to end-of-pipe stormwater management facilities. This drainage concept has led to downstream flooding, erosion, water quality degradation, reduced ground water recharge and stream baseflow, and aquatic habitat destruction. Prior to the implementation of the curb-gutter-sewer system, land drainage was primarily served by the open ditch conveyance system. The phasing-out of the ditch system has now reached many rural municipalities in southern Ontario. It is perceived by some municipalities to be essential since the curb-gutter-sewer system appears to be more effective in transporting runoff while being virtually maintenance free. This paper examines and compares the conventional curb-gutter-sewer drainage system and various forms of open ditch/swale drainage alternatives. These drainage alternatives not only provide drainage capacity but also other environmental benefits such as water quality treatment, erosion control, and ground water recharge.

Key words: drainage system, stormwater, curbs, gutters, sewers, ditches, swale.

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A RATIONAL APPROACH TO SELECT THE MOST APPROPRIATE ROAD & LOT DRAINAGE SYSTEM

James Li[1], Robert Orland[2], and Tom Hogenbirk[2]

Abstract: Traditionally, drainage systems are selected according to the land use designation of a site. As a result, ditches are used extensively in rural areas while curb-gutter-sewer systems are primarily employed in urban areas. The increased urbanization in the Greater Toronto Area has prompted many municipalities to adopt a unilateral drainage standard throughout their municipalities. Not only are new urban subdivisions served with the curb-gutter-sewer system, but many rural estate subdivisions are also designed with the same drainage systems. As drainage systems have evolved to become one of the stormwater management practices, it should provide more than just the conveyance function. These municipal drainage standards do not allow the efficient use of a drainage system for conveyance, water quality treatment, ground water recharges, and other environmental functions. The selection of drainage systems must be based on the multiple objectives of stormwater management. A rational approach to select the best drainage system for urban and rural development has been developed. It consists of (1) development of drainage objectives criteria; (2) preliminary screening of alternatives; and (3) multi-objective evaluation of alternatives. Two case studies are presented to demonstrate the rational approach.

Key words: drainage system, storm water, curb, gutter, sewer, ditch, swale.

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APPENDIX B

List of References

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APPENDIX C

Questionnaires / Surveys and responses

#1 Municipal Engineers and Planners
#2 Real Estate Agents and Developers

An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices

Questionnaire / Survey

(Municipal Engineer and Planners)

Introduction:

As indicated in our covering letter, one objective of the study is to identify and evaluate public attitudes, experiences and costs associated with various types of roadside drainage alternatives. The commonly known systems that are above ground and visible to sight include the conventional curb and gutter, the conventional roadside ditch and a shallow grass swale. The third alternative, the swale, is a system which is similar to the road side ditch but is not as deep and has a gentler sideslopes than the roadside ditch.

We need your input to determine if you have used or would use alternative drainage systems for new developments in rural or urban areas, or if you have used or would use alternative drainage systems in upgrading an existing system.

We are on a strict schedule and kindly ask that you complete and return the enclosed Questionnaire / Survey before May 10, 1996.

If you have any questions or need assistance with the questionnaire please do not hesitate to call;

J.F. Sabourin and Associates Inc.

Mr. John Malkin or
Mr. Jean-François Sabourin
in the Ottawa area at (613) 727-5199, or toll free at 1-800-517-3491.

Section 1: Definitions

For this study the following definitions are being used.

Urban Area - Properties located within the boundaries of Cities and Towns. Typical lot sizes are less than or equal to 0.2 acres with lot frontages less than or equal to 60 feet.

Rural Area - Properties located outside the boundaries of Cities and Towns. Typical lot sizes are greater than 0.2 acres with lot frontages greater than 60 feet.

Swale - Trapezoidal channel, grassed lined, side slopes maximum 5:1, maximum depth .5m (from edge of shoulder), minimum bottom width .75m.

Ditch - V shaped channel, natural state of vegetation, side slope 3:1, minimum depth .5 m (below bottom of subgrade).

Section 2: Description of Alternative Drainage Systems

Listed below are some alternatives that were investigated in a paper entitled "Environmental Drainage Designs - Alternatives to the Curb-Gutter-Sewer System" by James Li, Robert Orland and Tom Hogenbirk. Some of these systems are only concepts and some have been implemented. Could you please indicate the following for each alternative.

A) Have you heard of this system?
B) Have you implemented this system?
C) Do you know of anyone who has implemented this system?
(To answer Yes, please circle all that apply.)

<u>System</u> *(see attached preliminary sketches)*			
1) Grass swale	(A) 23	(B) 9	(C) 3
2) Grass swale with dipped driveways	(A) 16	(B) 2	(C) 2
3) Grass swale with raised culverts	(A) 14	(B) 5	(C) 3
4) Grass swale with check dams	(A) 9	(B) 3	(C) 1
5) Grass swale with infiltration trench system	(A) 20	(B) 6	(C) 4
6) Grass swale with infiltration manhole system	(A) 16	(B) 3	(C) 2
7) Grass swale with curb and gutter (no sewer)	(A) 10	(B) 3	(C) 1
8) Grass swale with perforated storm sewer	(A) 19	(B) 5	(C) 4
9) Grass swale with storm sewer	(A) 14	(B) 6	(C) 3
10) Grass swale with curb gutter and sewer	(A) 12	(B) 6	(C) 1
11) Curb gutter and sewer with exfiltration system	(A) 16	(B) 1	(C) 3
12) Curb gutter and sewer with filtration system	(A) 13	(B) 2	(C) 4
13) Curb and gutter with greenbelt system	(A) 6	(B) 1	(C) 0
14) Oil grit separator and sumpless catchbasins	(A) 16	(B) 6	(C) 1
15) Other systems			

If you circled "C" for any of the above, please provide a contact name and address for the system.

Type of system	Municipality	Contact Name	Telephone

Section 3: New Drainage Systems in Urban Areas

1) Have you ever designed and/or constructed an alternative drainage system instead of the conventional curb gutter and sewer system in an urban area? 10 (Yes) 20 (No)

<u>If yes</u>: Please complete Section 10 for each alternative drainage system.

2) Have you considered, or would you consider using an alternative drainage system for a new subdivision in an Urban Area? 16 (Yes) 11(No)

<u>IF YES</u> A) What systems would you consider? *(numbers below correspond to alternatives described in Section 2)*

Please circle all that apply ——> (1) 5 (2) 3 (3) 7 (4) 0 (5) 5 (6) 2 (7) 2
(8) 4 (9) 4 (10) 4 (11) 2 (12) 2 (13) 5 (14) 4

Other:

Are there any reasons why you may not have designed and/or constructed an alternative drainage system in the past?

B) In terms of stormwater management, what level of service would be required for a new conventional curb gutter drainage system in an urban area?

minor system: (e.g. 1:5 yr) <u>(1:2) 4 (1:5) 10</u>
major system: (e.g. 1:100 yr) <u>(1:100) 15</u>

Would you expect to provide the same level of service with an alternative type of drainage system?
15 (Yes) 3 (No)

C) During a major storm event, what would be the maximum permissible depth of water on an urban street with curb and gutter?

max. depth <u>(0.03m - 0.4m)</u> for which event? <u>(1:5) 1 (1:100) 14</u>

Would this depth be the same if the road was draining to a grass swale?
15 (same) 2 (Other) ____________

D) During more frequent storm events (i.e. 25 mm or less) would temporary water accumulations in roadside swales be acceptable?
14 (Yes) 5 (No)
<u>If yes</u>: How long after the storm event should the water take to drain?
1 (0 min) 5 (less than 60 min) 7 (12 hours) 1 (24 hours) 1 (Other)

<u>IF NO</u>: Please indicate which of the following items could represent reasons why you would not use an alternative drainage system. *(check as many as needed)*

18 (perceived additional maintenance costs)
10 (lack of information on how systems would work)
8 (possible need for special construction techniques for road construction and entrances into properties)
15 (perceived lower level of standards for road)
15 (lack of long term maintenance and operations history of systems)
6 (Safety -vehicular, cyclist, pedestrian)
10 (other)

Section 4: New Drainage Systems in Rural Areas

1) Have you ever designed and/or constructed an alternative drainage system instead of the conventional curb gutter and sewer system in a rural area? 8 (Yes) 15 (No)

<u>If yes</u>: Please complete Section 10 for each alternative drainage system.

2) Have you considered, or would you consider using an alternative drainage system for a new subdivision in a Rural Area? 15 (Yes) 3 (No)

<u>IF YES</u> A) What systems would you consider? *(numbers below correspond to alternatives described in Section 2)*

Please circle all that apply -------> (1) 10 (2) 2 (3) 4 (4) 1 (5) 4 (6) 2 (7) 0
(8) 3 (9) 2 (10) 2 (11) 1 (12) 1 (13) 2 (14) 2

Other:

Are there any reasons why you may not have designed and/or constructed an alternative drainage system in the past?

B) In terms of stormwater management, what level of service would be required for a new conventional roadside ditch drainage system in a rural area?

ditch system (e.g. 1 5 yr) <u>(1 2) 1 (1 5) 9 (1 10) 2 (1 25) 1</u>
major system: (e.g. 1 100 yr) <u>(1 25) 1 (1 50) 3 (1 100) 9</u>

Would you expect to provide the same level of service with an alternative type of drainage system?
11 (Yes) 1 (No)

C) During a major storm event, what would be the maximum permissible depth of water on a rural street?
max. depth <u>0 05 - 0 5 m</u> for which event? <u>(1 5) 1 (1 25) 2 (1 50 2 (1100) 7</u>

Would this depth be the same if the road was draining to a grass swale?
9 (same) 2 (Other) ____________

D) During more frequent storm events (i.e. 25 mm or less) would temporary water accumulations in roadside swales or ditches be acceptable?
14 (Yes) 2 (No)
<u>If yes</u> How long after the storm event should the water take to drain?
0 (0 min) 5 (less than 60 min) 5 (12 hours) 4 (24 hours) 0 (Other)

<u>IF NO</u>: Please indicate which of the following items could represent reasons why you would not use an alternative drainage system.

13	(perceived additional maintenance costs)
8	(lack of information on how systems would work)
8	(possible need for special construction techniques for road construction and entrances into properties)
7	(additional capital costs)
7	(lack of long term maintenance and operations history of systems)
5	(Safety -vehicular, cyclist, pedestrian)
5	(other)

Section 5: Upgrade of Drainage System in Older Areas

1) Have you ever upgraded a drainage system in an existing area from a conventional ditch to an alternative drainage system instead of to a curb gutter and sewer system? 8 (Yes) 21 (No)

<u>If yes</u>: Please complete Section 10 for each alternative drainage system.

2) Have you considered, or would you consider using an alternative drainage system for an upgrade of a conventional roadside ditch ? 20 (Yes) 2 (No)

<u>IF YES</u>: A) What systems would you consider? *(numbers below correspond to alternatives described in Section 2)*

Please circle all that apply ———> (1) 10 (2) 2 (3) 8 (4) 1 (5) 7 (6) 3 (7) 3
(8) 8 (9) 6 (10) 6 (11) 1 (12) 1 (13) 4 (14) 3

Other:

Are there any reasons why you may not have designed and/or constructed an alternative drainage system to upgrade or retrofit a conventional drainage ditch in the past?

B) In terms of stormwater management, what level of service would be required in a retrofit situation?
6 (same as existing conditions) 9 (better)

if better, please elaborate:

<u>IF NO</u>: Please indicate which of the following items could represent reasons why you would not use an alternative drainage system.

12 (perceived additional maintenance costs)
6 (lack of information on how systems would work)
5 (possible need for special construction techniques for road construction and entrances into properties)
13 (perceived lower level of standards for road)
12 (lack of long term maintenance and operations history of systems)
5 (other)

Section 6: General Stormwater Management Guidelines

Does your municipality have its own set of Stormwater Management Guidelines?
14 (Yes) 13 (No)

<u>if yes</u>: If possible, please include a copy of your SWM guidelines when returning this survey.

<u>if no</u>: Which SWM guidelines do you follow? (Enter NONE if applicable)

Section 7: Attitudes & Perceptions

1) How does a ditch drainage system in an urban and rural area influence your perception/attitude towards the following aspects? (1=negatively, 2=no influence, 3=positively, 4=unsure)

		Urban				**Rural**			
a)	Aesthetics	(1)26	(2)1	(3)3	(4)0	(1)2	(2)14	(3)9	(4)2
b)	Safety	(1)20	(2)8	(3)1	(4)1	(1)2	(2)20	(3)3	(4)2
c)	Perception of service	(1)24	(2)5	(3)0	(4)1	(1)5	(2)14	(3)5	(4)3
d)	Maintenance requirements	(1)22	(2)6	(3)2	(4)0	(1)7	(2)16	(3)3	(4)0
e)	House market value	(1)18	(2)6	(3)0	(4)5	(1)3	(2)17	(3)3	(4)3
f)	Environmental impacts	(1)0	(2)11	(3)13	(4)5	(1)0	(2)14	(3)10	(4)2

2) How does a swale drainage system in an urban and rural area influence your perception/attitude towards the following aspects? (1=negatively, 2=no influence, 3=positively, 4=unsure)

		Urban				**Rural**			
a)	Aesthetics	(1)12	(2)9	(3)4	(4)4	(1)1	(2)11	(3)10	(4)3
b)	Safety	(1)7	(2)18	(3)0	(4)4	(1)1	(2)16	(3)5	(4)3
c)	Perception of service	(1)11	(2)11	(3)1	(4)6	(1)4	(2)12	(3)5	(4)4
d)	Maintenance requirements	(1)18	(2)7	(3)0	(4)4	(1)7	(2)11	(3)3	(4)4
e)	House market value	(1)9	(2)12	(3)0	(4)8	(1)1	(2)14	(3)6	(4)4
f)	Environmental impacts	(1)0	(2)9	(3)13	(4)6	(1)0	(2)12	(3)8	(4)5

3) How does a curb and gutter drainage system in an urban and rural area influence your perception/attitude towards the following aspects? (1=negatively, 2=no influence, 3=positively, 4=unsure)

		Urban				**Rural**			
a)	Aesthetics	(1)0	(2)7	(3)22	(4)0	(1)7	(2)8	(3)8	(4)3
b)	Safety	(1)0	(2)4	(3)24	(4)1	(1)4	(2)9	(3)9	(4)4
c)	Perception of service	(1)0	(2)2	(3)27	(4)0	(1)5	(2)9	(3)9	(4)3
d)	Maintenance requirements	(1)1	(2)9	(3)19	(4)0	(1)7	(2)8	(3)9	(4)2
e)	House market value	(1)0	(2)5	(3)22	(4)2	(1)3	(2)8	(3)10	(4)5
f)	Environmental impacts	(1)10	(2)14	(3)3	(4)2	(1)10	(2)10	(3)1	(4)5

4) Based on an overall assessment of environmental, engineering, economic and public concerns, which type of drainage system do you feel is most appropriate in an urban area and in a rural area?

		Roadside ditch	**Swales**	**Curb & gutter**	**Drainage system makes no difference**	**Unsure**
a)	Urban area	(1) 0	(2) 1	(3) 25	(4) 0	(5) 0
b)	Rural area	(1) 18	(2) 3	(3) 1	(4) 1	(5) 1

5) In your opinion, which type of drainage system offers the best level of service under the following conditions?

		Roadside ditch	**Swales**	**Curb & gutter**	**Drainage system makes no difference**	**Unsure**
a)	during the spring	(1) 3	(2) 0	(3) 25	(4) 2	(5) 0
b)	during the summer	(1) 0	(2) 4	(3) 17	(4) 9	(5) 0
c)	during the fall	(1) 2	(2) 1	(3) 18	(4) 8	(5) 1
d)	during the winter	(1) 7	(2) 0	(3) 17	(4) 6	(5) 0

6) In your opinion, how would you rate the level of maintenance required by the homeowners associated with each of the following systems?

		High	**Medium**	**Low**	**Unsure**
a)	Roadside ditches	(1) 19	(2) 10	(3) 2	(4) 0
b)	Swales	(1) 3	(2) 21	(3) 7	(4) 0
c)	Curb & gutter	(1) 2	(2) 0	(3) 28	(4) 1

Section 8: Safety

1) Based on your driving experience, how would you rate your level of comfort on a local roadway with a roadside ditch, a swale, or a curb & gutter system?

	Very comfortable	Comfortable	Not comfortable	Very uncomfortable	No effect
a) Roadside drainage ditch	(1) 5	(2) 20	(3) 5	(4) 0	(5) 1
b) Roadside swale	(1) 7	(2) 20	(3) 1	(4) 0	(5) 1
c) Roadside curb & gutter	(1) 16	(2) 12	(3) 1	(4) 0	(5) 1

2) How comfortable do you feel walking or riding a bicycle on a local roadway with a roadside ditch, a swale, or a curb & gutter drainage system?

	Very comfortable	Comfortable	Not comfortable	Very uncomfortable	No effect
a) Roadside drainage ditch	(1) 6	(2) 11	(3) 8	(4) 5	(5) 0
b) Roadside swale	(1) 6	(2) 18	(3) 3	(4) 2	(5) 0
c) Roadside curb & gutter	(1) 16	(2) 11	(3) 3	(4) 0	(5) 0

3) How comfortable are you walking along a local roadway with and without a sidewalk?

	Very comfortable	Comfortable	Not comfortable	Very uncomfortable	No effect
a) Roadway with sidewalk	(1) 25	(2) 5	(3) 1	(4) 0	(5) 0
b) Roadway without sidewalk	(1) 1	(2) 9	(3) 15	(4) 6	(5) 0

4) What is your level of comfort regarding the temporary pooling of water after a heavy rainstorm?

	Very comfortable	Comfortable	Not comfortable	Very uncomfortable	No effect
a) Pooling of water on street	(1) 2	(2) 8	(3) 17	(4) 3	(5) 1
b) Pooling of water in roadway ditch	(1) 5	(2) 19	(3) 6	(4) 0	(5) 1
c) Pooling of water in a swale	(1) 6	(2) 16	(3) 7	(4) 0	(5) 2

Section 9: Right of Way and Lot Planning

1) In your opinion can a swale or conventional road side ditch be accommodated within a standard road allowance (20 metres) without compromising the allocation of other utilities?

Swale: 14 (Yes) 5 (No) 8 (Depends on site) 4 (Don't know)
Ditch: 11 (Yes) 12 (No) 7 (Depends on site) 1 (Don't know)
<u>IF No</u> What ROW width would be required? Swale <u>20, 23, 25, 26+ m</u> Ditch <u>20, 20-24, 23, 26, 26+, 30 m</u>

2) In your opinion can a swale or conventional road side ditch be accommodated within a reduced road allowance without compromising the allocation of other utilities?

Swale: 4 (Yes) 16 (No) 7 (Depends on site) 3 (Don't know)
Ditch: 3 (Yes) 21 (No) 6 (Depends on site) 1 (Don't know)
<u>IF Yes</u> What ROW width would be required? Swale <u>15, 18, 18-20, 26 m, 66'</u> Ditch <u>18, 18, 18-20, 26 m, 66'</u>

3) How comfortable are you with parking a vehicle on a local roadway with a roadside ditch, a swale, or curb and gutter drainage system?

	Very comfortable	Comfortable	Not comfortable	Very uncomfortable	No effect
a) Roadside ditches	(1) 3	(2) 14	(3) 12	(4) 2	(5) 1
b) Roadside swale	(1) 6	(2) 18	(3) 6	(4) 0	(5) 1
c) Curb & gutter	(1) 18	(2) 11	(3) 2	(4) 0	(5) 1

4) What type of landscape treatment do you feel is appropriate for a swale or conventional road side ditch?

26 (grass) 9 (natural vegetation) 0 (hard surface) 0 (other)

5) Do you feel that a swale or roadside ditch system would compromise the planting of trees in the public road allowance?

Swale: 8 (Yes) 20 (No) 2 (Don't know)

Ditch: 12 (Yes) 14 (No) 2 (Don't know)

Section 10: Detailed Questions Pertaining to Alternative Drainage Systems Which Have Been Constructed

(only required if you answered yes to questions (1) in Sections 3, 4, or 5).

Note: *If you have designed or constructed more than one alternative drainage system, can you please copy this page and the next page and complete for each type of system. If you have more than one, enter system ID # _______*

1) Type of system constructed *(how many)*____

2) A- Constructed in: ☐ urban, ☐ rural

B- Was this construction in a new area or an upgrade to an existing drainage system?
☐ new area, ☐ upgrade

3) Year constructed ____________________

4) Length of system constructed (m)__________________

5) Area of land serviced by drainage system (ha)__________________

6) Level of SWM provided (i.e. 1:5 year, 1:100 year) ______________________

7) Why was this system chosen for this area? *(Circle appropriate options)*
   a) Soils in area
   b) No storm sewers in area
   c) Savings in capital costs
   d) Other ____

8) On what type of street was the system constructed? *(Circle appropriate options)*
   a) Urban - minor local street
   b) Urban - local street
   c) Urban - residential collector
   d) Urban - collector
   e) Urban - minor arterial
   f) Urban - other _____________________
   g) Rural - residential
   h) Rural - collector
   i) Rural - other ______________________

9) What other utilities were constructed in the same right of way with the alternative drainage system? *(Circle appropriate options)*
   a) Watermains
   b) Sanitary sewers
   c) Telephone ☐ Above ground, ☐ Below ground
   d) Power ☐ Above ground, ☐ Below ground
   e) Gas
   f) Cable TV ☐ Above ground, ☐ Below ground
   g) Other ______________ ☐ Above ground, ☐ Below ground

Repeat system ID #: ____

10) A- What was the right of way width used? ____________________

B- Was this the typical width that would have been used if curb and gutter or conventional ditches were used? ☐ Yes, ☐ No

If no: What would have been the typical width? ____________________

11) Were culverts used with the system? ☐ Yes, ☐ No

If yes: What was the minimum size used? ____________________

12) Have you encountered any problems associated with the system? ☐ Yes, ☐ No

If yes: What types of problems? ____________________

13) Were any special construction techniques or materials needed for the road and drainage alternative?
☐ Yes, ☐ No

If yes, please list the techniques and materials used. ____________________

14) Were any special construction techniques or materials needed to service the lots?
☐ Yes, ☐ No

If yes, please list the techniques and materials used. ____________________

15) Would you say that the system requires more, less, or the same amount of long term maintenance as a conventional system? ☐ More, ☐ Less, ☐ Same

If less, why? ____________________

If more, why? ____________________

16) Have you had any complaints from home owners in regards to the drainage system?
☐ Yes, ☐ No

If yes, what were they and how many? ____________________

17) Would you use this system again? ☐ Yes, ☐ No

If no, why not? ____________________

We would appreciate it if you could forward any typical cross sections you have for the project showing the ROW utility locations and the alternative drainage systems, and any construction costs, maintenance costs, and any studies as a comparison to a conventional system.

Section 11: Respondent information:

Name of Organization: ______________________

Full Address: ______________________

____

____

Phone: ____________ FAX: ____________ Email: ____________

Name of Respondent: ______________________

Respondent's Position: ______________________

Signature and date: ______________________

Name of person to contact if we need additional information: ______________________

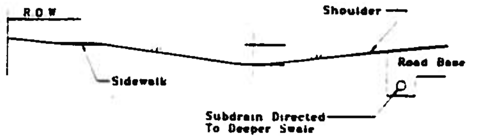
Thank you for your time in participating in our Survey / Questionnaire. Please return the completed forms to:

J.F. Sabourin and Associates Inc.
1111 Prince of Wales Drive, Suite 401
Ottawa, Ontario K2C 3T2
(you may also fax your responses to (613) 727-5699 or toll free 1-800-517-3491)

Attention: MTRCA Study

Preliminary sketches of roadside drainage alternatives as prepared by James Li (Ryerson Polytechnic University), Robert Orland and Tom Hogenbirk (Lake Simcoe Region Conservation Authority).

①

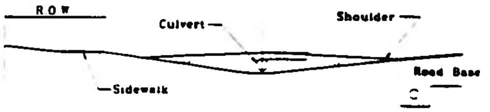


1) Grassed Swale

②

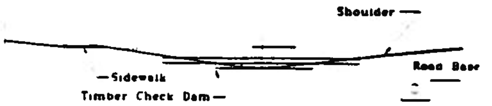
2) Grassed Swale With Dipped Driveway

③



3) Grassed Swale With Raised Culvert

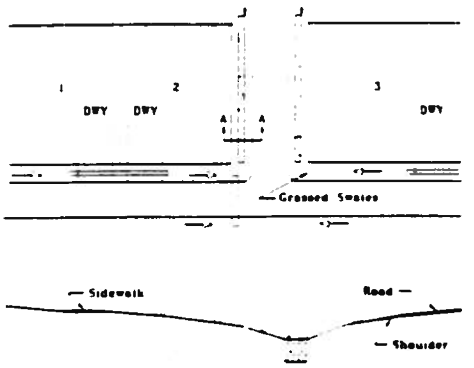
④



4) Grassed Swale With Check Dam

⑤

Gravel Infiltration Trench

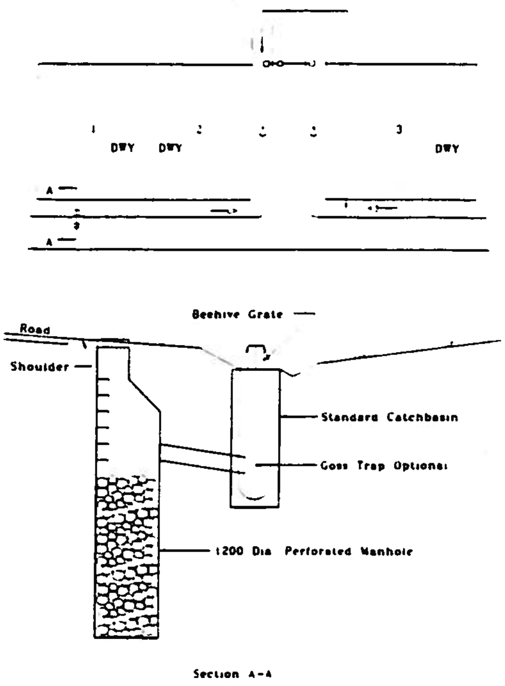


Section A-A

5) Grassed swale and infiltration system

⑥

Grassed Swales

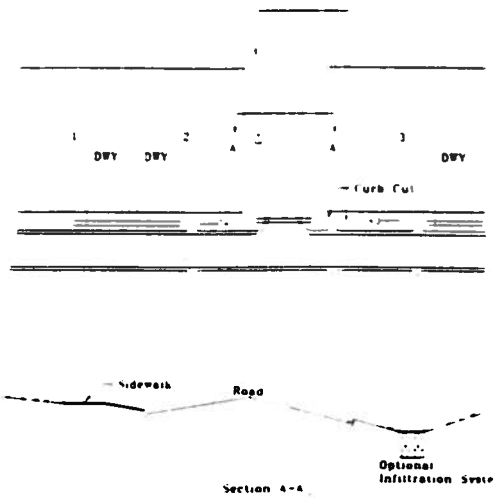


Section A-A

6) Grassed swale with vertical stone trench

⑦

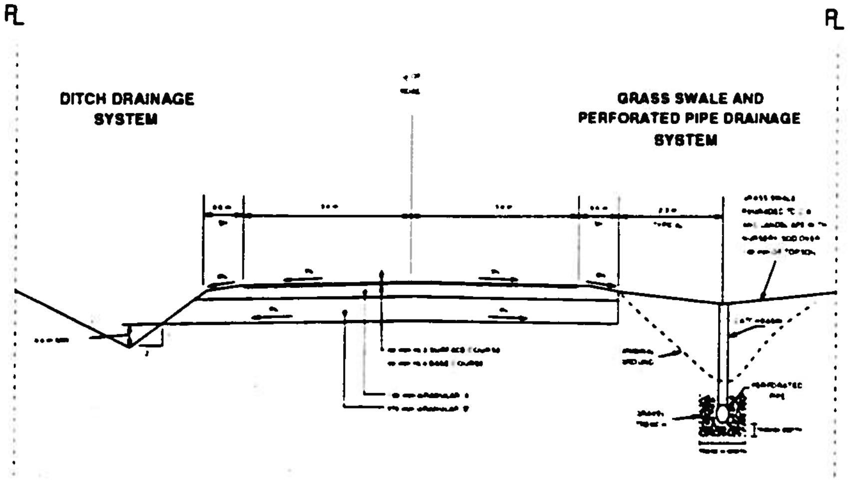
Grassed Swales



Section A-A

7) Grassed swale with curb and gutter

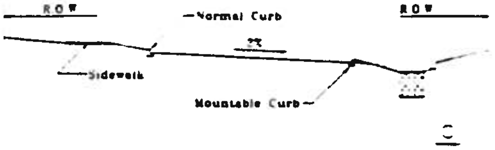
⑧*



*) prepared by J.F. Sabourin and Associates Inc.

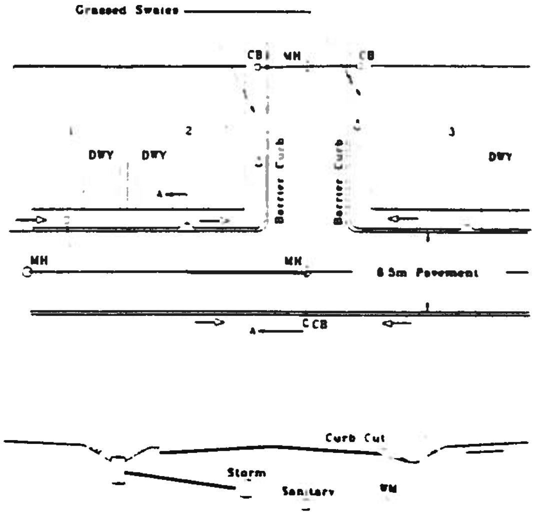
⑨

Grass Swales With Curb, Gutter, and Sewer
With Continuous Mountable Curb



9) Grassed swale and storm sewer

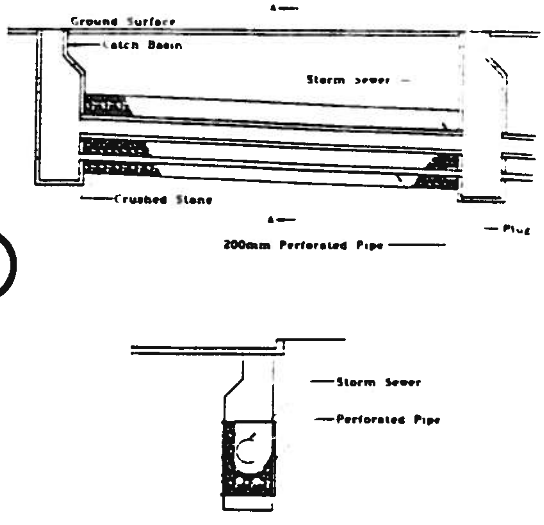
⑩



Section A-A

(10) Curb, grassed swale and storm sewer

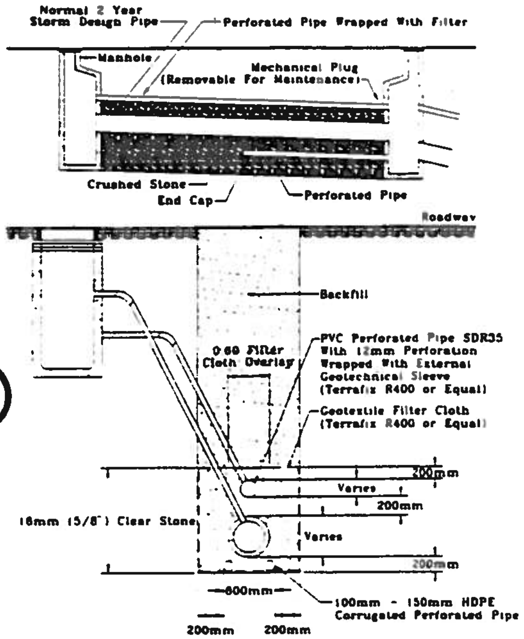
⑪



Section A-A

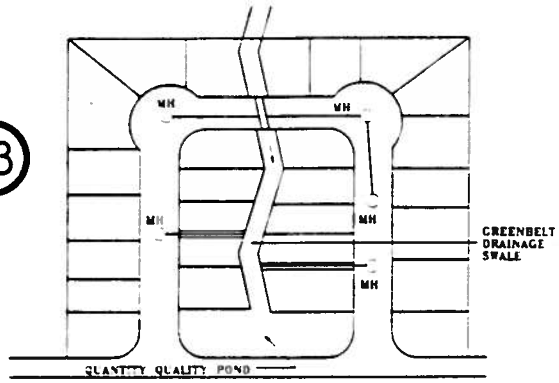
(11) Curb, gutter, and sewer with exfiltration system

⑫



(12) Curb, gutter, and sewer system with filtration system.

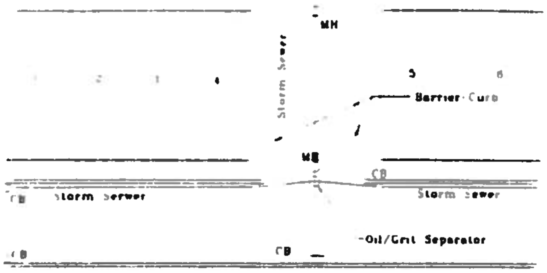
⑬



Greenbelt To Coincide With low Area Through Subdivision
This Low Area Is Not A Defined Watercourse

(13) Curb and gutter with greenbelt

⑭



(14) Oil/grit separator and sumpless catchbasins

An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices

Questionnaire / Survey

(real estate values and public perceptions)

Introduction:

As indicated in our covering letter, one objective of the study is to identify and evaluate public perceptions (if any) with respect to the type of drainage system which may service a given area. The commonly known drainage systems that are above ground and visible to sight include the conventional curb and gutter (photo 1), the conventional roadside ditch (photo 2) and shallow grass swales (photo 3).

We need your input to determine if the type of drainage systems affect the value of private properties and/or customer preferences and perceptions.

We are on a strict schedule and kindly ask that you complete and return the enclosed Questionnaire / Survey before May 10, 1996.

If you have any questions or need assistance with the questionnaire please do not hesitate to call;

J.F. Sabourin and Associates Inc.
Mr. John Malkin or
Mr. Jean-François Sabourin
in the Ottawa area at (613) 727-5199, or toll free at 1-800-517-3491.

Section 1: Definitions

For this study the following definitions are being used.

Urban Area - properties located within the boundaries of Cities and Towns. Typical lot sizes are less than or equal to 0.2 acres with lot frontages less than or equal to 60 feet.

Rural Area - properties located outside the boundaries of Cities and Towns. Typical lot sizes are greater than 0.2 acres with lot frontages greater than 60 feet.

Section 2: Real estate values

1) Do you feel that the value of a typical house in the Greater Toronto Area (or in the area in which you work) is influenced (or perceived to be influenced) by the type of drainage system servicing it?
13 (Yes) 5 (No) 1(Unsure)

2) Based on the attached photos which illustrate three different road side drainage systems would you decrease / increase the listing price for a house which is serviced by the different types of drainage systems? Use the conventional curb and gutter system (photo 1) as a baseline. (Circle one number for each system).

	<-decrease value		same value		increase value->
a) Conventional roadside drainage ditch (photo 2):	(1) 8	(2) 7	(3) 4	(4) 1	(5) 0
b) Grass swale without culvert (photo 3):	(1) 3	(2) 6	(3) 7	(4) 4	(5) 0

Section 3: Sale / Resale (Urban areas)

1) Have you had any experience with listing or selling homes which had a ditch or swale as a drainage system in an urban area? 3 (Ditch) 3 (Swale) 14 (No) (skip to question 2)

A) on average, did you feel that such homes take the same, less or more time to sell than a house with curb and gutter?

Same, . Less, . More

B) on average, do you feel that the selling price of homes on streets with roadside ditches or grass swales are the same as for similar types of homes on streets in the same area which have conventional curb and gutter type drainage systems?

Swale:	6 (Same)	1 (Less)	1 (More)
Ditch:	3 (Same)	5 (Less)	0 (More)

If you answered **Less** or **More** to the above question, please indicate which of the following ditch or swale characteristics you feel may have an impact on the selling price of such homes. (circle the 0 if no impact)

		<-Negative—|—Positive->				
		(reduces value)		**(increases value)**		
a)	overall visual aspect of streetscape or neighbourhood	0(-2)	4(-1)	0(0)	2(1)	0(2)
b)	overall visual aspect of individual properties	0(-2)	3(-1)	1(0)	2(1)	0(2)
c)	depth of ditch or swale (relative to property and road)	4(-2)	1(-1)	0(0)	0(1)	1(2)
d)	culvert under driveway	1(-2)	2(-1)	2(0)	1(1)	0(2)
e)	maintenance requirements imposed on owner	1(-2)	1(-1)	3(0)	1(1)	0(2)
f)	lot sizes	0(-2)	0(-1)	4(0)	2(1)	0(2)
g)	other: ____________________	0(-2)	0(-1)	0(0)	0(1)	1(2)

2) In your opinion, when selling homes in a new urban subdivision, what kind of drainage system do you feel people expect to have?

In an <u>urban area</u>: 15 (Curb and gutter) 1 (Roadside Ditch) 1 (Grass Swale) 3 (Unsure)

Please explain your choices: ____________________

3) Based on the type of drainage system and other local services, it may be required at times to install a sump pump in the basement of the house to collect and dispose of water which accumulates around the foundation. From your experience, do you feel that the requirements for sump pumps diminishes the value of the house? 11 (Yes) 7 (No) 1 (Unsure)

If <u>Yes</u>, why? ____________________

Section 4: Sale / Resale (Rural areas)

1) Have you had any experience with listing or selling homes which had a ditch or swale as a drainage system in a rural area? 2 (Ditch) 1 (Swale) 17 (No) (skip to question 2)

A) on average, did you feel that such homes take the same, less or more time to sell than a house with curb and gutter?

4 (Same) 0 (Less) 0 (More)

B) on average, do you feel that the selling price of homes on streets with roadside ditches or grass swales are the same as for similar types of homes on streets in the same area which have conventional curb and gutter type drainage systems?

Swale: 4 (Same) 1 (Less) 0 (More)
Ditch: 3 (Same) 2 (Less) 0 (More)

If you answered **Less** or **More** to the above question, please indicate which of the following ditch or swale characteristics you feel may have an impact on the selling price of such homes. (circle the 0 if no impact)

		<-Negative—		**|**		**—Positive->**
		(reduces value)				**(increases value)**
a)	overall visual aspect of streetscape or neighbourhood	0(-2)	2(-1)	0(0)	0(1)	0(2)
b)	overall visual aspect of individual properties	1(-2)	1(-1)	0(0)	0(1)	0(2)
c)	depth of ditch or swale (relative to property and road)	2(-2)	0(-1)	0(0)	0(1)	0(2)
d)	culvert under driveway	0(-2)	1(-1)	1(0)	0(1)	0(2)
e)	maintenance requirements imposed on owner	2(-2)	0(-1)	0(0)	0(1)	0(2)
f)	lot sizes	0(-2)	0(-1)	2(0)	0(1)	0(2)
g)	other: ______________	0(-2)	0(-1)	0(0)	0(1)	0(2)

2) In your opinion, when selling homes in a new rural subdivision, what kind of drainage system do you feel people expect to have?

In a <u>rural area</u>: 2 (Curb and gutter) 10 (Roadside Ditch) 8 (Grass Swale) 1 (Unsure)

Please explain your choices: ______________

3) Based on the type of drainage system and other local services, it may be required at times to install a sump pump in the basement of the house to collect and dispose of water which accumulates around the foundation. From your experience, do you feel that the requirements for sump pumps diminishes the value of the house? 5 (Yes) 10 (No) 2 (Unsure)

If <u>Yes</u>, why? ______________

Section 5: Public Attitudes & Perceptions

1) How does a ditch drainage system in an urban and rural area influence you or your clients' perception/attitude towards the following aspects? (1=negatively, 2=no influence, 3=positively, 4=unsure)

	Urban				Rural			
a) Aesthetics	15(1)	2(2)	2(3)	1(4)	3(1)	11(2)	3(3)	0(4)
b) Safety	11(1)	8(2)	0(3)	1(4)	3(1)	12(2)	1(3)	0(4)
c) Perception of service	12(1)	8(2)	0(3)	0(4)	1(1)	13(2)	3(3)	0(4)
d) Maintenance requirements	14(1)	5(2)	0(3)	1(4)	5(1)	9(2)	2(3)	1(4)
e) House market value	12(1)	6(2)	0(3)	2(4)	3(1)	11(2)	2(3)	1(4)
f) Environmental impacts	4(1)	8(2)	6(3)	3(4)	1(1)	9(2)	6(3)	1(4)

2) How does a swale drainage system in an urban and rural area influence you or your clients' perception/attitude towards the following aspects? (1=negatively, 2=no influence, 3=positively, 4=unsure)

	Urban				Rural			
a) Aesthetics	8(1)	8(2)	4(3)	0(4)	1(1)	9(2)	6(3)	1(4)
b) Safety	6(1)	12(2)	0(3)	2(4)	3(1)	9(2)	4(3)	1(4)
c) Perception of service	11(1)	7(2)	2(3)	0(4)	3(1)	8(2)	6(3)	0(4)
d) Maintenance requirements	9(1)	8(2)	2(3)	1(4)	3(1)	9(2)	3(3)	2(4)
e) House market value	9(1)	7(2)	3(3)	1(4)	3(1)	7(2)	5(3)	2(4)
f) Environmental impacts	2(1)	12(2)	4(3)	2(4)	1(1)	9(2)	5(3)	2(4)

3) How does a curb and gutter drainage system in an urban and rural area influence you or your clients' perception/attitude towards the following aspects? (1=negatively, 2=no influence, 3=positively, 4=unsure)

	Urban				Rural			
a) Aesthetics	1(1)	4(2)	14(3)	1(4)	3(1)	7(2)	6(3)	0(4)
b) Safety	1(1)	7(2)	10(3)	1(4)	0(1)	8(2)	9(3)	0(4)
c) Perception of service	1(1)	5(2)	13(3)	1(4)	0(1)	8(2)	9(3)	0(4)
d) Maintenance requirements	2(1)	8(2)	8(3)	2(4)	0(1)	11(2)	5(3)	1(4)
e) House market value	1(1)	7(2)	10(3)	2(4)	1(1)	8(2)	7(3)	1(4)
f) Environmental impacts	2(1)	9(2)	5(3)	3(4)	2(1)	7(2)	5(3)	3(4)

4) Which type of drainage system do you feel is most appropriate in an urban area and in a rural area from a homeowner's perspective?

	Roadside ditch	Swales	Curb & gutter	Drainage system makes no difference	Unsure
a) Urban area	0 (1)	1 (2)	15 (3)	3 (4)	0 (5)
b) Rural area	9 (1)	3 (2)	2 (3)	4 (4)	1 (5)

5) In your opinion, which type of drainage system offers the best level of service under the following conditions?

	Roadside ditch	Swales	Curb & gutter	Drainage system makes no difference	Unsure
a) during the spring	4 (1)	2 (2)	11 (3)	3 (4)	0 (5)
b) during the summer	1 (1)	4 (2)	9 (3)	6 (4)	0 (5)
c) during the fall	2 (1)	3 (2)	10 (3)	5 (4)	0 (5)
d) during the winter	4 (1)	2 (2)	10 (3)	4 (4)	0 (5)

6) In your opinion, how would you rate the level of maintenance required by the home owners associated with each of the following systems?

	High	Medium	Low	Unsure
a) Roadside ditches	9 (1)	9 (2)	1 (3)	1 (4)
b) Swales	1 (1)	12 (2)	6 (3)	1 (4)
c) Curb & gutter	1 (1)	2 (2)	16 (3)	1 (4)

Section 6: Customer Preferences

In trying to further identify public preferences and perceptions, please answer the following questions with respect to residential development in urban and rural areas.

a) Are streets with no sidewalks preferred over streets with sidewalks?
Urban: 8 (Yes) 11 (No) 1 (Don't know) **Rural:** 15 (Yes) 2 (No) 2 (Don't know)

b) Is a street with one sidewalk preferred over a street with two sidewalks?
Urban: 14 (Yes) 3 (No) 3 (Don't know) **Rural:** 12 (Yes) 1 (No) 6 (Don't know)

c) Are sidewalks next to curbs preferred over sidewalks away from curbs?
Urban: 4 (Yes) 9 (No) 6 (Don't know) **Rural:** 4 (Yes) 5 (No) 10 (Don't know)

d) Are underground franchise utilities preferred over overhead utilities?
Urban: 20 (Yes) 0 (No) 0 (Don't know) **Rural:** 9 (Yes) 5 (No) 5 (Don't know)

e) Are streets with light standards preferred over streets without lights?
Urban: 20 (Yes) 0 (No) 0 (Don't know) **Rural:** 14 (Yes) 2 (No) 3 (Don't know)

f) Are streets with curbs safer than streets without curbs?
Urban: 10 (Yes) 3 (No) 7 (Don't know) **Rural:** 8 (Yes) 4 (No) 6 (Don't know)

g) Are straight street layouts preferred over curved alignments?
Urban: 4 (Yes) 14 (No) 2 (Don't know) **Rural:** 6 (Yes) 8 (No) 5 (Don't know)

h) Are streets widths that allow for parking on street preferred over no parking on street?
Urban: 17 (Yes) 3 (No) 0 (Don't know) **Rural:** 10 (Yes) 1 (No) 8 (Don't know)

i) Are streets with Municipal trees on each lot preferred to streets with no Municipal trees?
Urban: 20 (Yes) 0 (No) 0 (Don't know) **Rural:** 14 (Yes) 1 (No) 4 (Don't know)

Section 7: Safety

1) Based on your driving experience, how would you rate your level of comfort on a local roadway with a roadside ditch, a swale, or a curb & gutter system?

	Very comfortable	**Comfortable**	**Not comfortable**	**Very uncomfortable**	**No effect**
a) Roadside drainage ditch	5 (1)	8 (2)	5 (3)	1 (4)	1 (5)
b) Roadside swale	7 (1)	11 (2)	1 (3)	0 (4)	1 (5)
c) Roadside curb & gutter	13 (1)	6 (2)	0 (3)	0 (4)	1 (5)

2) How comfortable do you feel walking or riding a bicycle on a local roadway with a roadside ditch, a swale, or a curb & gutter drainage system?

	Very comfortable	**Comfortable**	**Not comfortable**	**Very uncomfortable**	**No effect**
a) Roadside drainage ditch	4 (1)	8 (2)	5 (3)	2 (4)	1 (5)
b) Roadside swale	6 (1)	12 (2)	1 (3)	0 (4)	1 (5)
c) Roadside curb & gutter	10 (1)	5 (2)	4 (3)	0 (4)	1 (5)

3) How comfortable are you walking along a local roadway with and without a sidewalk?

	Very comfortable	**Comfortable**	**Not comfortable**	**Very uncomfortable**	**No effect**
a) Roadway with sidewalk	14 (1)	6 (2)	0 (3)	0 (4)	0 (5)
b) Roadway without sidewalk	3 (1)	6 (2)	9 (3)	2 (4)	0 (5)

4) What is your level of comfort regarding the temporary pooling of water after a heavy rainstorm?

	Very comfortable	**Comfortable**	**Not comfortable**	**Very uncomfortable**	**No effect**
a) Pooling of water on street	2 (1)	11 (2)	5 (3)	1(4)	1(5)
b) Pooling of water in roadway ditch	4 (1)	12 (2)	3 (3)	0 (4)	1(5)
c) Pooling of water in a swale	4 (1)	13 (2)	2 (3)	0 (4)	1(5)

Section 8: Respondent information

Name of Organization: ______________________________

Full Address: ______________________________

____

____

Phone: ____________ FAX: ____________ Email: ____________

Name of Respondent: ______________________________

Please indicate the general geographic area where you conduct your work and have used as a basis to answer the questions of this survey. You may refer to particular listing areas, towns, villages, municipalities, neighbourhoods, major roads, etc...:

____

____

____

Respondent's Position: ______________________________

Signature and date: ______________________________

Name of person to contact if we need additional information: ____________________

Thank you for your time in participating in our Survey / Questionnaire. Please return the completed forms to:

J.F. Sabourin and Associates Inc.
1111 Prince of Wales Drive, Suite 401
Ottawa, Ontario K2C 3T2
(you may also fax your responses to (613) 727-5699 or toll free 1-800-517-3491)

Attention: MTRCA Study

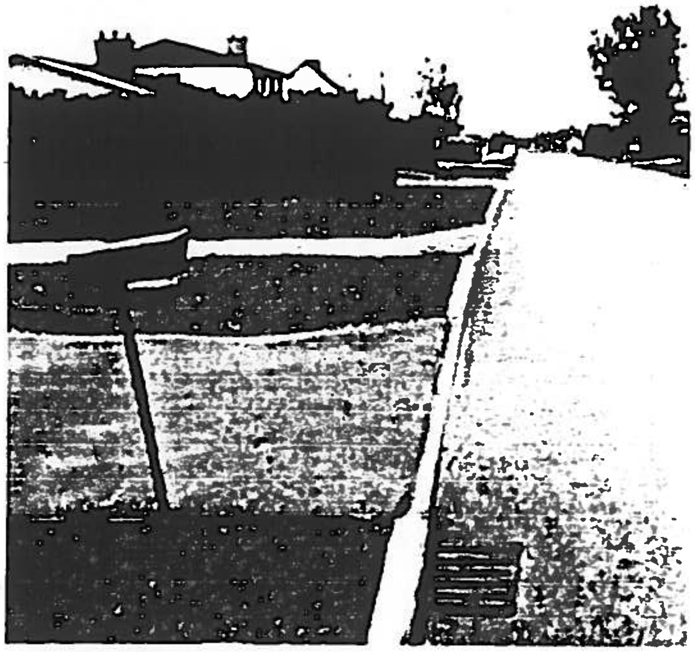


Photo 1:
Conventional Curb and Gutter Drainage System

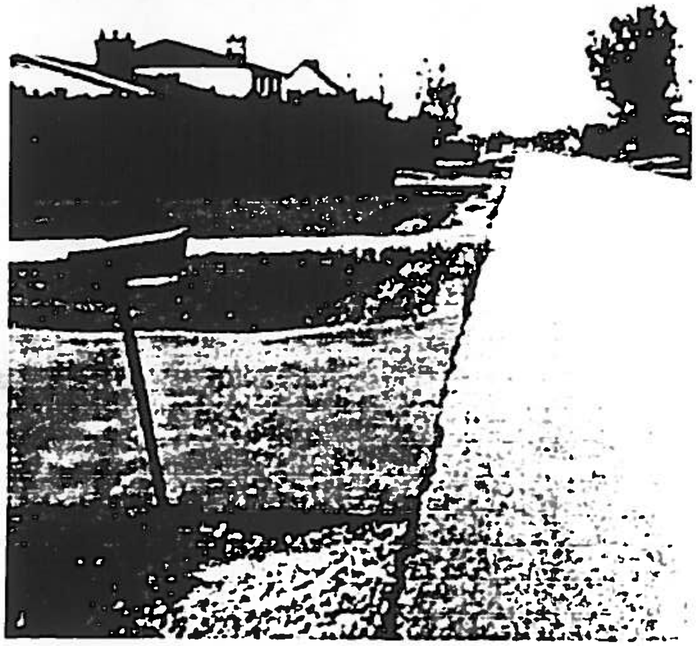


Photo 2:
Conventional Roadside Drainage Ditch

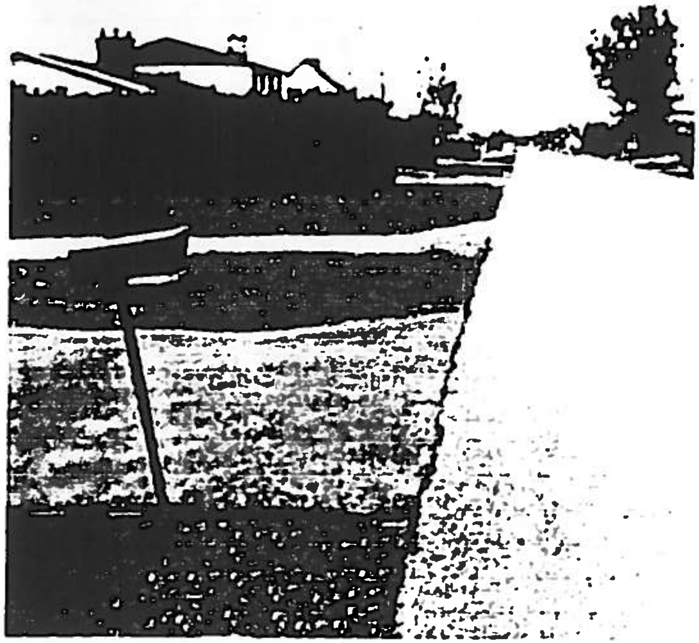


Photo 3:
Shallow Grass Swale

APPENDIX D

Hydrologic and Hydraulic Computations

ATMOSPHERIC ENVIRONMENT SERVICE
SERVICE DE L"ENVIRONNEMENT ATMOSPHERIQUE

RAINFALL INTENSITY-DURATION FREQUENCY VALUES
INTENSITE, DUREE ET FREQUENCE DES PLUIES

DATA INTEGRATION DIVISION
LA DIVISION DU TRAITEMENT DES DONNEES

GUMBEL - METHOD OF MOMENTS/METHODE DES MOMENTS - 1990

`*******************************************************************************`

TABLE 1 GREENWOOD MTRCA ONT 6153020

LATITUDE 4354 LONGITUDE 7904 ELEVATION/ALTITUDE 128 M

`*******************************************************************************`

YEAR ANNEE	5 MIN	10 MIN	15 MIN	30 MIN	1 H	2 H	6 H	12 H	24 H
1960	5.1	10.2	15.2	17.8	26.7	28.4	29.7	31.5	46.5
1961	-99.9	-99.9	8.1	14.0	17.8	18.0	18.0	18.8	22.9
1964	-99.9	5.6	8.1	9.7	11.4	15.5	31.2	51.8	68.1
1965	-99.9	8.1	12.2	15.2	17.3	26.4	33.3	34.0	39.4
1966	-99.9	10.9	13.5	19.6	21.1	26.7	35.8	36.1	44.4
1967	-99.9	9.9	11.7	16.3	20.6	25.1	25.7	36.6	45.5
1970	4.8	7.4	9.4	18.8	23.6	23.6	24.9	30.5	35.8
1971	11.9	14.7	18.8	30.0	43.4	51.8	70.9	76.7	87.4
1972	6.1	10.7	13.0	15.0	21.8	27.4	27.4	37.1	39.9
1973	10.4	10.4	10.4	10.7	10.7	12.4	16.3	19.0	22.9
1974	5.3	7.9	10.4	17.3	21.6	24.1	28.7	30.2	34.3
1976	6.3	10.7	15.2	26.2	26.2	26.4	26.4	26.4	30.5
1977	7.6	11.7	13.5	19.0	19.6	27.4	32.8	32.8	35.3
1978	6.3	12.6	13.1	14.1	16.4	17.6	25.8	32.3	35.8
1979	9.1	14.0	19.9	38.8	38.9	38.9	38.9	39.4	40.6
1980	12.0	14.4	20.2	23.2	23.2	25.6	32.0	38.8	55.8
1981	9.6	14.4	17.3	20.5	25.4	26.8	50.0	50.0	50.8
1982	6.4	10.0	12.0	15.4	16.4	20.6	22.8	28.6	29.2
1983	7.8	11.6	16.3	23.3	29.2	30.2	31.4	32.8	33.6
1984	5.7	9.5	13.7	17.2	18.2	18.7	31.2	33.2	42.0
1985	6.3	9.6	11.8	16.3	23.3	25.2	33.6	33.6	33.6
1986	10.2	17.2	18.7	29.5	49.1	57.4	70.0	74.0	74.0
1987	9.3	11.6	14.8	16.5	23.2	34.9	44.0	49.8	50.2
1988	6.0	8.6	10.2	10.8	17.8	20.7	35.5	40.8	44.2

NOTE:-99.9 INDICATES MSG DATA
DONNEES MANQUANTES

# YRS. ANNEES	19	23	24	24	24	24	24	24	24
MEAN MOYENNE	7.7	10.9	13.6	19.0	23.5	27.1	34.0	38.1	43.4
STD. DEV. ECART-TYPE	2.3	2.7	3.5	6.8	9.1	10.3	13.4	14.1	15.4
SKEW DISSYMETRIE	0.61	0.36	0.35	1.29	1.45	1.62	1.73	1.55	1.36
KURTOSIS KURTOSIS	2.52	3.48	2.66	5.22	5.49	6.36	6.39	5.93	5.27

NOTE: -99.9 INDICATES LESS THAN 10 YEARS OF DATA AVAILABLE

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                          ATMOSPHERIC ENVIRONMENT SERVICE
                     SERVICE DE L"ENVIRONNEMENT ATMOSPHERIQUE

                   RAINFALL INTENSITY-DURATION FREQUENCY VALUES
                     INTENSITE, DUREE ET FREQUENCE DES PLUIES

               GUMBEL - METHOD OF MOMENTS/METHODE DES MOMENTS - 1990
********************************************************************************

         TABLE 2         GREENWOOD MTRCA          ONT                   6153020

         LATITUDE 4354       LONGITUDE  7904       ELEVATION/ALTITUDE  128  M
********************************************************************************

                            RETURN PERIOD RAINFALL AMOUNTS (MM)
                        PERIODE DE RETOUR QUANTITIES DE PLUIE (MM)

        DURATION    2        5        10       25       50      100   # YEARS
         DUREE    YR/ANS   YR/ANS   YR/ANS   YR/ANS   YR/ANS   YR/ANS  ANNEES
         5 MIN     7.3      9.4     10.7     12.4     13.7     14.9       19
        10 MIN    10.5     12.9     14.5     16.5     18.0     19.4       23
        15 MIN    13.1     16.2     18.2     20.9     22.8     24.7       24
        30 MIN    17.9     23.8     27.8     32.8     36.5     40.2       24
          1 H     22.0     30.0     35.4     42.1     47.1     52.1       24
          2 H     25.4     34.5     40.5     48.2     53.8     59.4       24
          6 H     31.8     43.7     51.5     61.4     68.8     76.1       24
         12 H     35.8     48.2     56.5     66.8     74.5     82.2       24
         24 H     40.9     54.5     63.5     74.9     83.4     91.8       24

            RETURN PERIOD RAINFALL RATES (MM/HR)-95% CONFIDENCE' LIMITS
  INTENSITE DE LA PLUIE PAR PERIODE DE RETOUR (MM/H)-LIMITES DE CONFIANCE DE 95%

        DURATION  2 YR/ANS  5 YR/ANS 10 YR/ANS 25 YR/ANS 50 YR/ANS 100 YR/ANS
         DUREE
          5 MIN      87.8     112.2     128.5     148.9     164.1     179.2
                 +/- 11.4  +/- 19.2  +/- 26.0  +/- 35.0  +/- 41.9  +/- 48.8

         10 MIN      63.0      77.3      86.9      98.9     107.8     116.7
                 +/-  6.1  +/- 10.3  +/- 13.9  +/- 18.7  +/- 22.4  +/- 26.1

         15 MIN      52.3      64.7      73.0      83.4      91.1      98.8
                 +/-  5.2  +/-  8.7  +/- 11.8  +/- 15.9  +/- 19.0  +/- 22.1

         30 MIN      35.7      47.7      55.6      65.7      73.1      80.5
                 +/-  5.0  +/-  8.4  +/- 11.3  +/- 15.3  +/- 18.3  +/- 21.3

           1 H       22.0      30.0      35.4      42.1      47.1      52.1
                 +/-  3.4  +/-  5.7  +/-  7.6  +/- 10.3  +/- 12.3  +/- 14.3

           2 H       12.7      17.2      20.3      24.1      26.9      29.7
                 +/-  1.9  +/-  3.2  +/-  4.3  +/-  5.8  +/-  7.0  +/-  8.1

           6 H        5.3       7.3       8.6      10.2      11.5      12.7
                 +/-  0.8  +/-  1.4  +/-  1.9  +/-  2.5  +/-  3.0  +/-  3.5

          12 H        3.0       4.0       4.7       5.6       6.2       6.8
                 +/-  0.4  +/-  0.7  +/-  1.0  +/-  1.3  +/-  1.6  +/-  1.8

          24 H        1.7       2.3       2.6       3.1       3.5       3.8
                 +/-  0.2  +/-  0.4  +/-  0.5  +/-  0.7  +/-  0.9  +/-  1.0
```

ATMOSPHERIC ENVIRONMENT SERVICE
SERVICE DE L"ENVIRONNEMENT ATMOSPHERIQUE

RAINFALL INTENSITY-DURATION FREQUENCY VALUES
INTENSITE, DUREE ET FREQUENCE DES PLUIES

GUMBEL - METHOD OF MOMENTS/METHODE DES MOMENTS - 1990

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TABLE 3 GREENWOOD MTRCA ONT 6153020

LATITUDE 4354 LONGITUDE 7904 ELEVATION/ALTITUDE 128 M

****

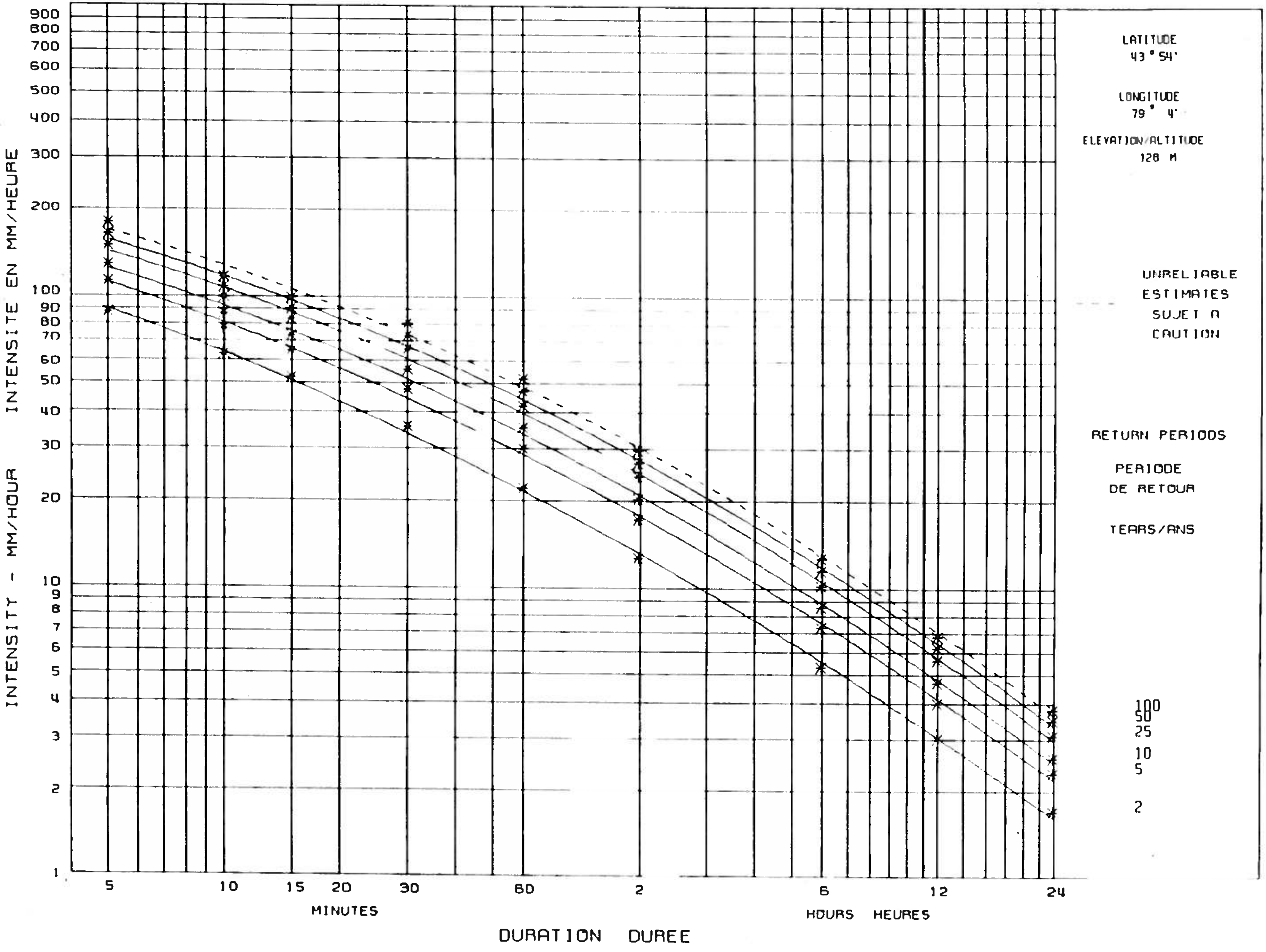
INTERPOLATION EQUATION / EQUATION D"INTERPOLATION: R = A * T ** B
R = RAINFALL RATE / INTENSITE DE LA PLUIE (MM /HR)
T = TIME IN HOURS / TEMPS EN HEURES

STATISTICS STATISTIQUES	2 YR ANS	5 YR ANS	10 YR ANS	25 YR ANS	50 YR ANS	100 YR ANS
MEAN OF R MOYENNE DE R	31.4	40.3	46.1	53.5	59.0	64.4
STD. DEV. R ECART-TYPE	30.5	38.2	43.3	49.8	54.7	59.5
STD. ERROR ERREUR STANDARD	8.6	11.0	12.6	14.8	16.4	18.0
COEFF. (A) COEFFICIENT (A)	18.6	24.5	28.3	33.2	36.8	40.4
EXPONENT (B) EXPOSANT (B)	-0.711	-0.697	-0.690	-0.684	-0.680	-0.677
MEAN % ERROR % D'ERREUR	10.7	12.3	13.2	14.2	14.8	15.2

SHORT DURATION RAINFALL INTENSITY-DURATION FREQUENCY DATA FOR-
DONNEES SUR L'INTENSITE, LA DUREE ET LA FREQUENCE DES CHUTES DE PLUIE DE COURTE DUREE A GREENWOOD MIRCA ONT

GUMBEL-METHOD OF MOMENTS
METHODE DES MOMENTS

BASED ON RECORDING RAIN GAUGE DATA FOR THE PERIOD-
BASEES SUR LES DONNEES DU PLUVIOGRAPHES POUR LA PERIOD 1960 - 1988 24 YEARS/AN



PREPARED BY - PREPARE PAR _E

ATMOSPHERIC ENVIRONMENT SERVICE - ENVIRONMENT CANADA
SERVICE DE L'ENVIRONNEMENT ATMOSPHERIQUE - ENVIRONNEMENT CANADA

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 ============================================================================
                                                        666   55555 ===============
                                                                    ===============
         T    T    HHHHH       M M M        0000                     Version [illegible]
         T    T    H   H       M   M              6666  5555         March  199[illegible]
         T    T    H   H       M   M                                ===============
                                                                     SERIAL# [illegible]
                                                        666   5555  ===============

   **************************************************************************
   ************************ [illegible] ************************************
   **************************************************************************
   ******* Distributed by:  J.F. Sabourin and Associates Inc.          *******
   *******                  Ottawa, Ontario  [illegible]               *******
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   *******                  E-Mail: JFSA@Compuserve.Com                *******
   **************************************************************************
   ******* Licensed user: J.F. Sabourin and Associates Inc.            *******
   *******                Ottawa           SERIAL# [illegible]         *******
   **************************************************************************
   **************************************************************************
   *******             ****** PROGRAM ARRAY DIMENSIONS ******          *******
   *******             Maximum value for ID numbers      [illegible]   *******
   *******             Max. number of rainfall points    500           *******
   *******             Max. number of flow points        500           *******
   **************************************************************************
   **************************************************************************
   ********************  D E T A I L E D   O U T P U T  ********************
   **************************************************************************
   *      DATE [illegible]        TIME [illegible]     RUN COUNTER [illegible] *
   **************************************************************************
   * Input   filename  [illegible] RAT-CR.DAT                               *
   * Output  filename  [illegible] RAT-CR.OUT                               *
   * Summary filename  [illegible] RAT-CR.sum                               *
   * User comments:                                                         *
   * 1:_____________________________________________________________________*
   * 2:_____________________________________________________________________*
   * 3:_____________________________________________________________________*
   **************************************************************************

 --------------------------------------------------------------------------------
 [illegible]------------------------------------------------------------------------
 *
 --------------------
 | START            |   Project dir.: [illegible]
 ----------------------  Rainfall dir.: [illegible]
   TZERO =     hrs
 --------------------
   METOUT=      (output = METRIC)
   NRUN  =
   NSTORM=
 --------------------------------------------------------------------------------
 --------------------------------------------------------------------------------
 *                         [illegible] filename [illegible]
 *
 --------------------
 | READ STORM       |   Filename: [illegible]
 | Ptotal= [illegible] mm |  Comments: [illegible]
 --------------------
                  TIME    RAIN    TIME    RAIN    TIME    RAIN    TIME    RAIN
                   hrs   mm/hr     hrs   mm/hr     hrs   mm/hr     hrs   mm/hr
                  [illegible]

 --------------------------------------------------------------------------------
 --------------------------------------------------------------------------------

 --------------------
 | DESIGN STANDHYD  |    Area    (ha)=
 | [illegible]      |    Total Imp(%)=  [illegible]   Dir. Conn.(%)= [illegible]
 --------------------
                            IMPERVIOUS    PERVIOUS (i)
     Surface Area    (ha)=
     Dep. Storage    (mm)=
     Average Slope    (%)=
     Length           (m)=
     Mannings n          =                      .25

     Max.eff.Inten.(mm/hr)=
              over (min)
     Storage Coeff. (min)=
     Unit Hyd. Tpeak (min)=
     Unit Hyd. peak  (cms)=
                                                          *TOTALS*
     PEAK FLOW       (cms)=
     TIME TO PEAK    (hrs)=
     RUNOFF VOLUME    (mm)=
     TOTAL RAINFALL   (mm)=
     RUNOFF COEFFICIENT   =
```

```
     *** WARNING: Storage Coefficient is smaller than DT!
                  Use a smaller DT or a larger area.

     (i)  CN PROCEDURE SELECTED FOR PERVIOUS LOSSES:
           CN*  =  80.0    Ia = Dep. Storage  (Above)
     (ii) TIME STEP (DT) SHOULD BE SMALLER OR EQUAL
          THAN THE STORAGE COEFFICIENT.
    (iii) PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

 -------------------------------------------------------------------------------
 0004---------------------------------------------------------------------------
 ******************************************************************************
 *# GRASS SWALES  SIDE SLOPE= 5:1  BOTTOM WIDTH=0.75 M  GRASS LINED
 *#  MAXIMUM DEPTH= 1 M  (Kentucky bluegrass mowed to 0.05 m
 *#  n values vary from 0.0575 up to 0.2 m and to 0.0425 up to 1.0 m
 ******************************************************************************
 *  SHORT GRASS SWALE SLOPE = 0.1%
 --------------------
 | ROUTE CHANNEL    |      Routing time step (min) =  5.00
 |  IN> 01:000101   |      Number of SEGMENTS =  3
 | OUT< 02:000201   |      Slopes (%), CHANNEL= [illegible]  FLOODPLAIN= [illegible]
 --------------------                  LENGTH = 1000.00     m

               <------- DATA FOR SECTION  (  1.0) ------->
                Distance      Elevation       Manning
                   .00          100.00          .0425
                  4.00           99.20        .0425 / .0575  Main Channel
                  5.00           99.00          .0575        Main Channel
                  5.75           99.00          .0575        Main Channel
                  6.75           99.20        .0575 / .0425  Main Channel
                 10.75          100.00          .0425

         <-------------------- TRAVEL TIME TABLE --------------------->
          DEPTH     ELEV      VOLUME     FLOW RATE    VELOCITY    TRAV.TIME
            m       (m)       (cu.m.)      (cms)       (m/s)        (min)
           .053   99.053   .500E+02       .003         .064       260.47
           .100   99.100   .125E+03       .012         .094       177.34
           .150   99.150   .225E+03       .026         .117       142.51
           .200   99.200   .350E+03       .048         .138       120.92
           .253   99.253   .511E+03       .087         .171        97.46
           .307   99.307   .700E+03       .139         .198        83.57
           .360   99.360   .910E+03       .205         .223        74.75
           .413   99.413   .116E+04       .286         .246        67.74
           .467   99.467   .144E+04       .385         .268        62.24
           .520   99.520   .174E+04       .503         .289        57.75
           .573   99.573   .207E+04       .640         .309        54.03
           .627   99.627   .243E+04       .798         .328        50.87
           .680   99.680   .282E+04       .975         .347        48.03
           .733   99.733   .324E+04      1.184         .365        45.61
           .787   99.787   .369E+04      1.413         .383        43.47
           .840   99.840   .416E+04      1.667         .401        41.57
           .893   99.893   .466E+04      1.946         .418        39.84
           .947   99.947   .519E+04      2.255         .435        38.32
          1.000  100.000   .575E+04      2.597         .452        36.9[illegible]

                                      <---- hydrograph ---->  <-pipe / channel->
                             AREA     QPEAK   TPEAK    R.V.  MAX DEPTH  MAX VEL
                             (ha)     (cms)   (hrs)    (mm)     (m)      (m/s)
   INFLOW : ID= 1:000101     1.00      .067    9.58   38.54     .226      .152
   OUTFLOW: ID= 2:000201     1.00      .023   10.42   38.84     .137      .110


 -------------------------------------------------------------------------------
 0005---------------------------------------------------------------------------
 *
 *  SHORT GRASS SWALE SLOPE = 0.25%
 --------------------
 | ROUTE CHANNEL    |      Routing time step (min) =  5.00
 |  IN> 01:000101   |      Number of SEGMENTS =  3
 | OUT< 02:000201   |      Slopes (%), CHANNEL= [illegible]  FLOODPLAIN= [illegible]
 --------------------                  LENGTH = 1000.00     m

               <------- DATA FOR SECTION  (  1.0) ------->
                Distance      Elevation       Manning
                   .00          100.00          .0425
                  4.00           99.20        .0425 / .0575  Main Channel
                  5.00           99.00          .0575        Main Channel
                  5.75           99.00          .0575        Main Channel
                  6.75           99.20        .0575 / .0425  Main Channel
                 10.75          100.00          .0425

         <-------------------- TRAVEL TIME TABLE --------------------->
          DEPTH     ELEV      VOLUME     FLOW RATE    VELOCITY    TRAV.TIME
            m        m        (cu.m.)      (cms)       (m/s)        (min)
           [illegible]  .500E+02   .005   .101   [illegible]
           [illegible]  .125E+03   .019   .149   [illegible]
           [illegible]  .225E+03   .042   .184   [illegible]
           [illegible]  .350E+03   .076   .219   [illegible]
           [illegible]  .511E+03   .138   .27[illegible]  [illegible]
           [illegible]  .700E+03   [illegible]   .314   [illegible]
           [illegible]  .910E+03   .324   .353   [illegible]
           [illegible]  .116E+04   .4[illegible]  .389   42.84
           [illegible]  .144E+04   [illegible]   .42[illegible]  [illegible]
           [illegible]  .174E+04   [illegible]   .45[illegible]  [illegible]
           [illegible]  .207E+04   [illegible]   .489   [illegible]
           .627   99.627   .243E+04   1.263   .51[illegible]  [illegible]
           .680   99.680   .282E+04   1.549   .549   [illegible]
           .733   99.733   .324E+04   1.871   .578   [illegible]
           .787   99.787   .369E+04   2.233   .607   [illegible]
           .840   99.840   .416E+04   2.636   .634   [illegible]
           .893   99.893   .466E+04   3.082   .661   [illegible]
           .947   99.947   .519E+04   3.573   .688   24.23
          1.000  100.000   .575E+04   4.107   .714   23.34

                                      <---- hydrograph ---->  <-pipe / channel->
                             AREA     QPEAK   TPEAK    R.V.  MAX DEPTH  MAX VEL
                             (ha)     (cms)   (hrs)    (mm)     (m)      (m/s)
   INFLOW : ID= 1:000101     1.00      .067    9.58   38.54     .187      .205
   OUTFLOW: ID= 2:000201     1.00      .0[illegible]   [illegible]   38.84   [illegible]   .60[illegible]


 -------------------------------------------------------------------------------
 0006---------------------------------------------------------------------------
 *
 *  SHORT GRASS SWALE SLOPE = 0.5%
 --------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |  IN> 01:000101   |      Number of SEGMENTS = [illegible]
 | OUT< 02:000201   |      Slopes (%), CHANNEL= [illegible]  FLOODPLAIN= [illegible]
 --------------------                  LENGTH = 1000.00     m

               <------- DATA FOR SECTION  ( [illegible] ) ------->
                Distance      Elevation       Manning
                   .00          100.00          .0425
                  4.00           99.20        .0425 / .0575  Main Channel
                  5.00           99.00          .0575        Main Channel
                  5.75           99.00          .0575        Main Channel
                  6.75           99.20        .0575 / .0425  Main Channel
                 10.75          100.00          .0425
```

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              ---------------------- TRAVEL TIME TABLE -----------------------
              DEPTH      ELEV        VOLUME     FLOW RATE     VELOCITY    TRAV TIME
               (m)        m          cu.m.        cms          m/s          min
               .050     99.05[illegible] .500E+0[illegible]   .00[illegible]   [illegible]   11[illegible] 40
               .100     99.1[illegible]  .125E+0[illegible]   .026          .210          79 3[illegible]
               .150     99.15[illegible] .225E+0[illegible]   .059          [illegible]   [illegible]
               .20[illegible] 99.2[illegible] .350E+0[illegible] .108      [illegible]   54 [illegible]
               .253     99.253     .511E+0[illegible]   .19[illegible] 38[illegible] 43 [illegible]
               .307     99.3[illegible]  .700E+0[illegible]   [illegible]   444           [illegible]
               .36[illegible] 99.36[illegible] .918E+0[illegible] 459      [illegible]   [illegible]
               .413     [illegible]  [illegible]E+04    [illegible]   [illegible]   [illegible]
               .467     99.467     .144E+04     [illegible]   [illegible]   [illegible]
               .52[illegible] [illegible] .174E+04 1.124      [illegible]   [illegible]
               .57[illegible] [illegible] .207E+04 1.43[illegible] [illegible] [illegible]
               .62[illegible] [illegible] .243E+04 [illegible] [illegible]  [illegible]
               .68[illegible] [illegible] .282E+04 [illegible] [illegible]  [illegible]
               .733     [illegible]  .324E+04     [illegible]   [illegible]   [illegible]
               .787     [illegible]  .368E+04     3.155         [illegible]   [illegible]
               .84      [illegible]  .416E+04     3.72[illegible] [illegible] [illegible]
               .893     [illegible]  .466E+04     4.358         [illegible]   [illegible]
               .947     [illegible]  .519E+04     5.05[illegible] [illegible] [illegible]
              1.000     [illegible]  .575E+04     5.[illegible] [illegible]   [illegible]

                                     ----- hydrograph -----    -pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                             (ha)    (cms)    (hrs)    (mm)      (m)      (m/s)
     INFLOW : ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
     OUTFLOW: ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]


--------------------------------------------------------------------------------
0007----------------------------------------------------------------------------
*
* SHORT GRASS SWALE SLOPE = [illegible]
---------------------
| ROUTE CHANNEL            Routing time step (min) = [illegible]
|   IN> 01:[illegible]     Number of SEGMENTS = [illegible]
| OUT< 02:[illegible]      Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
---------------------                  LENGTH = [illegible]        m

                  ------- DATA FOR SECTION  ( [illegible] ) -------
                  Distance       Elevation        Manning
                  [illegible]    [illegible]      [illegible]
                  [illegible]    [illegible]      .425  [illegible]   Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                  [illegible]    [illegible]      [illegible]  [illegible]  Main Channel
                  [illegible]    [illegible]      .425

              ---------------------- TRAVEL TIME TABLE -----------------------
              DEPTH      ELEV        VOLUME     FLOW RATE     VELOCITY    TRAV TIME
               (m)        m          cu.m.        cms          m/s          min
               [illegible]

                                     ----- hydrograph -----    -pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                             (ha)    (cms)    (hrs)    (mm)      (m)      (m/s)
     INFLOW : ID= [illegible]
     OUTFLOW: ID= [illegible]


--------------------------------------------------------------------------------
0008----------------------------------------------------------------------------
*
* SHORT GRASS SWALE [illegible]
---------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]        Number of SEGMENTS = [illegible]
  OUT< [illegible]         Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
---------------------                  LENGTH = [illegible]

                  ------- DATA FOR SECTION  ( [illegible] ) -------
                  Distance       Elevation        Manning
                  [illegible]    [illegible]      [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]  Main Channel

              ---------------------- TRAVEL TIME TABLE -----------------------
              DEPTH      ELEV        VOLUME     FLOW RATE     VELOCITY    TRAV TIME
               [illegible]

                                     ----- hydrograph -----    -pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
     INFLOW : ID= [illegible]
     OUTFL W: ID= [illegible]
```

```
--------------------------------------------------------------------------------
0009----------------------------------------------------------------------------
*
* SHORT GRASS SWALE SLOPE = 5%
---------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> 01:000101           Number of SEGMENTS = [illegible]
  OUT< 02:000201           Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
---------------------                  LENGTH = [illegible]        m

                  ------- DATA FOR SECTION  ( [illegible] ) -------
                  Distance       Elevation        Manning
                                                  .425
                  [illegible]    [illegible]      .425  [illegible]   Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                  [illegible]    [illegible]      [illegible]  .425   Main Channel
                  [illegible]    [illegible]      .425

              ---------------------- TRAVEL TIME TABLE -----------------------
              DEPTH      ELEV        VOLUME     FLOW RATE     VELOCITY    TRAV TIME
                m          m          cu.m        cms          m/s          min
               .050     99.05[illegible] .500E+0[illegible]  .02[illegible]  [illegible]  [illegible]
               .100     99.100     .125E+0[illegible]   .083          [illegible]   [illegible]
               .150     99.150     .225E+03     .187          [illegible]   [illegible]
               .200     99.200     .350E+03     .34[illegible] [illegible]  [illegible]
               .253     99.253     .511E+03     .61[illegible] [illegible]  [illegible]
               .307     99.307     .700E+03     .983          [illegible]   [illegible]
               .36[illegible] 99.36[illegible] .918E+0[illegible] 1.448  [illegible]  [illegible]
               .413     99.413     .116E+04     2.026         [illegible]   [illegible]
               .467     99.467     .144E+04     [illegible]   [illegible]   [illegible]
               .52[illegible] 99.52[illegible] .174E+04 3.5[illegible] [illegible] [illegible]
               .573     99.573     .207E+04     4.52[illegible] [illegible] [illegible]
               .627     99.627     .243E+04     5.648         [illegible]   [illegible]
               .68      99.68      .282E+04     [illegible]   [illegible]   [illegible]
               .733     99.733     .324E+04     [illegible]   [illegible]   [illegible]
               .787     99.787     .368E+04     [illegible]   [illegible]   [illegible]
               .84      99.84      .416E+04     [illegible]   [illegible]   [illegible]
               .893     99.893     .466E+04     13.79[illegible] [illegible] [illegible]
               .947     99.947     .519E+04     [illegible]   [illegible]   [illegible]
              1.000    100.000     .575E+04     [illegible]   [illegible]   [illegible]

                                     ----- hydrograph -----    -pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                             (ha)    (cms)    (hrs)    (mm)      (m)      (m/s)
     INFLOW : ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
     OUTFLOW: ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]


--------------------------------------------------------------------------------
 [illegible]--------------------------------------------------------------------
********************************************************************************
** GRASS SWALES   SIDE SLOPE= [illegible]   BOTTOM WIDTH= [illegible] m   GRASS LINED
** MAXIMUM DEPTH= [illegible] m   [illegible]
** [illegible] values vary from [illegible]
********************************************************************************
* LONG GRASS SWALE SLOPE = [illegible]
---------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
  OUT< [illegible]         Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
---------------------                  LENGTH = [illegible]

                  ------- DATA FOR SECTION  ( [illegible] ) -------
                  Distance       Elevation        Manning
                  [illegible]    [illegible]      [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]  Main Channel

              ---------------------- TRAVEL TIME TABLE -----------------------
              DEPTH      ELEV        VOLUME     FLOW RATE     VELOCITY    TRAV TIME
               [illegible]

                                     ----- hydrograph -----    -pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
     INFLOW : ID= [illegible]
     OUTFLOW: ID= [illegible]


--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
* [illegible] GRASS SWALE SLOPE = [illegible]
---------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
  OUT< [illegible]         Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
---------------------                  LENGTH = [illegible]

                  ------- DATA FOR SECTION  ( [illegible] ) -------
                  Distance       Elevation        Manning
                                                  .0500
                  [illegible]    [illegible]      .0500  [illegible]  Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                  [illegible]    [illegible]      [illegible]         Main Channel
                                                  .0500

              ---------------------- TRAVEL TIME TABLE -----------------------
              DEPTH      ELEV        VOLUME     FLOW RATE     VELOCITY    TRAV TIME
                m          m          cu.m        cms          m/s          min
               [illegible]
```

```
      .307   99.307   .700E+03     [illegible]     .242     49.95
      .360   99.360   .918E+03     .251            .272     [illegible]
      .413   99.413   .116E+04     .352            .303     [illegible]
      .467   99.467   .144E+04     .476            .331     50.38
      .520   99.520   .174E+04     .624            .358     [illegible]
      .573   99.573   .207E+04     .796            .385     43.[illegible]
      .627   99.627   .243E+04     [illegible]     .41[illegible]  [illegible]
      .680   99.680   .282E+04     1.23[illegible] .43[illegible]  38.[illegible]
      .733   99.733   .324E+04     1.492           .46[illegible]  [illegible]
      .787   99.787   .368E+04     1.79[illegible] .48[illegible]  34.[illegible]
      .840   99.840   .416E+04     2.[illegible]   .50[illegible]  32.[illegible]
      .893   99.893   .466E+04     2.4[illegible]  .52[illegible]  [illegible]
      .947   99.947   .519E+04     2.87[illegible] .55[illegible]  [illegible]
     [illegible]      .575E+04     [illegible]     .5[illegible]   [illegible]

                                   <---- hydrograph ---->   <-pipe / channel->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
 INFLOW : ID= [illegible]   [illegible]  [illegible]
 OUTFLOW: ID= [illegible]   [illegible]  [illegible]

-------------------------------------------------------------------------------
 12----------------------------------------------------------------------------
 *
 *  LONG GRASS SWALE SLOPE = [illegible]
 -------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN= [illegible]         Number of SEGMENTS = [illegible]
   OUT= [illegible]        Slopes (%), CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                   LENGTH = [illegible]   (m)

          <------- DATA FOR SECTION  ( 1.0) ------->
             Distance      Elevation       Manning
               [illegible]  100.[illegible]  .0500
              4.00         99.[illegible]   .0500 / .0750  Main Channel
              5.[illegible]  99.[illegible]    .0750   Main Channel
              5.75         99.[illegible]      .0750   Main Channel
              6.75         99.[illegible]   .0750 / .0500  Main Channel
             10.75         100.[illegible]     .0500

     <-------------------- TRAVEL TIME TABLE -------------------->
     DEPTH    ELEV      VOLUME    FLOW RATE   VELOCITY   TRAV.TIME
      (m)      (m)      (cu.m.)     (cms)      (m/s)       (min)
      .050   99.050   .500E+02   [illegible]  [illegible]  [illegible]
      .100   99.100   .125E+03   [illegible]  [illegible]  [illegible]
      .150   99.150   .225E+03   [illegible]  [illegible]  [illegible]
      .200   99.200   .350E+03   [illegible]  [illegible]  [illegible]
      .253   99.253   .511E+03   [illegible]  [illegible]  [illegible]
      .307   99.307   .700E+03   [illegible]  [illegible]  [illegible]
      .360   99.360   .918E+03   [illegible]  [illegible]  [illegible]
      .413   99.413   .116E+04   [illegible]  [illegible]  [illegible]
      .467   99.467   .144E+04   [illegible]  [illegible]  [illegible]
      .520   99.520   .174E+04   [illegible]  [illegible]  [illegible]
      .573   99.573   .207E+04   [illegible]  [illegible]  [illegible]
      .627   99.627   .243E+04   [illegible]  [illegible]  [illegible]
      .680   99.680   .282E+04   [illegible]  [illegible]  [illegible]
      .733   99.733   .324E+04   [illegible]  [illegible]  [illegible]
      .787   99.787   .368E+04   [illegible]  [illegible]  [illegible]
      .840   99.840   .416E+04   [illegible]  [illegible]  [illegible]
      .893   99.893   .466E+04   [illegible]  [illegible]  [illegible]
      .947   99.947   .519E+04   [illegible]  [illegible]  [illegible]
     [illegible]      .575E+04   [illegible]  [illegible]  [illegible]

                                   <---- hydrograph ---->   <-pipe / channel->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
 INFLOW : ID= [illegible]
 OUTFLOW: ID= [illegible]

-------------------------------------------------------------------------------
 13----------------------------------------------------------------------------
 *
 *  LONG GRASS SWALE SLOPE = [illegible]
 -------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN= [illegible]         Number of SEGMENTS = [illegible]
   OUT= 2:000201           Slopes (%), CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                   LENGTH = [illegible]

          <------- DATA FOR SECTION  ( [illegible] ) ------->
             Distance      Elevation       Manning
               [illegible]
              4.[illegible]   [illegible]   [illegible]  Main Channel
              [illegible]   [illegible]   [illegible]  Main Channel
              [illegible]   [illegible]   [illegible]  Main Channel
              [illegible]   [illegible]   [illegible]  Main Channel
              [illegible]   [illegible]   [illegible]

     <-------------------- TRAVEL TIME TABLE -------------------->
     DEPTH    ELEV      VOLUME    FLOW RATE   VELOCITY   TRAV.TIME
      (m)      (m)      (cu.m.)     (cms)      (m/s)       (min)
     [illegible]

                                   <---- hydrograph ---->   <-pipe / channel->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
 INFLOW : ID= [illegible]
 OUTFLOW: ID= [illegible]

-------------------------------------------------------------------------------
 14----------------------------------------------------------------------------
 *
 *  LONG GRASS SWALE SLOPE = [illegible]
 -------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN= [illegible]         Number of SEGMENTS = [illegible]
   OUT= [illegible]        Slopes (%), CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                   LENGTH = [illegible]
```

```
          <------- DATA FOR SECTION  ( 1.0) ------->
             Distance      Elevation       Manning
                 .00         100.00          .0500
                4.00          99.20     .0500 / .0750  Main Channel
                5.00          99.00          .0750     Main Channel
                5.75          99.00          .0750     Main Channel
                6.75          99.20     .0750 / .0500  Main Channel
               10.75         100.00          .0500

     <-------------------- TRAVEL TIME TABLE -------------------->
     DEPTH    ELEV      VOLUME    FLOW RATE   VELOCITY   TRAV.TIME
      (m)      (m)      (cu.m.)     (cms)      (m/s)       (min)
      .050   99.050   .500E+02      .012        .245       67.95
      .100   99.100   .125E+03      .045        .360       46.27
      .150   99.150   .225E+03      .101        .450       37.02
      .200   99.200   .350E+03      .185        .528       31.54
      .253   99.253   .511E+03      .335        .656       25.39
      .307   99.307   .700E+03      .535        .764       21.80
      .360   99.360   .918E+03      .792        .863       19.31
      .413   99.413   .116E+04     1.114        .957       17.42
      .467   99.467   .144E+04     1.506       1.046       15.93
      .520   99.520   .174E+04     1.973       1.133       14.71
      .573   99.573   .207E+04     2.523       1.217       13.70
      .627   99.627   .243E+04     3.160       1.298       12.83
      .680   99.680   .282E+04     3.890       1.379       12.09
      .733   99.733   .324E+04     4.717       1.456       11.44
      .787   99.787   .368E+04     5.647       1.533       10.87
      .840   99.840   .416E+04     6.685       1.607       10.37
      .893   99.893   .466E+04     7.834       1.681        9.92
      .947   99.947   .519E+04     9.100       1.753        9.51
     1.000  100.000   .575E+04    10.488       1.824        9.14

                                   <---- hydrograph ---->   <-pipe / channel->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
 INFLOW : ID= 1:000101    1.00     .067    9.58  38.904     .120       .351
 OUTFLOW: ID= 2:000201    1.00     .036    9.67  38.901     .085       .317

-------------------------------------------------------------------------------
 0015--------------------------------------------------------------------------
 *
 *  LONG GRASS SWALE SLOPE = 5%
 -------------------
  ROUTE CHANNEL            Routing time step (min) =  5.00
   IN= 1:000101            Number of SEGMENTS =  1
   OUT= 2:000201           Slopes (%), CHANNEL=5.00   FLOODPLAIN=5.00
 -------------------                   LENGTH = 1000.00    (m)

          <------- DATA FOR SECTION  ( 1.0) ------->
             Distance      Elevation       Manning
                 .00         100.00          .0500
                4.00          99.20     .0500 / .0750  Main Channel
                5.00          99.00          .0750     Main Channel
                5.75          99.00          .0750     Main Channel
                6.75          99.20     .0750 / .0500  Main Channel
               10.75         100.00          .0500

     <-------------------- TRAVEL TIME TABLE -------------------->
     DEPTH    ELEV      VOLUME    FLOW RATE   VELOCITY   TRAV.TIME
      (m)      (m)      (cu.m.)     (cms)      (m/s)       (min)
      .050   99.050   .500E+02      .017        .347       48.05
      .100   99.100   .125E+03      .064        .509       32.72
      .150   99.150   .225E+03      .143        .637       26.17
      .200   99.200   .350E+03      .262        .747       22.30
      .253   99.253   .511E+03      .474        .929       17.95
      .307   99.307   .700E+03      .757       1.081       15.42
      .360   99.360   .918E+03     1.121       1.221       13.65
      .413   99.413   .116E+04     1.575       1.353       12.32
      .467   99.467   .144E+04     2.129       1.480       11.26
      .520   99.520   .174E+04     2.791       1.602       10.40
      .573   99.573   .207E+04     3.568       1.721        9.69
      .627   99.627   .243E+04     4.469       1.836        9.08
      .680   99.680   .282E+04     5.501       1.949        8.55
      .733   99.733   .324E+04     6.671       2.060        8.09
      .787   99.787   .368E+04     7.986       2.168        7.69
      .840   99.840   .416E+04     9.453       2.273        7.33
      .893   99.893   .466E+04    11.079       2.377        7.01
      .947   99.947   .519E+04    12.870       2.479        6.72
     1.000  100.000   .575E+04    14.832       2.579        6.46

                                   <---- hydrograph ---->   <-pipe / channel->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
 INFLOW : ID= 1:000101    1.00     .067    9.58  38.904     .101       .524
 OUTFLOW: ID= 2:000201    1.00     .036    9.67  38.902     .074       .436

-------------------------------------------------------------------------------
 *-----------------------------------------------------------------------------
*******************************************************************************
** SHALLOW GRASS SWALES   V-SHAPE  SIDE SLOPE= 25:1   GRASS LINED N=0.0575
** MAXIMUM DEPTH = 1 m
*******************************************************************************
 *  SHALLOW GRASS SWALE SLOPE = 0.1%
 -------------------
  ROUTE CHANNEL            Routing time step (min) =  5.00
   IN= 1:000101            Number of SEGMENTS =  1
   OUT= 2:000201           Slopes (%), CHANNEL= .10   FLOODPLAIN= .10
 -------------------                   LENGTH = 1000.00    (m)

          <------- DATA FOR SECTION  ( 1.0) ------->
             Distance      Elevation       Manning
                 .00         100.00          .0575
               25.00          99.00     .0575 / .0575  Main Channel
               50.00         100.00          .0575     Main Channel

     <-------------------- TRAVEL TIME TABLE -------------------->
     DEPTH    ELEV      VOLUME    FLOW RATE   VELOCITY   TRAV.TIME
      (m)      (m)      (cu.m.)     (cms)      (m/s)       (min)
      .053   99.053   .692E+02      .003        .049      342.71
      .105   99.105   .277E+03      .021        .077      215.89
      .158   99.158   .623E+03      .061        .101      164.76
      .211   99.211   .111E+04      .136        .123      136.05
      .263   99.263   .173E+04      .246        .142      117.25
      .316   99.316   .249E+04      .400        .161      103.79
      .368   99.368   .339E+04      .604        .178       93.65
      .421   99.421   .443E+04      .862        .195       85.48
      .474   99.474   .561E+04     1.180        .210       79.21
      .526   99.526   .692E+04     1.563        .226       73.83
      .579   99.579   .838E+04     2.016        .241       69.29
      .632   99.632   .997E+04     2.542        .255       65.38
      .684   99.684   .117E+05     3.147        .269       61.96
      .737   99.737   .136E+05     3.834        .282       59.00
      .789   99.789   .156E+05     4.609        .296       56.35
      .842   99.842   .177E+05     5.474        .309       53.97
      .895   99.895   .200E+05     6.435        .321       51.83
      .947   99.947   .224E+05     7.494        .334       49.9
```

```
00775>      [illegible]        .250E+05        [illegible]        [illegible]      [illegible]
00776>
00777>                                        ----- hydrograph -----   --pipe / channel--
00778>                                 AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
00779>                                  ha      cms     hrs     mm        m        m/s
00780>    INFLOW   ID= [illegible]      [illegible]   .067    9.50  30.904   [illegible]   [illegible]
00781>    OUTFLOW  ID= [illegible]      [illegible]   [illegible]   10.42  30.884   [illegible]   [illegible]
00782>
00783>
00784> ------------------------------------------------------------------------------
00785> [illegible]--------------------------------------------------------------------
00786> *
00787> *  SHALLOW GRASS SWALE SLOPE = [illegible]
00788> --------------------
00789>  ROUTE CHANNEL          Routing time step (min) = [illegible]
00790>   IN> [illegible]        Number of SEGMENTS = [illegible]
00791>  OUT> [illegible]        Slopes  %  CHANNEL= [illegible]   FLOODPLAIN= [illegible]
00792> --------------------                   LENGTH = [illegible]      m
00793>
00794>             ------- DATA FOR SECTION   [illegible]  -------
00795>                 Distance       Elevation        Manning
00796>                    [illegible]
00797>                    [illegible]     [illegible]    [illegible]   Main Channel
00798>                    [illegible]     [illegible]    [illegible]   Main Channel
00799>
00800>        --------------------- TRAVEL TIME TABLE ----------------------
00801>         DEPTH     ELEV      VOLUME     FLOW RATE    VELOCITY   TRAV TIME
00802>           m         m        cu.m         cms         m/s        min
          [illegible]
00829>
00830> ------------------------------------------------------------------------------
00831> [illegible]--------------------------------------------------------------------
00832> *
00833> *  SHALLOW GRASS SWALE SLOPE = [illegible]
00834> --------------------
00835>  ROUTE CHANNEL          Routing time step (min) = [illegible]
          [illegible]
```

```
00904>        .526    99.526    .692E+04      4.943       [illegible]   [illegible]
00905>        .579    99.579    .838E+04      6.374       [illegible]   [illegible]
00906>        .632    99.632    .997E+04      8.018       .806        [illegible]
00907>        .684    99.684    .117E+05      9.951       .850        19.60
00908>        .737    99.737    .136E+05     12.125       .893        18.66
00909>        .789    99.789    .156E+05     14.574       .935        17.82
00910>        .842    99.842    .177E+05     17.311       .977        [illegible]
00911>        .895    99.895    .200E+05     20.349      1.017        16.39
00912>        .947    99.947    .224E+05     23.699      1.056        15.78
00913>       1.000   100.000    .250E+05     27.375      1.095        15.22
00914>
00915>                                        ----- hydrograph -----   --pipe / channel--
00916>                                 AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
00917>                                  ha      cms     hrs     mm        m        m/s
00918>    INFLOW   ID= [illegible]      [illegible]   .067    9.50  30.904   [illegible]   .244
00919>    OUTFLOW  ID= [illegible]      [illegible]   .027   10.42  30.884   [illegible]   [illegible]
00920>
00921>
00922> ------------------------------------------------------------------------------
00923> [illegible]--------------------------------------------------------------------
00924> *
00925> *  SHALLOW GRASS SWALE SLOPE = 2.5%
00926> --------------------
00927>  ROUTE CHANNEL          Routing time step (min) = 5.0
00928>   IN> [illegible]        Number of SEGMENTS = [illegible]
00929>  OUT> [illegible]        Slopes  %  CHANNEL=2.50   FLOODPLAIN=[illegible]
00930> --------------------                   LENGTH = 1000.0      m
00931>
00932>             ------- DATA FOR SECTION   [illegible]  -------
00933>                 Distance       Elevation        Manning
00934>                    [illegible]
00935>                    [illegible]     [illegible]    [illegible]   Main Channel
00936>                    [illegible]     [illegible]    .0575         Main Channel
00937>
00938>        --------------------- TRAVEL TIME TABLE ----------------------
00939>         DEPTH     ELEV      VOLUME     FLOW RATE    VELOCITY   TRAV TIME
00940>           m         m        cu.m         cms         m/s        min
00941>        [illegible]  [illegible]  .692E+03  [illegible]  [illegible]  [illegible]
00942>        [illegible]  [illegible]  .277E+03  [illegible]  [illegible]  43.14
00943>        .158    99.158    .623E+03      .315       [illegible]   32.95
00944>        [illegible]  [illegible]  .111E+04   .679      [illegible]  [illegible]
00945>        .263    99.263    .173E+04     1.231       [illegible]   23.44
00946>        .316    99.316    .249E+04     2.002       [illegible]   [illegible]
00947>        .368    99.368    .339E+04     3.019       [illegible]   [illegible]
00948>        .421    99.421    .443E+04     4.311       [illegible]   [illegible]
00949>        .474    99.474    .561E+04     5.901       1.052         [illegible]
          [illegible]
```

```
   ------------------------------------------------------------------------------
   * V-SHAPE ... SHAPE WITH [illegible] SIDE SLOPE
   * MAXIMUM DEPTH ... KENTUCKY BLUEGRASS ... [illegible]
   ------------------------------------------------------------------------------
          [illegible]
            ------- DATA FOR SECTION   [illegible]  -------
                Distance       Elevation        Manning
                   [illegible]     [illegible]    [illegible]   Main Channel
                   [illegible]     [illegible]    [illegible]   Main Channel
```

```
         ---------------------- TRAVEL TIME TABLE ----------------------
         DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
          (m)       m        (cu.m.)       cms         (m/s)       min
          .053    99.053    .831E+01       .001         .064      262.22
          .105    99.105    .332E+02       .003         .101      165.15
          .158    99.158    .748E+02       .010         .132      126.06
          .211    99.211    .133E+03       .021         .160      104.06
          .263    99.263    .208E+03       .039         .186       89.68
          .316    99.316    .299E+03       .063         .210       79.4
          .368    99.368    .407E+03       .095         .233       71.48
          .421    99.421    .532E+03       .135         .254       65.55
          .474    99.474    .673E+03       .185         .275       60.6
          .526    99.526    .831E+03       .245         .295       56.4
          .579    99.579    .101E+04       .316         .314       53.
          .632    99.632    .120E+04       .399         .333       50.
          .684    99.684    .140E+04       .494         .351       47.43
          .737    99.737    .163E+04       .6           .369       45.14
          .789    99.789    .187E+04       [illegible]  .387       43.1
          .842    99.842    .213E+04       [illegible]  .404       41.3
          .895    99.895    .240E+04       1.          .420       39.6
          .947    99.947    .269E+04       1.175        .437       39.14
         1.000   100.000    .300E+04       1.355        .453       36.83

                                      <---- hydrograph ----> <-pipe / channel->
                            AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                             ha      cms     hrs      mm        m        m/s
    INFLOW : ID= [illegible]  1.00   [illegible]  [illegible]   .321       .313
    OUTFLOW: ID= [illegible]  1.00   [illegible]  [illegible]   .324       .288


 ------------------------------------------------------------------------------
 023---------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 3:1 SLOPE =  .25% MOWED GRASS
 ---------------------
 | ROUTE CHANNEL          Routing time step (min) = 5.[illegible]
 |   IN> 01:000101        Number of SEGMENTS = [illegible]
 |  OUT< 02:000202        Slopes (%), CHANNEL= .25   FLOODPLAIN= .25
 ---------------------                  LENGTH = [illegible]  m

                <------- DATA FOR SECTION    ( 2.0) ------->
                Distance       Elevation        Manning
                                [illegible]       .0425
                  [illegible]     99.[illegible]   .0425   .0425  Main Channe.
                  [illegible]    100.[illegible]     .0425        Main Channe.

         ---------------------- TRAVEL TIME TABLE ----------------------
         DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
           m         m         cu.m        cms          m/s         min
          .053    99.053    .831E+01    [illegible]      .101      165.44
          .105    99.105    .332E+02       .005         .160      104.47
          .158    99.158    .748E+02       .016         .209       79.[illegible]
          .211    99.211    .133E+03       .034         .253       65.94
          .263    99.263    .208E+03       .061         .294       56.[illegible]
          .316    99.316    .299E+03       .099         .331       50.[illegible]
          .368    99.368    .407E+03       .15          .368       45.31
          .421    99.421    .532E+03       .214         .402       41.48
          .474    99.474    .673E+03       .292         .435       38.[illegible]
          .526    99.526    .831E+03       .388         .466       35.7
          .579    99.579    .101E+04       [illegible]  .497       33.5
          .632    99.632    .120E+04       .63          .527       31.64
          .684    99.684    .140E+04       [illegible]  .556       [illegible]
          .737    99.737    .163E+04       [illegible]  .584       [illegible]
          .789    99.789    .187E+04       [illegible]  [illegible] [illegible]
          .842    99.842    .213E+04       [illegible]  .63        [illegible]
          .895    99.895    .240E+04       [illegible]  .664       [illegible]
          .947    99.947    .269E+04       [illegible]  .69        24.[illegible]
         1.000   100.000    .300E+04       [illegible]  [illegible] [illegible]

                                      <---- hydrograph ----> <-pipe / channel->
                            AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                             ha      cms     hrs      mm        m        m/s
    INFLOW : ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
    OUTFLOW: ID= [illegible]  [illegible]  [illegible]  [illegible]  .24


 ------------------------------------------------------------------------------
 [illegible]-------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% MOWED GRASS
 ---------------------
 | ROUTE CHANNEL          Routing time step (min) = [illegible]
 |   IN> [illegible]      Number of SEGMENTS = [illegible]
 |  OUT< [illegible]      Slopes (%), CHANNEL= [illegible]  FLOODPLAIN= [illegible]
 ---------------------                  LENGTH = [illegible]  m

                <------- DATA FOR SECTION    ( [illegible] ) ------->
                Distance       Elevation        Manning
                                                  .0425
                                [illegible]   .0425   .0425  Main Channe.
                                                .0425        Main Channe.

         ---------------------- TRAVEL TIME TABLE ----------------------
         DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
           m         m         cu.m        cms          m/s         min
          .053    99.053    .831E+01    [illegible]   [illegible]  [illegible]
          .105    99.105    .332E+02    [illegible]   [illegible]  [illegible]
          .158    99.158    .748E+02    [illegible]   [illegible]  [illegible]
          .211    99.211    .133E+03       .04         .354        46.54
          .263    99.263    .208E+03    [illegible]   [illegible]  [illegible]
          .316    99.316    .299E+03       .14         [illegible]  [illegible]
          .368    99.368    .407E+03    [illegible]   [illegible]  [illegible]
          .421    99.421    .532E+03    [illegible]   [illegible]  [illegible]
          .474    99.474    .673E+03    [illegible]   [illegible]  [illegible]
          .526    99.526    .831E+03    [illegible]   [illegible]  [illegible]
          .579    99.579    .101E+04    [illegible]   [illegible]  [illegible]
          .632    99.632    .120E+04    [illegible]   [illegible]  [illegible]
          .684    99.684    .140E+04    [illegible]   [illegible]  [illegible]
          .737    99.737    .163E+04    [illegible]   [illegible]  [illegible]
          .789    99.789    .187E+04    [illegible]   [illegible]  [illegible]
          .842    99.842    .213E+04    [illegible]   [illegible]  [illegible]
          .895    99.895    .240E+04    [illegible]   [illegible]  [illegible]
          .947    99.947    .269E+04    [illegible]   [illegible]  [illegible]
         1.000   100.000    .300E+04       1.012      [illegible]  [illegible]

                                      <---- hydrograph ----> <-pipe / channel->
                            AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                             ha      cms     hrs      mm        m        m/s
    INFLOW : ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  .39
    OUTFLOW: ID= [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  .3


 ------------------------------------------------------------------------------
 025---------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MOWED GRASS
 ---------------------
 | ROUTE CHANNEL          Routing time step (min) = [illegible]
 |   IN> [illegible]      Number of SEGMENTS = [illegible]
```

```
 |  OUT< 02:000202        Slopes (%), CHANNEL=1.00   FLOODPLAIN=1.00
 ---------------------                  LENGTH = 1000.00     m

                <------- DATA FOR SECTION    ( 2.0) ------->
                Distance       Elevation        Manning
                    .00          100.00          .0425
                   3.00           99.00       .0425   .0425  Main Channe.
                   6.00          100.00          .0425       Main Channe.

         ---------------------- TRAVEL TIME TABLE ----------------------
         DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          (m)       (m)      (cu.m.)       cms         m/s         min
          .053    99.053    .831E+01       .002         .201       82.92
          .105    99.105    .332E+02       .011         .319       52.24
          .158    99.158    .748E+02       .031         .418       39.86
          .211    99.211    .133E+03       .067         .506       32.93
          .263    99.263    .208E+03       .122         .588       28.36
          .316    99.316    .299E+03       .199         .664       25.1
          .368    99.368    .407E+03       .299         .736       22.66
          .421    99.421    .532E+03       .428         .804       20.73
          .474    99.474    .673E+03       .585         .870       19.16
          .526    99.526    .831E+03       .775         .933       17.86
          .579    99.579    .101E+04      1.000         .994       16.76
          .632    99.632    .120E+04      1.261        1.054       15.82
          .684    99.684    .140E+04      1.561        1.111       15.00
          .737    99.737    .163E+04      1.902        1.168       14.28
          .789    99.789    .187E+04      2.286        1.222       13.63
          .842    99.842    .213E+04      2.715        1.276       13.06
          .895    99.895    .240E+04      3.191        1.329       12.54
          .947    99.947    .269E+04      3.717        1.380       12.07
         1.000   100.000    .300E+04      4.293        1.431       11.65

                                      <---- hydrograph ----> <-pipe / channel->
                            AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                             ha      cms     hrs      mm        m        m/s
    INFLOW : ID= 1:000101    1.00    .067    9.58   38.904     .211      .577
    OUTFLOW: ID= 2:000202    1.00    .061    9.67   38.900     .202      .554


 ------------------------------------------------------------------------------
 0026--------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 3:1 SLOPE = 2.5% MOWED GRASS
 ---------------------
 | ROUTE CHANNEL          Routing time step (min) =  5.00
 |   IN> 01:000101        Number of SEGMENTS =  2
 |  OUT< 02:000202        Slopes (%), CHANNEL=2.50   FLOODPLAIN=2.50
 ---------------------                  LENGTH = 1000.00     m

                <------- DATA FOR SECTION    ( 2.0) ------->
                Distance       Elevation        Manning
                    .00          100.00          .0425
                   3.00           99.00       .0425   .0425  Main Channe.
                   6.00          100.00          .0425       Main Channe.

         ---------------------- TRAVEL TIME TABLE ----------------------
         DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          (m)       (m)      (cu.m.)      (cms)         m/s        (min)
          .053    99.053    .831E+01       .003         .318       52.44
          .105    99.105    .332E+02       .017         .504       33.06
          .158    99.158    .748E+02       .049         .661       25.21
          .211    99.211    .133E+03       .106         .801       20.81
          .263    99.263    .208E+03       .193         .929       17.94
          .316    99.316    .299E+03       .314        1.049       15.89
          .368    99.368    .407E+03       .474        1.163       14.33
          .421    99.421    .532E+03       .676        1.271       13.11
          .474    99.474    .673E+03       .926        1.375       12.12
          .526    99.526    .831E+03      1.226        1.475       11.30
          .579    99.579    .101E+04      1.580        1.571       10.60
          .632    99.632    .120E+04      1.993        1.666       10.01
          .684    99.684    .140E+04      2.468        1.757        9.49
          .737    99.737    .163E+04      3.007        1.846        9.03
          .789    99.789    .187E+04      3.614        1.933        8.62
          .842    99.842    .213E+04      4.293        2.018        8.26
          .895    99.895    .240E+04      5.046        2.101        7.93
          .947    99.947    .269E+04      5.877        2.183        7.64
         1.000   100.000    .300E+04      6.788        2.263        7.37

                                      <---- hydrograph ----> <-pipe / channel->
                            AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                             ha      cms     hrs      mm        m        m/s
    INFLOW : ID= [illegible]  [illegible]  .67   9.58   38.904    .174      .859
    OUTFLOW: ID= [illegible]  [illegible]  .64   9.67   38.902    .152      .840


 ------------------------------------------------------------------------------
 [illegible]-------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = 5% MOWED GRASS
 ---------------------
 | ROUTE CHANNEL          Routing time step (min) =  5.00
 |   IN> 01:000101        Number of SEGMENTS =  2
 |  OUT< 02:000202        Slopes (%), CHANNEL=5.00   FLOODPLAIN=5.00
 ---------------------                  LENGTH = 1000.00     m

                <------- DATA FOR SECTION    ( 2.0) ------->
                Distance       Elevation        Manning
                    .00          100.00          .0425
                   3.00           99.00       .0425   .0425  Main Channe.
                   6.00          100.00          .0425       Main Channe.

         ---------------------- TRAVEL TIME TABLE ----------------------
         DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
           m         m         cu.m        cms          m/s        (min)
          .053    99.053    .831E+01       .004         .449       37.08
          .105    99.105    .332E+02       .024         .713       23.38
          .158    99.158    .748E+02       .070         .935       17.83
          .211    99.211    .133E+03       .151        1.133       14.71
          .263    99.263    .208E+03       .273        1.314       12.69
          .316    99.316    .299E+03       .444        1.484       11.23
          .368    99.368    .407E+03       .670        1.645       10.13
          .421    99.421    .532E+03       .956        1.798        9.27
          .474    99.474    .673E+03      1.309        1.945        8.57
          .526    99.526    .831E+03      1.734        2.086        7.99
          .579    99.579    .101E+04      2.235        2.223        7.50
          .632    99.632    .120E+04      2.819        2.356        7.07
          .684    99.684    .140E+04      3.490        2.485        6.71
          .737    99.737    .163E+04      4.252        2.611        6.38
          .789    99.789    .187E+04      5.111        2.734        6.10
          .842    99.842    .213E+04      6.071        2.854        5.84
          .895    99.895    .240E+04      7.136        2.971        5.61
          .947    99.947    .269E+04      8.311        3.087        5.4
         1.000   100.000    .300E+04      9.600        3.200        5.21

                                      <---- hydrograph ----> <-pipe / channel->
                            AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                             ha      cms     hrs      mm        m        m/s
    INFLOW : ID= [illegible]  [illegible]  .067   9.58   38.904    .155     1.16
    OUTFLOW: ID= [illegible]  [illegible]  .064   9.67   38.902    .134     1.1
```

```
-------------------------------------------------------------------------------
0028---------------------------------------------------------------------------
*
*******************************************************************************
*# ROAD SIDE DITCH [illegible] V SHAPE WITH 3 : 1 SIDE SLOPE
*#  MAXIMUM DEPTH= [illegible] KENTUCKY BLUEGRASS LENGTH= [illegible]
*******************************************************************************
*  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
--------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]        Slopes (%): CHANNEL= [illegible]  FLOODPLAIN= [illegible]
--------------------                      LENGTH = 1000.[illegible]  m

              ------- DATA FOR SECTION  [illegible] -------
              Distance      Elevation      Manning
                 [illegible]                .050[illegible]
                 [illegible]   [illegible]  .050[illegible] .050  Main Channel
                 [illegible]   [illegible]     .050          Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
       DEPTH    ELEV       VOLUME     FLOW RATE   VELOCITY   TRAV.TIME
         m        m         cu.m        cms         m/s        min
       [illegible]  [illegible]  .831E+[illegible]  [illegible]
       [illegible]  [illegible]  .332E+[illegible]  [illegible]
       [illegible]  [illegible]  .498E+[illegible]  [illegible]
       [illegible]  [illegible]  .133E+[illegible]  [illegible]
       [illegible]  [illegible]  .208E+[illegible]  [illegible]
       [illegible]  [illegible]  .299E+[illegible]  [illegible]
       [illegible]  [illegible]  .407E+[illegible]  [illegible]
        .421   99.421    .532E+[illegible]  [illegible]
        .474   99.474    .673E+[illegible]  [illegible]
        .526   99.526    .831E+[illegible]  [illegible]
        .579   99.579    .101E+04  [illegible]
        .632   99.632    .120E+04  [illegible]
        .684   99.684    .140E+04  [illegible]
        .737   99.737    .163E+04  [illegible]
        .789   99.789    .187E+04  [illegible]
        .842   99.842    .213E+04  [illegible]
        .895   99.895    .240E+04  [illegible]
        .947   99.947    .269E+04  [illegible]
       [illegible]  [illegible]  .300E+04  [illegible]

                               ---- hydrograph ----   <-pipe / channel->
                        AREA   QPEAK  TPEAK   R.V.  MAX DEPTH  MAX VEL
                         ha     cms    hrs     mm      m        m/s
  INFLOW   ID= [illegible]  [illegible]  [illegible] 30.[illegible]  .343  [illegible]
  OUTFLOW  ID= [illegible]  [illegible]  [illegible] 30.[illegible]  .2[illegible]  [illegible]


-------------------------------------------------------------------------------
0029---------------------------------------------------------------------------
*
*  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
--------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]        Slopes (%): CHANNEL= [illegible]  FLOODPLAIN= [illegible]
--------------------                      LENGTH = [illegible]  m

              ------- DATA FOR SECTION  [illegible] -------
              Distance      Elevation      Manning
              [illegible]
              [illegible]                               Main Channel
              [illegible]                               Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
       DEPTH    ELEV       VOLUME     FLOW RATE   VELOCITY   TRAV.TIME
         m        m         cu.m        cms         m/s        min
       [illegible]

                               ---- hydrograph ----   <-pipe / channel->
                        AREA   QPEAK  TPEAK   R.V.  MAX DEPTH  MAX VEL
                         ha     cms    hrs     mm      m        m/s
  INFLOW   ID= [illegible]
  OUTFLOW  ID= [illegible]


-------------------------------------------------------------------------------
0030---------------------------------------------------------------------------
*
*  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
--------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]        Slopes (%): CHANNEL= [illegible]  FLOODPLAIN= [illegible]
--------------------                      LENGTH = [illegible]  m

              ------- DATA FOR SECTION  [illegible] -------
              Distance      Elevation      Manning
                 [illegible]                .050[illegible]
                 [illegible]                [illegible]  Main Channel
                 [illegible]                .050          Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
       DEPTH    ELEV       VOLUME     FLOW RATE   VELOCITY   TRAV.TIME
         m        m         cu.m        cms         m/s        min
       [illegible]
        .684   99.684    .140E+04       .930        .666       24.95
        .737   99.737    .163E+04      1.143     [illegible]   [illegible]
        .789   99.789    .187E+04      1.374     [illegible]   [illegible]
        .842   99.842    .213E+04      1.632     [illegible]   [illegible]
        .895   99.895    .240E+04      1.910     [illegible]   20.87
        .947   99.947    .269E+04      2.234        .830       20.09
       1.000  100.000    .300E+04      2.580        .860       19.38

                               ---- hydrograph ----   <-pipe / channel->
                        AREA   QPEAK  TPEAK   R.V.  MAX DEPTH  MAX VEL
                        (ha)   (cms)  (hrs)   (mm)     (m)      (m/s)
  INFLOW   ID= 1:000101   1.00   .067   9.58 30.904    .254      .343
  OUTFLOW  ID= 2:000202   1.00   .034   9.67 30.896    .195      .286


-------------------------------------------------------------------------------
0031---------------------------------------------------------------------------
*
*  ROAD SIDE DITCH 3:1 SLOPE = 1.0% MEDIUM GRASS
--------------------
  ROUTE CHANNEL            Routing time step (min) = 5.00
   IN> 1:000101            Number of SEGMENTS = [illegible]
   OUT< 2:000202           Slopes (%): CHANNEL=1.00  FLOODPLAIN=1.00
--------------------                      LENGTH = 1000.00  m

              ------- DATA FOR SECTION  [illegible] -------
              Distance      Elevation      Manning
                 [illegible]   100.00        .0500
                 3.00           99.00        .0500 / .0500  Main Channel
                 6.00          100.00        .0500          Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
       DEPTH    ELEV       VOLUME     FLOW RATE   VELOCITY   TRAV.TIME
         m       (m)       (cu.m.)     (cms)        m/s       (min)
        .053   99.053    .831E+01       .001     [illegible]    97.55
       [illegible]   99.105    .332E+02       .009     [illegible]    61.46
       [illegible]   99.158    .748E+02       .027        .355       46.90
       [illegible]   99.211    .133E+03       .057        .431       38.71
        .263   99.263    .208E+03       .104        .500       33.36
        .316   99.316    .299E+03       .169        .564       29.54
        .368   99.368    .407E+03       .255        .625       26.66
        .421   99.421    .532E+03       .363        .683       24.39
        .474   99.474    .673E+03       .496        .739       22.55
        .526   99.526    .831E+03       .654        .793       21.02
        .579   99.579    .101E+04       .95[illegible]    .845       19.72
        .632   99.632    .120E+04    [illegible]      .895       18.62
        .684   99.684    .140E+04    [illegible]      .945       17.64
        .737   99.737    .163E+04       [illegible]   .992       16.79
        .789   99.789    .187E+04      1.943     1.039       16.04
        .842   99.842    .213E+04      [illegible]   1.085       15.36
        .895   99.895    .240E+04      [illegible]   1.130       14.76
        .947   99.947    .269E+04      [illegible]   1.173       14.20
       [illegible]  [illegible]  .300E+04      [illegible]   1.21[illegible]   13.70

                               ---- hydrograph ----   <-pipe / channel->
                        AREA   QPEAK  TPEAK   R.V.  MAX DEPTH  MAX VEL
                         ha     cms    hrs     mm      (m)      (m/s)
  INFLOW   ID= [illegible]   [illegible]   .067   9.58 30.904    .222      .444
  OUTFLOW  ID= [illegible]   [illegible]   .039   9.67 30.895    .178      .381


-------------------------------------------------------------------------------
0032---------------------------------------------------------------------------
*
*  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
--------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]        Slopes (%): CHANNEL= [illegible]  FLOODPLAIN= [illegible]
--------------------                      LENGTH = [illegible]  m

              ------- DATA FOR SECTION  [illegible] -------
              Distance      Elevation      Manning
                 [illegible]                .050[illegible]
                 [illegible]   99.[illegible]   .050[illegible]  .050[illegible]  Main Channel
                 [illegible]   [illegible]      .050             Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
       DEPTH    ELEV       VOLUME     FLOW RATE   VELOCITY   TRAV.TIME
         m        m         cu.m        cms         m/s        min
       [illegible]   .831E+[illegible]   [illegible]   [illegible]   61.7[illegible]
       [illegible]   .332E+[illegible]   [illegible]   .429      38.87
       [illegible]   .498E+[illegible]   [illegible]   [illegible]   29.6[illegible]
       [illegible]   .133E+[illegible]   [illegible]   [illegible]   24.49
       [illegible]   .208E+[illegible]   [illegible]   [illegible]   [illegible]
       [illegible]   .299E+[illegible]   [illegible]   [illegible]   19.[illegible]
       [illegible]   .407E+[illegible]   [illegible]   [illegible]   16.8[illegible]
       [illegible]   .532E+[illegible]   [illegible]   [illegible]   15.4[illegible]
       [illegible]   .673E+[illegible]   [illegible]   [illegible]   14.2[illegible]
       [illegible]   .831E+[illegible]   [illegible]   [illegible]   13.2[illegible]
       [illegible]   .101E+04  [illegible]   [illegible]   12.4[illegible]
       [illegible]   .120E+04  [illegible]   [illegible]   [illegible]
       [illegible]   .140E+04  [illegible]   [illegible]   [illegible]
       [illegible]   .163E+04  [illegible]   [illegible]   10.6[illegible]
       [illegible]   .187E+04  [illegible]   [illegible]   10.14
        .842   99.842    .213E+04   [illegible]   [illegible]    9.7[illegible]
        .895   99.895    .240E+04   [illegible]   [illegible]    9.33
        .947   99.947    .269E+04   [illegible]   [illegible]    9.98
       [illegible]           .300E+04   [illegible]   [illegible]    8.6[illegible]

                               ---- hydrograph ----   <-pipe / channel->
                        AREA   QPEAK  TPEAK   R.V.  MAX DEPTH  MAX VEL
                         ha     cms    hrs     mm      (m)      (m/s)
  INFLOW   ID= [illegible]   [illegible]   [illegible]   9.58 30.904   .185   .618
  OUTFLOW  ID= [illegible]   [illegible]   .045   [illegible]   [illegible]   .56[illegible]


-------------------------------------------------------------------------------
0033---------------------------------------------------------------------------
*
*  ROAD SIDE DITCH 3:1 SLOPE = 5% MEDIUM GRASS
--------------------
  ROUTE CHANNEL            Routing time step (min) = [illegible]
   IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]        Slopes (%): CHANNEL= [illegible]  FLOODPLAIN=5.[illegible]
--------------------                      LENGTH = 1000.[illegible]  m

              ------- DATA FOR SECTION  [illegible] -------
              Distance      Elevation      Manning
                 [illegible]   100.00        .0500
                 3.00           99.00        .0500  .0500  Main Channel
                 6.00          100.00        .0500         Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
       DEPTH    ELEV       VOLUME     FLOW RATE   VELOCITY   TRAV.TIME
         m        m         cu.m        cms         m/s        min
       [illegible]   .831E+[illegible]   [illegible]   .39[illegible]   43.63
       [illegible]   .332E+02   [illegible]   .6[illegible]   27.48
        .158  [illegible]   .748E+02   [illegible]   [illegible]   20.9[illegible]
```

```
      [illegible]
                                <----- hydrograph ----->  <-pipe / channel->
                    AREA    QPEAK   TPEAK    R.V.     MAX DEPTH  MAX VEL
                    (ha)    (cms)   (hrs)    (mm)       (m)       (m/s)
  INFLOW  ID= [illegible]   [illegible]  9.50  38.9[illegible]  .164  [illegible]
  OUTFLOW ID= [illegible]   [illegible]  [illegible]  38.90[illegible]  .16[illegible]  [illegible]

 ----------------------------------------------------------------------------
   34------------------------------------------------------------------------
 *
 ****************************************************************************
 ** ROAD SIDE DITCH [illegible] SHAPE WITH [illegible] SIDE SLOPE
 **  MAXIMUM DEPTH= [illegible] M  KENTUCKY BLUEGRASS LENGTH=[illegible] M  N=0.095
 ****************************************************************************
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% HIGH GRASS
 ---------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]         Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 ---------------------                  LENGTH = [illegible]     m

              <------- DATA FOR SECTION ( [illegible] ) ------->
               Distance       Elevation       Manning
                [illegible]
                                                            Main Channel
                                                            Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        m        m         (cu.m.)      (cms)        m/s        min
      [illegible]

 ----------------------------------------------------------------------------
 [illegible]
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% HIGH GRASS
 ---------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]         Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 ---------------------                  LENGTH = [illegible]     m

              <------- DATA FOR SECTION ( [illegible] ) ------->
               Distance       Elevation       Manning
                [illegible]
                                                            Main Channel
                                                            Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        m        m         (cu.m.)      (cms)        m/s        min
      [illegible]

                                <----- hydrograph ----->  <-pipe / channel->
                    AREA    QPEAK   TPEAK    R.V.     MAX DEPTH  MAX VEL
                    (ha)    (cms)   (hrs)    (mm)       (m)       (m/s)
  INFLOW  ID= [illegible]
  OUTFLOW ID= [illegible]

 ----------------------------------------------------------------------------
 [illegible]
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% HIGH GRASS
 ---------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
   OUT< [illegible]         Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 ---------------------                  LENGTH = [illegible]     m
```

```
              <------- DATA FOR SECTION ( 2.0) ------->
               Distance       Elevation       Manning
                   .00          100.00          .0950
                  3.00           99.00          .0950 / .0950  Main Channel
                  6.00          100.00          .0950          Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
       (m)      (m)        (cu.m.)      (cms)        (m/s)      (min)
       .053    99.053     .831E+01       .001         .064     262.13
       .105    99.105     .332E+02       .003         .101     165.13
       .158    99.158     .740E+02       .010         .132     126.02
       .211    99.211     .133E+03       .021         .160     104.03
       .263    99.263     .208E+03       .039         .186      89.65
       .316    99.316     .299E+03       .063         .210      79.34
       .368    99.368     .407E+03       .095         .233      71.63
       .421    99.421     .532E+03       .135         .254      65.53
       .474    99.474     .673E+03       .185         .275      60.58
       .526    99.526     .831E+03       .245         .295      56.47
       .579    99.579     .101E+04       .316         .314      53.00
       .632    99.632     .120E+04       .399         .333      50.01
       .684    99.684     .140E+04       .494         .352      47.41
       .737    99.737     .163E+04       .602         .369      45.13
       .789    99.789     .187E+04       .723         .387      43.10
       .842    99.842     .213E+04       .859         .404      41.28
       .895    99.895     .240E+04      1.010         .420      39.65
       .947    99.947     .269E+04      1.176         .437      38.16
      1.000   100.000     .300E+04      1.358         .453      36.81

                                <----- hydrograph ----->  <-pipe / channel->
                    AREA    QPEAK   TPEAK    R.V.     MAX DEPTH  MAX VEL
                    (ha)    (cms)   (hrs)    (mm)       (m)       (m/s)
  INFLOW  ID= 1.000101  1.00     .067    9.50  38.9[illegible]4    .322      .213
  OUTFLOW ID= 2.000202  1.00     .027   10.00  38.884      .229      .168


 ----------------------------------------------------------------------------
 0037------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 3:1 SLOPE = 1.0% HIGH GRASS
 ---------------------
   ROUTE CHANNEL            Routing time step (min) =  5.00
    IN> 01:000101           Number of SEGMENTS =  2
   OUT< 02:000202           Slopes (%): CHANNEL=1.00   FLOODPLAIN=1.00
 ---------------------                  LENGTH = 1000.00     m

              <------- DATA FOR SECTION ( 2.0) ------->
               Distance       Elevation       Manning
                   .00          100.00          .0950
                  3.00           99.00          .0950 / .0950  Main Channel
                  6.00          100.00          .0950          Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        m        m         (cu.m        (cms         m/s        min
       .053    99.053     .831E+01       .001         .090     185.35
       .105    99.105     .332E+02       .005         .143     [illegible]
       .158    99.158     .740E+02       .014         .187      89.11
       .211    99.211     .133E+03       .030         .227      73.56
       .263    99.263     .208E+03       .055         .263      63.39
       .316    99.316     .299E+03       .089         .297      56.13
       .368    99.368     .407E+03       .134         .329      50.65
       .421    99.421     .532E+03       .191         .360      46.34
       .474    99.474     .673E+03       .262         .389      42.84
       .526    99.526     .831E+03       .347         .417      39.93
       .579    99.579     .101E+04       .447         .445      37.47
       .632    99.632     .120E+04       .564         .471      35.36
       .684    99.684     .140E+04       .698         .497      33.53
       .737    99.737     .163E+04       .851         .522      31.91
       .789    99.789     .187E+04      1.023         .547      30.47
       .842    99.842     .213E+04      1.215         .571      29.19
       .895    99.895     .240E+04      1.428         .594      28.03
       .947    99.947     .269E+04      1.661         .616      26.99
      1.000   100.000     .300E+04      1.921         .642      26.03

                                <----- hydrograph ----->  <-pipe / channel->
                    AREA    QPEAK   TPEAK    R.V.     MAX DEPTH  MAX VEL
                    (ha)    (cms)   (hrs)    (mm)       (m)       (m/s)
  INFLOW  ID= [illegible]  [illegible]  .067    9.50  38.9[illegible]4    .203      .175
  OUTFLOW ID= [illegible]  [illegible]  .031  [illegible]  38.944      .212      .229


 ----------------------------------------------------------------------------
 [illegible]-------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 3:1 SLOPE = 2.5% HIGH GRASS
 ---------------------
   ROUTE CHANNEL            Routing time step (min) =  5.[illegible]
    IN> 1:000101            Number of SEGMENTS =  [illegible]
   OUT< 2:000202            Slopes (%): CHANNEL=2.50   FLOODPLAIN=2.50
 ---------------------                  LENGTH = 1000.00     m

              <------- DATA FOR SECTION ( [illegible] ) ------->
               Distance       Elevation       Manning
                   .00          100.00          .0950
                  3.00           99.00          .0950 / .0950  Main Channel
                  6.00          100.00          .0950          Main Channel

      ----------------------- TRAVEL TIME TABLE -----------------------
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        m        m         (cu.m        (cms         m/s        min
       .053    99.053     .831E+01       .003         .142     117.21
       .105    99.105     .332E+02       .008         .226      73.85
       .158    99.158     .740E+02       .022         .296      56.36
       .211    99.211     .133E+03       .048         .358      46.52
       .263    99.263     .208E+03       .086         .416      40.09
       .316    99.316     .299E+03       .140         .469      35.50
       .368    99.368     .407E+03       .212         .520      32.04
       .421    99.421     .532E+03       .302         .569      29.31
       .474    99.474     .673E+03       .414         .615      27.09
       .526    99.526     .831E+03       .548         .660      25.26
       .579    99.579     .101E+04       .707         .703      23.70
       .632    99.632     .120E+04       .892         .745      22.37
       .684    99.684     .140E+04      1.104         .786      21.20
       .737    99.737     .163E+04      1.345         .826      20.18
       .789    99.789     .187E+04      1.617         .865      19.27
       .842    99.842     .213E+04      1.921         .903      18.46
       .895    99.895     .240E+04      2.257         .94[illegible]      17.73
       .947    99.947     .269E+04      2.627         .976      17.07
      1.000   100.000     .300E+04      3.037        1.012      16.46

                                <----- hydrograph ----->  <-pipe / channel->
                    AREA    QPEAK   TPEAK    R.V.     MAX DEPTH  MAX VEL
                    (ha)    (cms)   (hrs)    (mm)       (m)       (m/s)
  INFLOW  ID= 1.000101  1.00     .067    9.50  38.9[illegible]4    .237      .395
  OUTFLOW ID= 2.000202  1.00     .036    9.67  38.944      .187      .327
```

```
 ---------------------------------------------------------------------------------
 0039-----------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 3:1 SLOPE = 5% HIGH GRASS
 -------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |   IN> 01:000101  |      Number of SEGMENTS = [illegible]
 | OUT< 02:000202   |      Slopes %   CHANNEL=5 [illegible]   FLOODPLAIN= [illegible]
 -------------------                       LENGTH = [illegible]   m

               ------- DATA FOR SECTION   [illegible] ------
               Distance       Elevation        Manning
                 [illegible]  [illegible]       .095
                 [illegible]  [illegible]      .0950   .095   Main Channel
                 [illegible]  [illegible]       .0950         Main Channel

       --------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE     VELOCITY    TRAV TIME
          m         m        cu.m          cms           m/s         min
        .053    99.053    .631E+[illegible]   [illegible]   [illegible]   [illegible]
        .105    99.105    .332E+[illegible]   [illegible]   [illegible]   [illegible]
        .158    99.158    .748E+[illegible]   .031       .41[illegible]   [illegible]
        .211    99.211    .133E+[illegible]   [illegible]   [illegible]   [illegible]
        .263    99.263    .208E+[illegible]   .121       [illegible]   [illegible]
        .316    99.316    .299E+[illegible]   .19[illegible]   [illegible]   [illegible]
        .368    99.368    .407E+[illegible]   .30[illegible]   [illegible]   [illegible]
        .421    99.421    .532E+[illegible]   .42[illegible]   [illegible]   [illegible]
        .474    99.474    .673E+[illegible]   .58[illegible]   [illegible]   [illegible]
        .526    99.526    .831E+[illegible]   [illegible]   [illegible]   [illegible]
        .579    99.579    .101E+ 4   [illegible]   [illegible]   [illegible]
        .632    99.632    .120E+ 4   [illegible]   [illegible]   [illegible]
        .684    99.684    .140E+ 4   [illegible]   [illegible]   [illegible]
        .737    99.737    .163E+ 4   [illegible]   [illegible]   [illegible]
        .789    99.789    .187E+ 4   [illegible]   [illegible]   [illegible]
        .842    99.842    .213E+ 4   [illegible]   [illegible]   [illegible]
        .895    99.895    .240E+ 4   [illegible]   [illegible]   [illegible]
        .947    99.947    .269E+ 4   [illegible]   [illegible]   [illegible]
       1.000   100.000    .300E+ 4   4.295      [illegible]   [illegible]

                                      ----- hydrograph -----   <-pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                              ha      cms      hrs      mm        m        m/s
   INFLOW   ID= 1:000101  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
   OUTFLOW  ID= 2:000202  [illegible]  [illegible]  [illegible]  [illegible]  .619


 ---------------------------------------------------------------------------------
 0040-----------------------------------------------------------------------------
 *
 *********************************************************************************
 ** ROAD SIDE DITCH [illegible] SHAPE WITH [illegible] SIDE SLOPE
 **  MAXIMUM DEPTH= [illegible] M  MOWED GRASS  N= .025
 *********************************************************************************
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MOWED GRASS
 -------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |   IN> [illegible]|      Number of SEGMENTS = [illegible]
 | OUT< [illegible] |      Slopes %   CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                       LENGTH = [illegible]   m

               ------- DATA FOR SECTION   [illegible] ------
               Distance       Elevation        Manning
                 [illegible]  [illegible]       .025
                 [illegible]  [illegible]      .025   .025   Main Channel
                 4[illegible] [illegible]       .025         Main Channel

       --------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE     VELOCITY    TRAV TIME
          m         m        cu.m          cms           m/s         min
 [illegible]

                                      ----- hydrograph -----   <-pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                              ha      cms      hrs      mm        m        m/s
   INFLOW   ID= [illegible]
   OUTFLOW  ID= [illegible]                                                 .64


 ---------------------------------------------------------------------------------
 0041-----------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MOWED GRASS
 -------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |   IN> [illegible]|      Number of SEGMENTS = [illegible]
 | OUT< [illegible] |      Slopes %   CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                       LENGTH = [illegible]   m

               ------- DATA FOR SECTION   [illegible] ------
               Distance       Elevation        Manning
                 [illegible]  [illegible]       .025
                 [illegible]  [illegible]      .025   .025   Main Channel
                 4[illegible] [illegible]       .025         Main Channel

       --------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE     VELOCITY    TRAV TIME
          m         m        cu.m          cms           m/s         min
 [illegible]
        .789    99.789    .125E+04   [illegible]   [illegible]   [illegible]
        .842    99.842    .142E+04   [illegible]   [illegible]   [illegible]
        .895    99.895    .160E+04   [illegible]   [illegible]   [illegible]
        .947    99.947    .179E+04   [illegible]   [illegible]   [illegible]
       1.000   100.000    .200E+04   [illegible]   [illegible]   [illegible]

                                      ----- hydrograph -----   <-pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                              ha      cms      hrs      mm        m        m/s
   INFLOW   ID= 1:000101  [illegible]  .267   9.58  38.914   .322      .323
   OUTFLOW  ID= 2:000202  [illegible]  .233   9.67  38.894   .245      .268


 ---------------------------------------------------------------------------------
 0042-----------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = 0.5% MOWED GRASS
 -------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |   IN> [illegible]|      Number of SEGMENTS = [illegible]
 | OUT< 02:000202   |      Slopes %   CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                       LENGTH = [illegible]   m

               ------- DATA FOR SECTION   [illegible] ------
               Distance       Elevation        Manning
                 [illegible]   100.[illegible]       .025
                 2.0[illegible]  99.0[illegible]    .025   .025   Main Channel
                 4.0[illegible] 100.0[illegible]     .025         Main Channel

       --------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE     VELOCITY    TRAV TIME
          m         m        cu.m          cms           m/s         min
        .053    99.053    .554E+01   [illegible]   [illegible]   [illegible]
        .105    99.105    .222E+02   .005       [illegible]   76.03
        .158    99.158    .499E+02   .014       .204       58.63
        .211    99.211    .888E+02   .031       .344       48.4[illegible]
        .263    99.263    .139E+03   .055       .40[illegible]   41.7[illegible]
        .316    99.316    .199E+03   .090       .45[illegible]   36.94
        .368    99.368    .271E+03   .136       .50[illegible]   33.33
        .421    99.421    .355E+03   .194       .54[illegible]   30.49
        .474    99.474    .449E+03   .265       .59[illegible]   28.19
        .526    99.526    .554E+03   .351       .634       26.28
        .579    99.579    .670E+03   .453       .676       24.66
        .632    99.632    .798E+03   .57[illegible]   [illegible]   [illegible]
        .684    99.684    .936E+03   .70[illegible]   [illegible]   [illegible]
        .737    99.737    .109E+04   .862       .794       [illegible]
        .789    99.789    .125E+04   1.03[illegible]   [illegible]   [illegible]
        .842    99.842    .142E+04   1.23[illegible]   [illegible]   [illegible]
        .895    99.895    .160E+04   1.44[illegible]   [illegible]   20.45
        .947    99.947    .179E+04   1.68[illegible]   .93[illegible]   [illegible]
       1.000   100.000    .200E+04   1.94[illegible]   .97[illegible]   [illegible]

                                      ----- hydrograph -----   <-pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                              ha      cms      hrs      mm        m        m/s
   INFLOW   ID= [illegible]                                       .281      .416
   OUTFLOW  ID= [illegible]                                       .225      .359


 ---------------------------------------------------------------------------------
 0043-----------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MOWED GRASS
 -------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |   IN> [illegible]|      Number of SEGMENTS = [illegible]
 | OUT< [illegible] |      Slopes %   CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                       LENGTH = [illegible]   m

               ------- DATA FOR SECTION   [illegible] ------
               Distance       Elevation        Manning
                 [illegible]  [illegible]       .025
                 [illegible]   99[illegible]   .025   .025   Main Channel
                 4[illegible] [illegible]       .025         Main Channel

       --------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE     VELOCITY    TRAV TIME
          m         m        cu.m          cms           m/s         min
 [illegible]

                                      ----- hydrograph -----   <-pipe / channel->
                             AREA    QPEAK    TPEAK    R.V.   MAX DEPTH  MAX VEL
                              ha      cms      hrs      mm        m        m/s
   INFLOW   ID= [illegible]                                       .247      .538
   OUTFLOW  ID= [illegible]                                       .208      .482


 ---------------------------------------------------------------------------------
 0044-----------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible] MOWED GRASS
 -------------------
 | ROUTE CHANNEL    |      Routing time step (min) = [illegible]
 |   IN> [illegible]|      Number of SEGMENTS = [illegible]
 | OUT< [illegible] |      Slopes %   CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 -------------------                       LENGTH = [illegible]   m

               ------- DATA FOR SECTION   [illegible] ------
               Distance       Elevation        Manning
                 [illegible]   100.[illegible]     .025
                 [illegible]    99.[illegible]    .025   .025   Main Channel
                 4.[illegible] 100.[illegible]     .025         Main Channel

       --------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE     VELOCITY    TRAV TIME
          m         m        cu.m          cms           m/s         min
 [illegible]
```

```
        .316    99.316    .199E+03      .20[illegible]     1.009      16.5[illegible]
        .368    99.368    .271E+03      .304       1.11[illegible]     14.9[illegible]
        .421    99.421    .355E+03      .433       1.222      13.64
        .474    99.474    .449E+03      .593       1.322      12.6[illegible]
        .526    99.526    .554E+03      .786       1.418      11.75
        .579    99.579    .670E+03     1.013       1.511      11.0[illegible]
        .632    99.632    .798E+03     1.27[illegible]      1.602      10.4[illegible]
        .684    99.684    .936E+03     1.5[illegible]       1.68[illegible]      9.9[illegible]
        .737    99.737    .109E+04     [illegible]       1.771       9.3[illegible]
        .789    99.789    .125E+04     [illegible]       1.855       8.9[illegible]
        .842    99.842    .142E+04     [illegible]       1.94[illegible]       8.5[illegible]
        .895    99.895    .160E+04     3.234       2.0[illegible]       8.[illegible]
        .947    99.947    .179E+04     3.7[illegible]       2.09[illegible]       7.94
       1.000   100.000    .200E+04     4.351       2.17[illegible]       7.66

                                  <---- hydrograph ---->   <-pipe / channe.->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                           ha      cms     hrs     mm        m        m/s
  INFLOW : ID= [illegible]     1.00     .067    9.50 38.914     .20[illegible]      .7[illegible]
  OUTFLOW: ID= [illegible]     1.00     .04[illegible]    9.67 38.9[illegible]     .19      .68[illegible]

 ---------------------------------------------------------------------------
 0045-----------------------------------------------------------------------
 *
 * ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
 -------------------
   ROUTE CHANNEL            Routing time step (min) =
    IN> [illegible]             Number of SEGMENTS =
    OUT> [illegible]            Slopes (%), CHANNEL=         FLOODPLAIN=
 -------------------                        LENGTH =              m

             <------- DATA FOR SECTION  [illegible]  ------->
             Distance      Elevation       Manning
               [illegible]          [illegible]            .0425
               2.00          99.[illegible]       .0425 / .0425  Main Channe.
               4.00         100.[illegible]            .0425     Main Channe.

      <-------------------- TRAVEL TIME TABLE -------------------->
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
        m        m          cu.m.        cms          m/s        min
      .053    99.053     .554E+01       .00[illegible]         .41[illegible]      40.5[illegible]
      .105    99.105     .222E+02       [illegible]         .6[illegible]      24.[illegible]
      .158    99.158     .499E+02       .04[illegible]         .8[illegible]      19.54
      .211    99.211     .886E+02       [illegible]         [illegible]      [illegible]
      .263    99.263     .138E+03       [illegible]        1.[illegible]4      [illegible]
      .316    99.316     .199E+03       [illegible]        1.[illegible]      [illegible]
      .368    99.368     .271E+03       [illegible]        1.[illegible]      [illegible]
      .421    99.421     .355E+03       [illegible]        [illegible]       [illegible]
      .474    99.474     .449E+03       [illegible]        [illegible]       [illegible]
      .526    99.526     .554E+03       [illegible]        [illegible]       [illegible]
      .579    99.579     .670E+03       [illegible]        [illegible]       [illegible]
      .632    99.632     .798E+03       [illegible]        [illegible]       [illegible]
      .684    99.684     .936E+03       [illegible]        [illegible]       [illegible]
      .737    99.737     .109E+04       [illegible]        [illegible]       [illegible]
      .789    99.789     .125E+04       [illegible]        [illegible]       [illegible]
      .842    99.842     .142E+04       [illegible]        [illegible]       [illegible]
      .895    99.895     .160E+04       [illegible]        [illegible]       [illegible]
      .947    99.947     .179E+04       [illegible]        [illegible]       [illegible]
     1.000   100.000     .200E+04       [illegible]        [illegible]       [illegible]

                                  <---- hydrograph ---->   <-pipe / channe.->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                           ha      cms     hrs     mm        m        m/s
  INFLOW : ID= [illegible]     [illegible]
  OUTFLOW: ID= [illegible]     [illegible]

 ---------------------------------------------------------------------------
 [illegible]4---------------------------------------------------------------------
 *
 ***************************************************************************
 ** ROAD SIDE DITCH [illegible] SHAPE WITH [illegible] SIDE SLOPE
 ** MAXIMUM DEPTH [illegible] MEDIUM LENGTH GRASS [illegible]
 ***************************************************************************
 * ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
 -------------------
   ROUTE CHANNEL            Routing time step (min) =
    IN> [illegible]             Number of SEGMENTS =
    OUT> [illegible]            Slopes (%), CHANNEL=         FLOODPLAIN=
 -------------------                        LENGTH =              m

             <------- DATA FOR SECTION  [illegible]  ------->
             Distance      Elevation       Manning
               [illegible]
                                                           Main Channe.
                                                           Main Channe.

      <-------------------- TRAVEL TIME TABLE -------------------->
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
        m        m          cu.m.        cms          m/s        min
      .053    [illegible]     .554E+[illegible]       [illegible]
      [illegible]
      .158    [illegible]     .499E+[illegible]
      [illegible]
      .474    [illegible]
      [illegible]
      .632
      .684
      [illegible]
      .842
      .895
      .947
     1.000

                                  <---- hydrograph ---->   <-pipe / channe.->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                           ha      cms     hrs     mm        m        m/s
  INFLOW : ID= [illegible]
  OUTFLOW: ID= [illegible]

 ---------------------------------------------------------------------------
 [illegible]4---------------------------------------------------------------------
 *
 * ROAD SIDE DITCH [illegible] SLOPE = [illegible] MEDIUM GRASS
 -------------------
   ROUTE CHANNEL            Routing time step (min) =
    IN> [illegible]             Number of SEGMENTS =
    OUT> [illegible]            Slopes (%), CHANNEL=         FLOODPLAIN=
 -------------------                        LENGTH =              m

             <------- DATA FOR SECTION  [illegible]  ------->
```

```
             Distance      Elevation       Manning
                  .00         100.00         .0500
                 2.00          99.00         .0500 / .0500  Main Channe.
                 4.00         100.00         .0500          Main Channe.

      <-------------------- TRAVEL TIME TABLE -------------------->
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
       (m)       (m)       (cu.m.)      (cms)        (m/s)      (min)
      .053    99.053     .554E+01       .000         .082      202.92
      .105    99.105     .222E+02       .003         .131      127.83
      .158    99.158     .499E+02       .009         .171       97.55
      .211    99.211     .886E+02       .018         .207       80.53
      .263    99.263     .138E+03       .033         .240       69.40
      .316    99.316     .199E+03       .054         .271       61.46
      .368    99.368     .271E+03       .082         .301       55.45
      .421    99.421     .355E+03       .116         .329       50.73
      .474    99.474     .449E+03       .159         .355       46.90
      .526    99.526     .554E+03       .211         .381       43.72
      .579    99.579     .670E+03       .272         .406       41.03
      .632    99.632     .798E+03       .343         .431       38.71
      .684    99.684     .936E+03       .425         .454       36.70
      .737    99.737     .109E+04       .518         .477       34.93
      .789    99.789     .125E+04       .623         .500       33.36
      .842    99.842     .142E+04       .740         .522       31.96
      .895    99.895     .160E+04       .869         .543       30.69
      .947    99.947     .179E+04      1.013         .564       29.54
     1.000   100.000     .200E+04      1.172         .585       28.50

                                  <---- hydrograph ---->   <-pipe / channe.->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
  INFLOW   ID= 1:000101   1.00     .067    9.50 38.914     .341      .285
  OUTFLOW  ID= 2:000202   1.00     .031   10.08 38.892     .256      .235

 ---------------------------------------------------------------------------
 0048-----------------------------------------------------------------------
 *
 * ROAD SIDE DITCH 2:1 SLOPE = 0.5% MEDIUM GRASS
 -------------------
   ROUTE CHANNEL            Routing time step (min) =  5.00
    IN> 01:000101           Number of SEGMENTS =  2
    OUT> 02:000202          Slopes (%), CHANNEL= .50   FLOODPLAIN= .50
 -------------------                        LENGTH = 1000.00      m

             <------- DATA FOR SECTION  ( 2.0) ------->
             Distance      Elevation       Manning
                  .00         100.00         .0500
                 2.00          99.00         .0500 / .0500  Main Channel
                 4.00         100.00         .0500          Main Channel

      <-------------------- TRAVEL TIME TABLE -------------------->
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV TIME
       (m)       (m)       (cu.m.)      (cms)        (m/s)      (min)
      .053    99.053     .554E+01       .001         .116      143.49
      .105    99.105     .222E+02       .004         .184       90.39
      .158    99.158     .499E+02       .012         .242       68.98
      .211    99.211     .886E+02       .026         .293       56.94
      .263    99.263     .138E+03       .047         .340       49.07
      .316    99.316     .199E+03       .076         .384       43.46
      .368    99.368     .271E+03       .115         .425       39.21
      .421    99.421     .355E+03       .165         .465       35.87
      .474    99.474     .449E+03       .226         .503       33.16
      .526    99.526     .554E+03       .299         .539       30.91
      .579    99.579     .670E+03       .385         .575       29.01
      .632    99.632     .798E+03       .486         .6[illegible]       27.38
      .684    99.684     .936E+03       .601         .642       25.95
      .737    99.737     .109E+04       .733         .675       24.70
      .789    99.789     .125E+04       .881         .7[illegible]       23.59
      .842    99.842     .142E+04      1.046         .7[illegible]       22.60
      .895    99.895     .160E+04      1.230         .7[illegible]       21.[illegible]
      .947    99.947     .179E+04      1.432         .7[illegible]       20.89
     1.000   100.000     .200E+04      1.654         .827       20.15

                                  <---- hydrograph ---->   <-pipe / channe.->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
  INFLOW   ID= 1:000101   1.00     .067    9.50 38.914     .299      .369
  OUTFLOW  ID= 2:000202   1.00     .035    9.67 38.896     .234      .322

 ---------------------------------------------------------------------------
 [illegible]4---------------------------------------------------------------------
 *
 * ROAD SIDE DITCH [illegible] SLOPE = 1.0% MEDIUM GRASS
 -------------------
   ROUTE CHANNEL            Routing time step (min) =  5.0[illegible]
    IN> [illegible]             Number of SEGMENTS =  2
    OUT> [illegible]            Slopes (%), CHANNEL=1.00   FLOODPLAIN=1.00
 -------------------                        LENGTH = 1000.00      m

             <------- DATA FOR SECTION  ( 2.0) ------->
             Distance      Elevation       Manning
                  [illegible]         100.00         .0500
                 [illegible]          99.00         .0500 / .0500  Main Channe.
                 4.00         100.00         .0500          Main Channe.

      <-------------------- TRAVEL TIME TABLE -------------------->
      DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        m         m        (cu.m.)       cms          m/s       (min)
      .053    99.053     .554E+01       .001         .164      101.46
      .105    99.105     .222E+02       .006         .261       63.92
      .158    99.158     .499E+02       .017         .342       48.78
      .211    99.211     .886E+02       .037         .414       40.26
      .263    99.263     .138E+03       .067         .48[illegible]       34.70
      .316    99.316     .199E+03       .108         .542       30.73
      .368    99.368     .271E+03       .163         .[illegible]       27.73
      .421    99.421     .355E+03       .233         .657       25.37
      .474    99.474     .449E+03       .319         .7[illegible]       23.45
      .526    99.526     .554E+03       .422         .7[illegible]       21.86
      .579    99.579     .670E+03       .545         .8[illegible]       20.51
      .632    99.632     .798E+03       .687         .8[illegible]       19.36
      .684    99.684     .936E+03       .850         .9[illegible]       18.35
      .737    99.737     .109E+04      1.03[illegible]         .954       17.47
      .789    99.789     .125E+04      1.245         .9[illegible]       16.68
      .842    99.842     .142E+04      1.479        1.0[illegible]       15.98
      .895    99.895     .160E+04      1.73[illegible]        1.0[illegible]       15.35
      .947    99.947     .179E+04      2.02[illegible]        1.1[illegible]       14.77
     1.000   100.000     .200E+04      2.33[illegible]        1.1[illegible]       14.25

                                  <---- hydrograph ---->   <-pipe / channe.->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                          (ha)    (cms)   (hrs)   (mm)      (m)      (m/s)
  INFLOW   ID= 1:000101   1.00     .067    9.50 38.914     .264      .491
  OUTFLOW  ID= 2:000202   1.00     .040    9.67 38.8[illegible]     .217      .421

 ---------------------------------------------------------------------------
 [illegible]005----------------------------------------------------------------------
```

```
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% MEDIUM GRASS
 --------------------
   ROUTE CHANNEL            Routing time step (min) =  5.00
    IN> [illegible]         Number of SEGMENTS = [illegible]
    OUT< [illegible]        Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 --------------------                    LENGTH = 1000.00      m

               <------ DATA FOR SECTION     [illegible]  ------>
               Distance       Elevation        Manning
                  [illegible]     [illegible]        .0500
                  [illegible]     [illegible]   .0500   .0500  Main Channel
                  [illegible]     [illegible]           .0500  Main Channel

        ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          m         m         cu.m        cms          m/s        min
        [illegible]
 *
 *              <---- hydrograph ----> <-pipe / channel->
                                  AREA    QPEAK   TPEAK   R.V.  MAX DEPTH  MAX VEL
                                   ha      cms     hrs     mm      m        m/s
     INFLOW   ID= [illegible]
     OUTFLOW  ID= [illegible]

 ----------------------------------------------------------------------------
 0053------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% MEDIUM GRASS
 --------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
    OUT< [illegible]        Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 --------------------                    LENGTH = [illegible]  m

               <------ DATA FOR SECTION     [illegible]  ------>
               Distance       Elevation        Manning
                  [illegible]
                                          [illegible]      Main Channel
                  4                       [illegible]      Main Channel

        ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          m         m         cu.m        cms          m/s        min
        [illegible]

                                        <---- hydrograph ----> <-pipe / channel->
                                  AREA    QPEAK   TPEAK   R.V.  MAX DEPTH  MAX VEL
                                   ha      cms     hrs     mm      m        m/s
     INFLOW   ID= [illegible]
     OUTFLOW  ID= [illegible]

 ----------------------------------------------------------------------------
 0053------------------------------------------------------------------------
 *
 ****************************************************************************
 ** ROAD SIDE DITCH    SHAPE WITH [illegible] SIDE SLOPE
 ** MAXIMUM DEPTH= [illegible] [illegible] AND GRASS [illegible] HIGH [illegible]
 ****************************************************************************
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% HIGH GRASS
 --------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
    OUT< [illegible]        Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 --------------------                    LENGTH = [illegible]  m

               <------ DATA FOR SECTION     [illegible]  ------>
               Distance       Elevation        Manning
                                                 .095
                  [illegible]     [illegible]   .095   .095  Main Channel
                  4               [illegible]          .095  Main Channel

        ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          m         m         cu.m        cms          m/s        min
        [illegible]
          .895    99.895    .160E+04      .209         .181       92.20
          .947    99.947    .179E+04      .337         .188       88.76
         1.000   100.000    .200E+04      .389         .195       85.61

                                        <---- hydrograph ----> <-pipe / channel->
                                  AREA    QPEAK   TPEAK   R.V.  MAX DEPTH  MAX VEL
                                   ha      cms     hrs     mm      m        m/s
     INFLOW   ID= 01:000101        1.00    .067    9.50 38.904    .517      .125
     OUTFLOW  ID= 02:000202        1.00    .021   10.42 38.868    .331      .093

 ----------------------------------------------------------------------------
 0053------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 2:1 SLOPE = 0.25% HIGH GRASS
 --------------------
   ROUTE CHANNEL            Routing time step (min) =  5.00
    IN> 01:000101           Number of SEGMENTS = [illegible]
    OUT< 02:000202          Slopes (%): CHANNEL= .25   FLOODPLAIN= .25
 --------------------                    LENGTH = 1000.00      m

               <------ DATA FOR SECTION     [illegible]  ------>
               Distance       Elevation        Manning
                   .00         100.00          .0950
                  2.00          99.00    .0950   .0950  Main Channel
                  4.00         100.00            .0950  Main Channel

        ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          m         m         cu.m        cms          m/s        min
          .053    99.053    .554E+01   [illegible]      .043      385.55
          .105    99.105    .222E+02   [illegible]      .069      242.08
          .158    99.158    .499E+02   [illegible]      .090      185.35
          .211    99.211    .888E+02   [illegible]      .109      153.01
          .263    99.263    .138E+03   [illegible]      .127      131.06
          .316    99.316    .199E+03   [illegible]      .143      116.7[illegible]
          .368    99.368    .271E+03      .043          .158      105.36
          .421    99.421    .355E+03   [illegible]      .173       96.39
          .474    99.474    .449E+03   [illegible]      .187       89.11
          .526    99.526    .554E+03   [illegible]      .201       83.04
          .579    99.579    .670E+03      .143          .214       77.95
          .632    99.632    .798E+03   [illegible]      .227       73.56
          .684    99.684    .936E+03      .224          .239       69.73
          .737    99.737    .109E+04      .273          .251       66.37
          .789    99.789    .125E+04      .320          .263       63.39
          .842    99.842    .142E+04      .389          .274       60.72
          .895    99.895    .160E+04      .459          .286       58.31
          .947    99.947    .179E+04      .533          .297       56.13
         1.000   100.000    .200E+04      .616          .308       54.15

                                        <---- hydrograph ----> <-pipe / channel->
                                  AREA    QPEAK   TPEAK   R.V.  MAX DEPTH  MAX VEL
                                   ha      cms     hrs     mm      m        m/s
     INFLOW   ID= 01:000101        1.00    .067    9.50 38.904    .435      [illegible]
     OUTFLOW  ID= 02:000202        1.00    .025   [illegible] 38.881    .294      [illegible]

 ----------------------------------------------------------------------------
 0054------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% HIGH GRASS
 --------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
    OUT< [illegible]        Slopes (%): CHANNEL=[illegible]   FLOODPLAIN= .50
 --------------------                    LENGTH = [illegible]  m

               <------ DATA FOR SECTION     [illegible]  ------>
               Distance       Elevation        Manning
                  [illegible]     [illegible]       .095
                  [illegible]     [illegible]   .095   .095  Main Channel
                  4               [illegible]          .095  Main Channel

        ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          m         m         cu.m        cms          m/s        min
        [illegible]
                                                        [illegible]   55.[illegible]
                                                        [illegible]   52.[illegible]
                                                         .338          49.3[illegible]
                                                         .355          46.[illegible]
                                                         .372          44.02
                                                         .388          42.94
                                                         .404          41.2[illegible]
                                                         .420          39.[illegible]
                                                         .435          38.[illegible]

                                        <---- hydrograph ----> <-pipe / channel->
                                  AREA    QPEAK   TPEAK   R.V.  MAX DEPTH  MAX VEL
                                   ha      cms     hrs     mm      m        m/s
     INFLOW   ID= [illegible]                                    .302      .229
     OUTFLOW  ID= [illegible]                                    .275      .204

 ----------------------------------------------------------------------------
 ----------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] SLOPE = [illegible]% HIGH GRASS
 --------------------
   ROUTE CHANNEL            Routing time step (min) = [illegible]
    IN> [illegible]         Number of SEGMENTS = [illegible]
    OUT< [illegible]        Slopes (%): CHANNEL=[illegible]   FLOODPLAIN=[illegible]
 --------------------                    LENGTH = [illegible]  m

               <------ DATA FOR SECTION     [illegible]  ------>
               Distance       Elevation        Manning
                                                 .95
                  [illegible]     [illegible]   .95   .95  Main Channel
                  4               [illegible]         .95  Main Channel

        ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
          m         m         cu.m        cms          m/s        min
        [illegible]
```

```
         .421   99.421   .355E+0[illegible]   [illegible]      .346     40.1[illegible]
         .474   99.474   .449E+03      .168      .374     44.55
         .526   99.526   .554E+[illegible]   [illegible]      .401     41.53
         .579   99.579   .670E+03      .207      .428     38.98
         .632   99.632   .798E+03      .362      .453     36.79
         .684   99.684   .936E+0[illegible]      .449      .478     34.87
         .737   99.737   .109E+04      .545      .502     33.19
         .789   99.789   .125E+04      .651      .526     31.69
         .842   99.842   .142E+04      .776      .549     30.36
         .895   99.895   .160E+04      .915      .572     29.16
         .947   99.947   .179E+04     [illegible]      .594     28.07
        1.000  100.000   .200E+04     [illegible]      .616     27.07

                                   ----- hydrograph -----   -pipe  channel-
                             AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              ha      cms     hrs     mm        m        m/s
  INFLOW   ID= 1:000101   [illegible]    .67    9.50  38.904    .335      .296
  OUTFLOW  ID= 2:000202   [illegible]    .632  10.00  38.893    .253      .245


 ----------------------------------------------------------------------------
 0056------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH 2:1 SLOPE @ [illegible] HIGH GRASS
 --------------------
   ROUTE CHANNEL           Routing time step (min) = [illegible]
    IN= 1:000[illegible]          Number of SEGMENTS = [illegible]
   OUT= 2:000[illegible]          Slopes (%) CHANNEL=[illegible]    FLOODPLAIN=[illegible]
 --------------------                      LENGTH = [illegible]       m

              ------- DATA FOR SECTION  [illegible]  ------
              Distance      Elevation       Manning
                [illegible]       [illegible]          .095
                [illegible]       [illegible]          .095 / .095   Main Channel
                4.[illegible]      [illegible]          .095          Main Channel

       ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
          m         m         cu.m        cms          m/s         min
         .053   99.053   .554E+0[illegible]     .001       .127     [illegible]
         .105   99.105   .222E+0[illegible]   [illegible]       .217     [illegible]
         .158   99.158   .499E+0[illegible]     .014       .294     [illegible]
         .211   99.211   .888E+0[illegible]   [illegible]       .344     40.[illegible]
         .263   99.263   .139E+0[illegible]     .05[illegible]     .4[illegible]     [illegible]
         .316   99.316   .199E+0[illegible]   [illegible]      .45[illegible]     [illegible]
         .368   99.368   .271E+0[illegible]     .13[illegible]     .50[illegible]     [illegible]
         .421   99.421   .355E+0[illegible]     .19[illegible]     .54[illegible]     [illegible]
         .474   99.474   .449E+0[illegible]   [illegible]      .59[illegible]     [illegible]
         .526   99.526   .554E+0[illegible]   [illegible]      .63[illegible]     [illegible]
         .579   99.579   .670E+0[illegible]     .4[illegible]     .67[illegible]     [illegible]
         .632   99.632   .798E+0[illegible]   [illegible]      .71[illegible]     [illegible]
         .684   99.684   .936E+0[illegible]   [illegible]      .756     [illegible]
         .737   99.737   .109E+04     [illegible]      .794     [illegible]
         .789   99.789   .125E+04     [illegible]      .831     [illegible]
         .842   99.842   .142E+04     [illegible]      .868     [illegible]
         .895   99.895   .160E+04     1.447      .904     19.44
         .947   99.947   .179E+04     1.685      .939     [illegible]
        1.000  100.000   .200E+04     [illegible]      .97[illegible]     [illegible]

                                   ----- hydrograph -----   -pipe  channel-
                             AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              ha      cms     hrs     mm        m        m/s
  INFLOW   ID= [illegible]   [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
  OUTFLOW  ID= [illegible]   [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]


 ----------------------------------------------------------------------------
 0057------------------------------------------------------------------------
 *
 *  ROAD SIDE DITCH [illegible] HIGH GRASS
 --------------------
   ROUTE CHANNEL           Routing time step (min) = [illegible]
    IN= [illegible]          Number of SEGMENTS = [illegible]
   OUT= [illegible]          Slopes (%) CHANNEL=[illegible]    FLOODPLAIN=[illegible]
 --------------------                      LENGTH = [illegible]       m

              ------- DATA FOR SECTION  [illegible]  ------
              Distance      Elevation       Manning
                [illegible]       [illegible]          [illegible]
                [illegible]       [illegible]          [illegible]   Main Channel
                [illegible]       [illegible]          [illegible]   Main Channel

       ---------------------- TRAVEL TIME TABLE ----------------------
        DEPTH     ELEV       VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
          m         m         cu.m        cms          m/s         min
 [illegible]


                                   ----- hydrograph -----   -pipe  channel-
                             AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
                              ha      cms     hrs     mm        m        m/s
  INFLOW   ID= [illegible]   [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
  OUTFLOW  ID= [illegible]   [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]


 ----------------------------------------------------------------------------
 0058------------------------------------------------------------------------
 *
    FINISH
 ----------------------------------------------------------------------------
 ****************************************************************************
    WARNINGS / ERRORS / NOTES
    -------------------------
  [illegible] DESIGN CHANNEL
    *** WARNING: [illegible] is smaller than [illegible]
                 [illegible] a larger area
  Simulation ended [illegible]
 ****************************************************************************
```

```
 ==========================================================================
  OOO   TTTTT TTTTT H   H  Y   Y M   M  OOO        999   55555 ===============
                                                    9   9  5     ===============
                  T     HHHHH       M M M       ####  9   9  5      Version 2.2
                  T     H   H       M   M            9999  5555    March  1997
  OOO    T     T    H   H       M   M  OOO             9      5  ===============
                                                    9   9      5 SERIAL# 4249[illegible]
                                                     999   555   ===============

 ***************************************************************************
 ************************* OTTHYMO-95w Ver/2.2 ******************************
 ***************************************************************************
 ******* Distributed by:  J.F. Sabourin and Associates Inc.          *******
 *******                   Ottawa, Ontario: (613) 727-5[illegible]        *******
 *******                   Gatineau, Quebec: (819) 243-6858         *******
 *******                   E-Mail: JFSA@CompuServe.Com              *******
 ***************************************************************************
 ******* Licensed user: J.F. Sabourin and Associates Inc             *******
 *******                 Ottawa            SERIAL# 4249[illegible]         *******
 ***************************************************************************
 ***************************************************************************
 *******             ++++++ PROGRAM ARRAY DIMENSIONS ++++++         *******
 *******             Maximum value for ID numbers                   *******
 *******             Max. number of rainfall points    [illegible]  *******
 *******             Max. number of flow points        [illegible]  *******
 ***************************************************************************
 ***************************************************************************
 ********************   D E T A I L E D   O U T P U T   *******************
 ***************************************************************************
 *       DATE  1997-[illegible]       TIME  [illegible]:14      RUN COUNTER  [illegible]   *
 ***************************************************************************
 * Input    filename  C:\PROJ\96-103\HYDRO\ROAD.DAT                        *
 * Output   filename  C:\PROJ\96-103\HYDRO\ROAD.out                        *
 * Summary  filename  C:\PROJ\96-103\HYDRO\ROAD.sum                        *
 * User comments                                                           *
 * 1:_____________________________________________________________________ *
 * 2:_____________________________________________________________________ *
 * 3:_____________________________________________________________________ *
 ***************************************************************************

 ---------------------------------------------------------------------------
 0001----------------------------------------------------------------------
 *
 --------------------
  START                  Project dir.:  C:\PROJ\96-103\HYDRO\
  TZERO=   [illegible] hrs     Rainfall dir.: C:\PROJ\96-103\HYDRO\
 --------------------
    METOUT=  [illegible]  output = METRIC
    NRUN   = [illegible]
    NSTORM=
 ---------------------------------------------------------------------------
 0002----------------------------------------------------------------------
 *             [illegible]  <--storm filename, one per line for NSTORM time
 *
 --------------------
    READ STORM           Filename: C:\PROJ\96-103\HYDRO\SAMPLE.STM
  Ptotal= [illegible] mm        Comments: [illegible]  STORM
 --------------------
                     TIME    RAIN    TIME    RAIN    TIME    RAIN    TIME    RAIN
                      hrs   mm/hr     hrs   mm/hr     hrs   mm/hr     hrs   mm/hr
                     [illegible]

 ---------------------------------------------------------------------------
 0003----------------------------------------------------------------------
 *
 ------------------------
  DESIGN STANDHYD        Area   (ha)=  [illegible]
  [illegible]            Total Imp(%)=  [illegible]   Dir. Conn.(%)= [illegible]
 ------------------------
                               IMPERVIOUS   PERVIOUS [illegible]
    Surface Area     (ha)=   [illegible]
    Dep. Storage     (mm)=   [illegible]
    Average Slope     (%)=   [illegible]
    Length            (m)=   [illegible]
    Mannings         n   =   [illegible]

    Max.eff.Inten.(mm/hr)=   [illegible]
               over (min)    [illegible]
    Storage Coeff.  (min)=   [illegible]
    Unit Hyd. Tpeak (min)=   [illegible]
    Unit Hyd. peak  (cms)=   [illegible]
                                                       *TOTALS*
    PEAK FLOW        (cms)=   [illegible]
    TIME TO PEAK     (hrs)=   [illegible]
    RUNOFF VOLUME     (mm)=   53.[illegible]     24.[illegible]     [illegible]
    TOTAL RAINFALL    (mm)=   54.5      54.5      [illegible]
    RUNOFF COEFFICIENT    =   [illegible]       44       [illegible]

      *** WARNING: Storage Coefficient is smaller than DT!
                   Use a smaller DT or a larger area.

      (i)  CN PROCEDURE SELECTED FOR PERVIOUS LOSSES:
           CN* =  80.0    Ia = Dep. Storage  (Above)
     (ii)  TIME STEP (DT) SHOULD BE SMALLER OR EQUAL
           THAN THE STORAGE COEFFICIENT.
    (iii)  PEAK FLOW DOES NOT INCLUDE BASEFLOW IF ANY.

 ---------------------------------------------------------------------------
 0004----------------------------------------------------------------------
 ***************************************************************************
 *#  ROAD : 20 m ROW, 8.5 M PAVEMENT WIDTH (2%), 150 MM CURB, 2.6% SHOULDERS
 *#  MAXIMUM DEPTH= 0.3  TYPICAL MOWED GRASS ON SHOULDERS (N=0.0425
 ***************************************************************************
 *  ROAD X-SECTION SLOPE = [illegible]%
 --------------------
 | ROUTE CHANNEL     |     Routing time step (min) =  5.00
 |  IN= 01:000101    |     Number of SEGMENTS =  3
 | OUT= 02:000202    |     Slopes (%): CHANNEL= .10   FLOODPLAIN= .10
 --------------------                    LENGTH = 1000.00    (m)

                 <------- DATA FOR SECTION  ( 2.0) ------->
                 Distance      Elevation        Manning
                    9.25         100.00          .0425
                   15.00          99.85        .0425 / .0130
                   15.01          99.7[illegible]          .0130
                   19.25          99.78          .0130
                   23.49          99.7[illegible]          .0130
                   23.50          99.85        .0130 / .0425
                   29.25         100.00          .0425

        --------------------- TRAVEL TIME TABLE ---------------------
         DEPTH     ELEV       VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
           m        (m)       (cu.m.)    (cms)        (m/s)       (min)
          .015    99.715    .113E+02     .001         .092       181.[illegible]
          .030    99.730    .450E+02     .007         .146       114.05
          .045    99.745    .101E+03     .019         .191        87.07
          .060    99.760    .180E+03     .042         .232        71.87
          .075    99.775    .281E+03     .076         .269        61.94
          .090    99.790    .404E+03     .127         .315        52.94
          .105    99.805    .531E+03     .200         .377        44.19
          .120    99.820    .659E+03     .286         .434        38.37
          .135    99.835    .786E+03     .383         .488        34.18
          .150    99.850    .914E+03     .491         .538        30.99
          .167    99.867    .107E+04     .625         .586        28.42
          .183    99.883    .124E+04     .773         .623        26.74
          .200    99.900    .143E+04     .935         .652        25.58
          .217    99.917    .165E+04    1.111         .673        24.76
          .233    99.933    .189E+04    1.303         .69[illegible]        24.[illegible]
          .250    99.950    .215E+04    1.509         .703        23.71
          .267    99.967    .243E+04    1.731         .713        23.37
          .283    99.983    .273E+04    1.968         .72[illegible]        23.[illegible]
          .300   100.000    .305E+04    2.222         .728        22.90

                             <---- hydrograph ---->   <-pipe / channel->
                   AREA     QPEAK   TPEAK   R.V.    MAX DEPTH   MAX VEL
                   (ha)     (cms)   (hrs)   (mm)       (m)       (m/s)
  INFLOW : ID= 1 (000101)  [illegible]   .367   [illegible].50  38.904     [illegible]       .[illegible]55
 OUTFLOW : ID= 2 (000202)  [illegible]   .33[illegible]  [illegible]  38.894     .052       .2[illegible]

 ---------------------------------------------------------------------------
 ---------------------------------------------------------------------------
 *
 *  ROAD X-SECTION SLOPE = [illegible]%
 --------------------
 | ROUTE CHANNEL     |     Routing time step (min) = [illegible]
 |  IN= [illegible]  |     Number of SEGMENTS = [illegible]
 | OUT= 2:000202     |     Slopes (%): CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 --------------------                    LENGTH = 1000.00    m

                 <------- DATA FOR SECTION  ( [illegible] ) ------->
                 Distance      Elevation        Manning
                  [illegible]    [illegible]        .0425
                  [illegible]      99.85        .0425 / .0130
                  [illegible]    [illegible]          .0130
                  [illegible]    [illegible]          .0130
                   23.49       [illegible]          .0130
                  [illegible]      99.85        .0130 / .0425
                  [illegible]    [illegible]          .0425

        --------------------- TRAVEL TIME TABLE ---------------------
         DEPTH     ELEV       VOLUME    FLOW RATE    VELOCITY    TRAV.TIME
           m         m        cu.m       cms          m/s          min
          [illegible]                                 .146       114.54
          [illegible]  45[illegible]E+[illegible]                           [illegible]
          .045    99.745  [illegible]                 .303        55.07
          [illegible]                                 .367        45.46
          [illegible]                                 .425        39.17
          [illegible]  4[illegible]E+[illegible]                     .498        33.48
          [illegible]  531E+03                        .596        27.95
          [illegible]                    45[illegible]     .607        24.[illegible]
          [illegible]
          [illegible]                                 .657
          [illegible]
          [illegible]
          [illegible]  .43[illegible]E+04    1.47[illegible]
          [illegible]
          [illegible]                    1.56[illegible]
          [illegible]                    1.30[illegible]
          .267    99.967  .243E+04
          .283    99.983  .273E+04    3.[illegible]                    24.[illegible]
          .300   [illegible]  .305E+04    [illegible]                    24.48

                             <---- hydrograph ---->   <-pipe / channel->
                   AREA     QPEAK   TPEAK   R.V.    MAX DEPTH   MAX VEL
                   (ha)     (cms)   (hrs)   (mm)       (m)       (m/s)
  INFLOW : ID= 1 (00[illegible])  [illegible]   [illegible]   9.50  38.904     .060       .160
 OUTFLOW : ID= 2 (0002[illegible])  [illegible]   .035   [illegible]  38.890     .047       .1[illegible]

 ---------------------------------------------------------------------------
 ---------------------------------------------------------------------------
 *
 *  ROAD X-SECTION SLOPE = [illegible]%
 --------------------
 | ROUTE CHANNEL     |     Routing time step (min) = [illegible]
 |  IN= [illegible]  |     Number of SEGMENTS = [illegible]
 | OUT= [illegible]  |     Slopes (%): CHANNEL= [illegible]   FLOODPLAIN= [illegible]
 --------------------                    LENGTH = [illegible]    m.

                 <------- DATA FOR SECTION  ( [illegible] ) ------->
                 Distance      Elevation        Manning
                    9.25         100.00          .0425
                   15.00          99.85        .0425 / .0130
                   15.01          99.7[illegible]          .0130
                   19.25          99.78          .0130
                   23.49          99.7[illegible]          .0130
```

```
00255>                  23.5?        99.??     .0130     .0425
00260>                  29.25       100.??               .0425
00261>
00262>       ---------------------- TRAVEL TIME TABLE ----------------------
00263>       DEPTH     ELEV      VOLUME     FLOW RATE    VELOCITY   TRAV. TIME
00264>        (m)       m        (cu.m.)      cms          m/s         min
00265>       .015    99.715    .113E+02      .002         .21?       8?.??
00266>       .03?    99.73?    .450E+02      .015         .3??       5?.??
00267>       .045    99.745    .101E+03      .043         .42?       38.94
00268>       .06     99.76     .180E+03      .093         .51?       3?.?4
00269>       .075    99.775    .281E+03      .166         [illegible]
00270>       .090    99.790    .404E+03      .284         [illegible]
00271>       .105    99.805    .531E+03      .448         [illegible]
00272>       .12?    99.82?    .659E+03      .640         [illegible]
00273>       .135    99.835    .786E+03      .85?         [illegible]
00274>       .150    99.850    .914E+03     1.09?         [illegible]
00275>       .167    99.867    .107E+04     1.3??         [illegible]
00276>       .183    99.883    .124E+04     1.?2?       1.?94        [illegible]
00277>       .200    99.900    .143E+04     2.09?       1.41?        [illegible]
00278>       .21?    99.91?    .165E+04     2.4??         [illegible]
00279>       .233    99.933    .189E+04     2.?13         [illegible]
00280>       .25?    99.95?    .215E+04     [illegible]
00281>       .2??    [illegible] .243E+04   [illegible]
00282>       .283    99.983    .273E+04     4.4??         [illegible]
00283>       .300    [illegible] .305E+04   4.9??         [illegible]
00284>
00285>                                  ----- hydrograph ----   <-pipe / channel->
00286>                           AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
00287>                           (ha)    (cms)   (hrs)   (mm)     (m)       (m/s)
00288>    INFLOW : ID= [illegible]                                          .4??
00289>    OUTFLOW: ID= [illegible]                                          .4??
00290>
00291>
00292> ------------------------------------------------------------------------------
00293> 0007--------------------------------------------------------------------------
00294> *
00295> *  ROAD X-SECTION  SLOPE = [illegible]
00296> ---------------------
00297>   ROUTE CHANNEL          Routing time step (min) =
00298>    IN> [illegible]       Number of SEGMENTS =
00299>   OUT< [illegible]       Slopes (%): CHANNEL=        FLOODPLAIN=
00300> ---------------------                 LENGTH =            m
00301>
00302>             ------- DATA FOR SECTION  [illegible]  -------
00303>             Distance        Elevation        Manning
00304>                              10?               .0425
00305>                              99.8?        .0425
00306>                              99.7?
00307>                              99.7?
00308>                              99.7?
00309>                              99.8?        .0130     .0425
00310>              29.25          100.0?              .0425
00311>
00312>       ---------------------- TRAVEL TIME TABLE ----------------------
00313>       DEPTH     ELEV      VOLUME     FLOW RATE    VELOCITY   TRAV. TIME
00314>         m         m         cu.m       cms          m/s         min
[illegible]
*** WARNING: Routing time step was adjusted
                                 ----- hydrograph ----   <-pipe / channel->
                          AREA    QPEAK   TPEAK   R.V.   MAX DEPTH  MAX VEL
```

```
00388>                       (ha)     (cms)    (hrs)    (mm)      (m)      (m/s)
00389>   INFLOW : ID= 1:000101    1.00     .067     9.50 38.904     .038     .837
00390>   OUTFLOW: ID= 2:000202    1.00     .048     9.62 38.902     .034     .775
00391>
00392>
00393> ---------------------------------------------------------------------------
00394> 0009-----------------------------------------------------------------------
00395> *
00396> *  ROAD X-SECTION  SLOPE = 5%
00397> --------------------
00398> | ROUTE CHANNEL          Routing time step (min) =  1.00
00399>    IN> 01:000101          Number of SEGMENTS =  3
00400>   OUT< 02:000202          Slopes (%): CHANNEL=5.00   FLOODPLAIN=5.00
00401> --------------------                  LENGTH = 1000.00    (m)
00402>
00403>              ------- DATA FOR SECTION  ( 2.0 ) -------
00404>              Distance      Elevation      Manning
00405>                9.25         100.00          .0425
00406>               15.00          99.85      .0425 / .0130
00407>               15.??          99.7?          .0130
00408>               19.25          99.74          .0130
00409>               23.49          99.7?          .0130
00410>               23.5?          99.85      .0130 / .0425
00411>               29.25         100.00          .0425
00412>
00413>       --------------------- TRAVEL TIME TABLE ----------------------
00414>       DEPTH     ELEV     VOLUME     FLOW RATE    VELOCITY   TRAV. TIME
00415>        (m)       (m)     (cu.m.)      (cms)       (m/s)       (min)
00416>       .015    99.715   .113E+02      .007         .651       25.61
00417>       .030    99.730   .450E+02      .046        1.033       16.13
00418>       .045    99.745   .101E+03      .137        1.354       12.31
00419>       .060    99.760   .180E+03      .295        1.640       10.16
00420>       .075    99.775   .281E+03      .535        1.903        8.76
00421>       .090    99.790   .404E+03      .899        2.224        7.49
00422>       .105    99.805   .531E+03     1.417        2.667        6.25
00423>       .120    99.820   .659E+03     2.023        3.071        5.43
00424>       .135    99.835   .786E+03     2.711        3.448        4.83
00425>       .150    99.850   .914E+03     3.475        3.802        4.38
00426>       .167    99.867   .107E+04     4.42?        4.14?        4.02
00427>       .183    99.883   .124E+04     5.465        4.409        3.78
00428>       .200    99.900   .143E+04     6.61?        4.67?        3.62
00429>       .217    99.917   .165E+04     7.859        4.7??        3.50
00430>       .233    99.933   .189E+04     9.2??        4.878        3.42
00431>       .250    99.950   .215E+04    10.672        4.969        3.35
00432>       .267    99.967   .243E+04    12.240        5.04?        3.31
00433>       .283    99.983   .273E+04    13.919        5.10?        3.27
00434>       .300   100.000   .305E+04    15.709        5.147        3.24
00435>
00436>     *** WARNING:  Routing time step was adjusted
00437>                               <---- hydrograph ---->   <-pipe / channel->
00438>                        AREA    QPEAK    TPEAK   R.V.    MAX DEPTH  MAX VEL
00439>                        (ha)    (cms)    (hrs)   (mm)      (m)      (m/s)
00440>   INFLOW : ID= 1:000101   1.00    .067     9.50 38.904     .033     1.091
00441>   OUTFLOW: ID= 2:000202   1.00    .053     9.62 38.903     .031     1.050
00442>
00443>
00444> ---------------------------------------------------------------------------
00445> 0010-----------------------------------------------------------------------
00446> *
00447> ***************************************************************************
00448> *# ROAD     24 m ROW, 15.? m PAVEMENT WIDTH (3% ), 150 MM CURB, ? 4% SHOULDERS
00449> *# MAXIMUM DEPTH= 0.3  TYPICAL MOWED GRASS IN SHOULDERS  N=0.0425
00450> ***************************************************************************
00451> *  ROAD X-SECTION SLOPE = 0.1%
00452> --------------------
00453>   ROUTE CHANNEL          Routing time step (min) =  5.00
00454>    IN> 01:000101          Number of SEGMENTS =  3
00455>   OUT< 02:000202          Slopes (%): CHANNEL= .10   FLOODPLAIN= .10
00456> --------------------                  LENGTH = 1000.00     m
00457>
00458>              ------- DATA FOR SECTION  ( 2.0 ) -------
00459>              Distance      Elevation      Manning
00460>                 .00         100.00          .0425
00461>                5.50          99.85      .0425 / .0130
00462>                5.51          99.7?          .0130
00463>               13.?0          99.6?          .0130
00464>               2?.5?          99.7?          .0130
00465>               2?.5?          99.85      .0130 / .0425
00466>               2?.??         100.??          .0425
00467>
00468>       --------------------- TRAVEL TIME TABLE ----------------------
00469>       DEPTH     ELEV     VOLUME     FLOW RATE    VELOCITY   TRAV. TIME
00470>         m         m        cu.m       cms          m/s         min
00471>       [illegible]        75.1E+??   [illegible]    .091      182.?9
00472>       .03     99.73     .300E+??     .??4         .145      114.9?
00473>       .045    99.745    .?7?E+??   [illegible]    .19?       87.?3
00474>       .06     99.76     .120E+03     .?2?         .23?       72.34
00475>       .075    99.775    .180E+03     .15?         .267       62.34
00476>       .090    99.790    .270E+03     .?0?         .30?       55.??
00477>       .105    99.805    .360E+03     .2??         .335       49.8?
00478>       .12     99.820    .480E+03     .?7?         .366       45.5?
00479>       .135    99.835    .600E+03     .24?         .396       42.1?
00480>       .15     99.850    .751E+03     .319         .426       39.2?
00481>       .167    99.867    .937E+03     .423         .45?       36.9?
00482>       .183    99.883    .116E+04     .540         .47?       35.3?
00483>       .20?    99.9??    .143E+04     .695         .487       34.19
00484>       .217    99.917    .173E+04     .867         .50?       33.24
00485>       .233    99.933    .207E+04    1.?00         .526       31.70
00486>       .250    99.95     .243E+04    1.350         .555       29.84
00487>       .267    99.967    .283E+04    1.654         .589       28.35
00488>       .283    99.983    .322E+04    1.976         .614       27.1?
00489>       .30    [illegible] .364E+04   2.3?3         .639       26.??
00490>
00491>                               <---- hydrograph ---->   <-pipe / channel->
00492>                        AREA    QPEAK    TPEAK   R.V.    MAX DEPTH  MAX VEL
00493>                         ha     cms      hrs      mm        m        m/s
00494>   INFLOW : ID= 1:000101   1.00    .067     9.50 38.904     .083     .285
00495>   OUTFLOW: ID= 2:000202   1.00    .03?    10.09 38.894     .062     .236
00496>
00497>
00498> ---------------------------------------------------------------------------
00499> 0011-----------------------------------------------------------------------
00500> *
00501> *  ROAD X-SECTION SLOPE = 0.25%
00502> --------------------
00503>   ROUTE CHANNEL          Routing time step (min) =  5.00
00504>    IN> 01:000101          Number of SEGMENTS =  3
00505>   OUT< 02:000202          Slopes (%): CHANNEL= .25   FLOODPLAIN= .25
00506> --------------------                  LENGTH = 1000.00     m
00507>
00508>              ------- DATA FOR SECTION  ( 2.0 ) -------
00509>              Distance      Elevation      Manning
00510>                 .00         100.00          .0425
00511>                5.50          99.85      .0425 / .0130
00512>                5.51          99.7?          .0130
00513>               13.50          99.6?          .0130
00514>               21.5?          99.7?          .0130
00515>               21.5?          99.85      .0130 / .0425
00516>               2?.??         100.??          .0425
```

```

     <---------------------- TRAVEL TIME TABLE ---------------------->
       DEPTH      ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        (m)       (m)        (cu.m.)     (cms)        (m/s)      (min)
        .015    99.715      .751E+01      .001         .141     [illegible]
        .030    99.730      .300E+02      .007         .224      [illegible]
        .045    99.745      .676E+02      .020         .301       55.4
        .060    99.760      .120E+03      .044         .364       45.7
        .075    99.775      .188E+03      .076         .422       39.41
        .090    99.790      .270E+03      .129         .477       34.9
        .105    99.805      .368E+03      .195         .524       31.5
        .120    99.820      .480E+03      .278         .579       28.8
        .135    99.835      .608E+03      .380         .626       26.64
        .150    99.850      .751E+03      .504         .67        24.84
        .167    99.867      .937E+03      .669         .714       23.34
        .183    99.883      .116E+04      .866         .745       22.36
        .200    99.900      .143E+04     1.099         .77        21.6
        .217    99.917      .173E+04     1.372         .79        21.0
        .233    99.933      .207E+04     1.720         .83        20.
        .250    99.95       .243E+04     2.147         .88        20.0
        .267    99.967      .282E+04     [illegible]   [illegible]  [illegible]
        .283    99.983      .322E+04     [illegible]   [illegible]  [illegible]
        .300   100.000      .364E+04     [illegible]   [illegible]  [illegible]

                               <---- hydrograph ---->   <-pipe / channel->
                        AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                        (ha)    (cms)   (hrs)    (mm)      (m)      (m/s)
   INFLOW : ID= 1(000101)  [illegible]  .067  9.58 38.904  [illegible]  .40
   OUTFLOW: ID= 2(000202)  [illegible]  .027  9.67 38.844  .054  .141


-----------------------------------------------------------------------------
0012-------------------------------------------------------------------------
*
*  ROAD X-SECTION SLOPE = 0.5%
--------------------
| ROUTE CHANNEL            Routing time step (min) = [illegible]
|   IN> 01:000101          Number of SEGMENTS = [illegible]
|  OUT< 02:000202          Slopes (%): CHANNEL= [illegible]   FLOODPLAIN= .5
--------------------                        LENGTH = [illegible]    m

                   <------- DATA FOR SECTION   [illegible] ------->
                    Distance     Elevation        Manning
                                   100.00           .0425
                      5.5           99.85      .0425 / .013
                      5.51          99.7            .013
                     13.            99.92           .013
                     20.5           99.7            .013
                     20.5           99.85      .013 / .0425
                     26.           100.00           .0425

     <---------------------- TRAVEL TIME TABLE ---------------------->
       DEPTH      ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        (m)       (m)        (cu.m.)     (cms)        (m/s)      (min)
        .015    99.715      .751E+01     [illegible]  [illegible]   91.5
        .030    99.73       .300E+02     [illegible]  [illegible]   51.35
        .045    99.745      .676E+02      .25          .4         39.19
        .06     99.76       .120E+03      .9          [illegible]   32.3
        .075    99.775      .188E+03     [illegible]   .4         27.84
        .09     99.79       .270E+03      .8          .4          24.6
        .105    99.805      .368E+03     [illegible]   .48        22.2
        .120    99.82       .480E+03      .14          .1         20.38
        .135    99.835      .608E+03      .38          .4         18.84
        .150    99.85       .751E+03     [illegible]   .4         17.5
        .167    99.867      .937E+03      .4          [illegible]   16.5
        .183    99.883      .116E+04     [illegible]   .4         15.6
        .200    99.90       .143E+04     [illegible]  [illegible]   15.2
        .217    99.917      .173E+04      .9          [illegible]   14.7
        .233    99.933      .207E+04      .4          [illegible]   14.2
        .250    99.950      .243E+04     [illegible]   .4         13.34
        .267    99.967      .282E+04      .69          .4         13.0
        .283    99.983      .322E+04     4.4          [illegible]   12.7
        .300   100.000      .364E+04     [illegible]   .4         12.4

                               <---- hydrograph ---->   <-pipe / channel->
                        AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                        (ha)    (cms)   (hrs)    (mm)      (m)      (m/s)
   INFLOW : ID= [illegible]      .067    9.58 38.904     .05      .523
   OUTFLOW: ID= [illegible]      .04     9.67 38.9       .05      .455


-----------------------------------------------------------------------------
0013-------------------------------------------------------------------------
*
*  ROAD X-SECTION SLOPE = [illegible] %
--------------------
  ROUTE CHANNEL            Routing time step (min) =
    IN> 01:000101          Number of SEGMENTS =
   OUT< 02:000202          Slopes (%): CHANNEL=        FLOODPLAIN=
--------------------                        LENGTH =            m

                   <------- DATA FOR SECTION   [illegible] ------->
                    Distance     Elevation        Manning
                                                    .0425
                                   99.85       .0425 / .013
                                   99.7             .013
                                   99.92            .013
                                   99.7             .013
                                   99.85        .013 / .0425
                     26.           100.00           .0425

     <---------------------- TRAVEL TIME TABLE ---------------------->
       DEPTH      ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        (m)       (m)        (cu.m.)     (cms)        (m/s)      (min)
        .015    99.715      .751E+01     [illegible]   .295       57.44
        .030    99.730      .300E+02      .18          .45        36.3
        .045    99.745      .676E+02      .4           .6        [illegible]
        .060    99.760      .120E+03      .08          .7         [illegible]
        .075    99.775      .188E+03      .15          .66        [illegible]
        .09     99.76       .270E+03      .28          .85        17.4
        .105    99.805      .368E+03      .39         [illegible]   15.
        .12     99.8        .480E+03      .5          [illegible]   14.
        .135    99.835      .608E+03      .7          [illegible]   13.
        .15     99.85       .751E+03     [illegible]  1.34         12.8
        .167    99.867      .937E+03     1.338        1.4         12.
        .183    99.883      .116E+04     [illegible]  1.4          11.
        .2      99.9        .143E+04     2.0          1.54         11.
        .217    99.917      .173E+04     2.4          1.59         10.
        .233    99.933      .207E+04     3.13         1.6          10.
        .25     99.95       .243E+04     3.9          1.7          9.44
        .267    99.967      .282E+04     4.3          1.85         9.
        .283    99.983      .322E+04     5.48         1.94         8.58
        .300   100.000      .364E+04     6.4          2.01         8.4

                               <---- hydrograph ---->   <-pipe / channel->
                        AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                        (ha)    (cms)   (hrs)    (mm)      (m)      (m/s)
   INFLOW : ID= [illegible]      .06     9.5  38.904      .03       .68
   OUTFLOW: ID= [illegible]      .0      9.   38.9        .04       .6


-----------------------------------------------------------------------------
0014-------------------------------------------------------------------------
*
*  ROAD X-SECTION  SLOPE = 2.5%
--------------------
  ROUTE CHANNEL            Routing time step (min) =  1.00
   IN> 01:000101           Number of SEGMENTS =  3
  OUT< 02:000202           Slopes (%): CHANNEL=2.50   FLOODPLAIN=2.50
--------------------                        LENGTH = 1000.00    (m)

                   <------- DATA FOR SECTION  ( 2.0) ------->
                    Distance     Elevation        Manning
                       .00        100.00           .0425
                      5.50         99.85       .0425 / .0130
                      5.51         99.70           .0130
                     13.00         99.92           .0130
                     20.50         99.70           .0130
                     20.50         99.85       .0130 / .0425
                     26.00        100.00           .0425

     <---------------------- TRAVEL TIME TABLE ---------------------->
       DEPTH      ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        (m)       (m)        (cu.m.)     (cms)        (m/s)      (min)
        .015    99.715      .751E+01      .003         .457       36.46
        .030    99.730      .300E+02      .022         .726       22.97
        .045    99.745      .676E+02      .064         .951       17.53
        .060    99.760      .120E+03      .138        1.152       14.47
        .075    99.775      .188E+03      .251        1.337       12.47
        .090    99.790      .270E+03      .408        1.510       11.04
        .105    99.805      .368E+03      .615        1.673        9.96
        .120    99.820      .480E+03      .879        1.829        9.11
        .135    99.835      .608E+03     1.203        1.978        8.43
        .150    99.850      .751E+03     1.593        2.122        7.85
        .167    99.867      .937E+03     2.115        2.258        7.38
        .183    99.883      .116E+04     2.739        2.357        7.07
        .200    99.900      .143E+04     3.476        2.437        6.84
        .217    99.917      .173E+04     4.334        2.507        6.65
        .233    99.933      .207E+04     5.438        2.629        6.34
        .250    99.950      .243E+04     6.788        2.793        5.97
        .267    99.967      .282E+04     8.269        2.939        5.67
        .283    99.983      .322E+04     9.879        3.072        5.43
        .300   100.000      .364E+04    11.616        3.192        5.22

     *** WARNING : Routing time step was adjusted
                               <---- hydrograph ---->   <-pipe / channel->
                        AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                        (ha)    (cms)   (hrs)    (mm)      (m)      (m/s)
   INFLOW : ID= 1(000101)  1.00    .067    9.58 38.904     .046      .958
   OUTFLOW: ID= 2(000202)  1.00    .050    9.60 38.902     .040      .862


-----------------------------------------------------------------------------
0015-------------------------------------------------------------------------
*
*  ROAD X-SECTION  SLOPE = 5%
--------------------
  ROUTE CHANNEL            Routing time step (min) =  1.00
   IN> 01:000101           Number of SEGMENTS =  3
  OUT< 02:000202           Slopes (%): CHANNEL=5.0.   FLOODPLAIN=5.00
--------------------                        LENGTH = 1000.00    m)

                   <------- DATA FOR SECTION   2.0) ------->
                    Distance     Elevation        Manning
                       .00        100.00           .0425
                      5.50         99.85       .0425 / .013
                      5.51         99.70           .0130
                     13.00         99.92           .0130
                     20.50         99.70           .0130
                     20.50         99.85       .0130 / .0425
                     26.00        100.00           .0425

     <---------------------- TRAVEL TIME TABLE ---------------------->
       DEPTH      ELEV       VOLUME     FLOW RATE    VELOCITY   TRAV.TIME
        (m)       (m)        (cu.m.)     (cms)        (m/s)      (min)
        .015    99.715      .751E+01      .005         .647       25.78
        .030    99.730      .300E+02      .031        1.026       16.24
        .045    99.745      .676E+02      .091        1.345       12.39
        .060    99.760      .120E+03      .196        1.629       10.23
        .075    99.775      .188E+03      .355        1.891        8.82
        .090    99.790      .270E+03      .577        2.135        7.81
        .105    99.805      .368E+03      .870        2.366        7.04
        .120    99.820      .480E+03     1.243        2.586        6.44
        .135    99.835      .608E+03     1.701        2.796        5.96
        .150    99.850      .751E+03     2.253        3.001        5.55
        .167    99.867      .937E+03     2.991        3.193        5.22
        .183    99.883      .116E+04     3.874        3.334        5.00
        .200    99.900      .143E+04     4.916        3.447        4.84
        .217    99.917      .173E+04     6.131        3.545        4.70
        .233    99.933      .207E+04     7.692        3.718        4.48
        .250    99.950      .243E+04     9.600        3.949        4.22
        .267    99.967      .282E+04    11.694        4.157        4.01
        .283    99.983      .322E+04    13.97         4.344        3.84
        .300   100.000      .364E+04    16.426        4.514        3.69

     *** WARNING : Routing time step was adjusted
                               <---- hydrograph ---->   <-pipe / channel->
                        AREA    QPEAK   TPEAK    R.V.   MAX DEPTH  MAX VEL
                        (ha)    (cms)   (hrs)    (mm)      (m)      (m/s)
   INFLOW : ID= 1(000101)  1.00     067    9.58 38.904     .039     1.199
   OUTFLOW: ID= 2(000202)  1.00     053    9.60 38.903     .035     1.123


-----------------------------------------------------------------------------
0016-------------------------------------------------------------------------
*
*
     FINISH
-----------------------------------------------------------------------------
=============================================================================
     WARNINGS / ERRORS / NOTES
     -------------------------
 001 DESIGN STANDHYD
     *** WARNING: Storage Coefficient is smaller than DT!
                  Use a smaller DT or a larger area.
 0012 ROUTE CHANNEL   ->
     *** WARNING : Routing time step was adjusted
 0013 ROUTE CHANNEL   ->
     *** WARNING : Routing time step was adjusted
 0014 ROUTE CHANNEL   ->
     *** WARNING : Routing time step was adjusted
 0015 ROUTE CHANNEL   ->
     *** WARNING : Routing time step was adjusted
   Simulation ended on 1997-04-11     at 20:12:15
=============================================================================
```

APPENDIX E

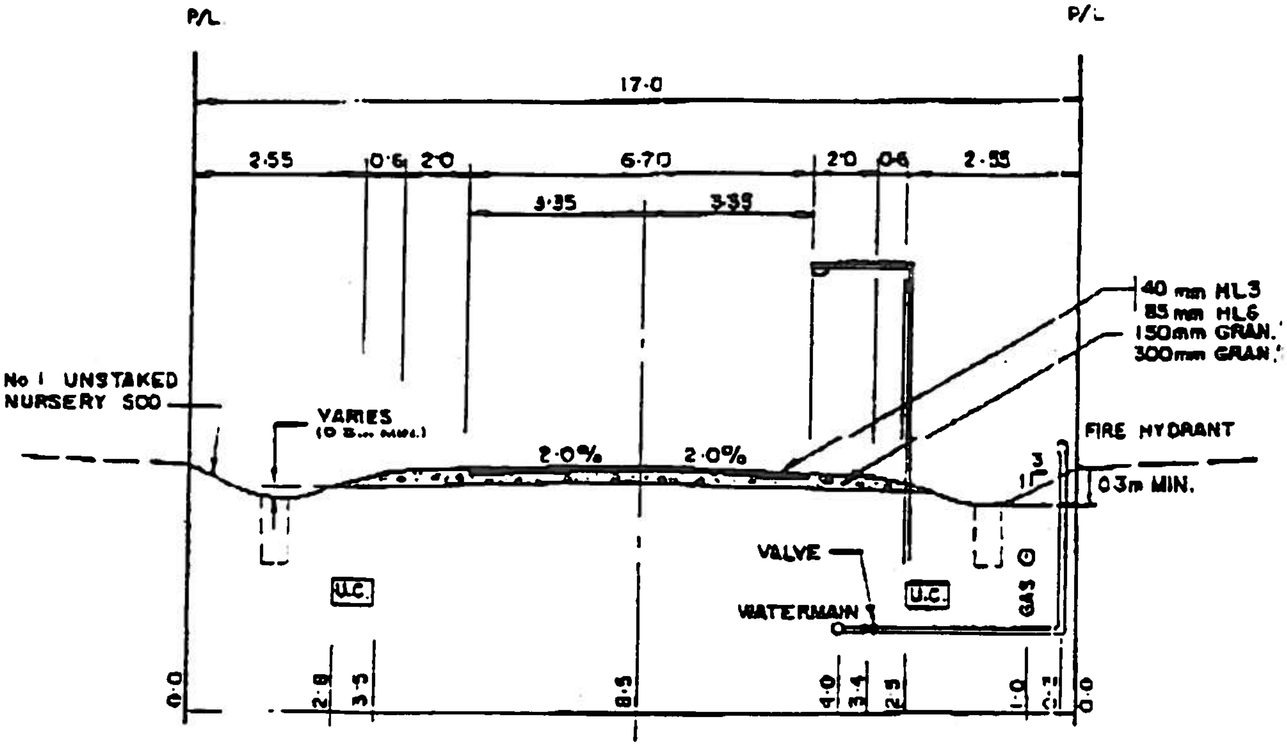
Typical standards for ROW and road widths and location of utilities

APPENDIX E

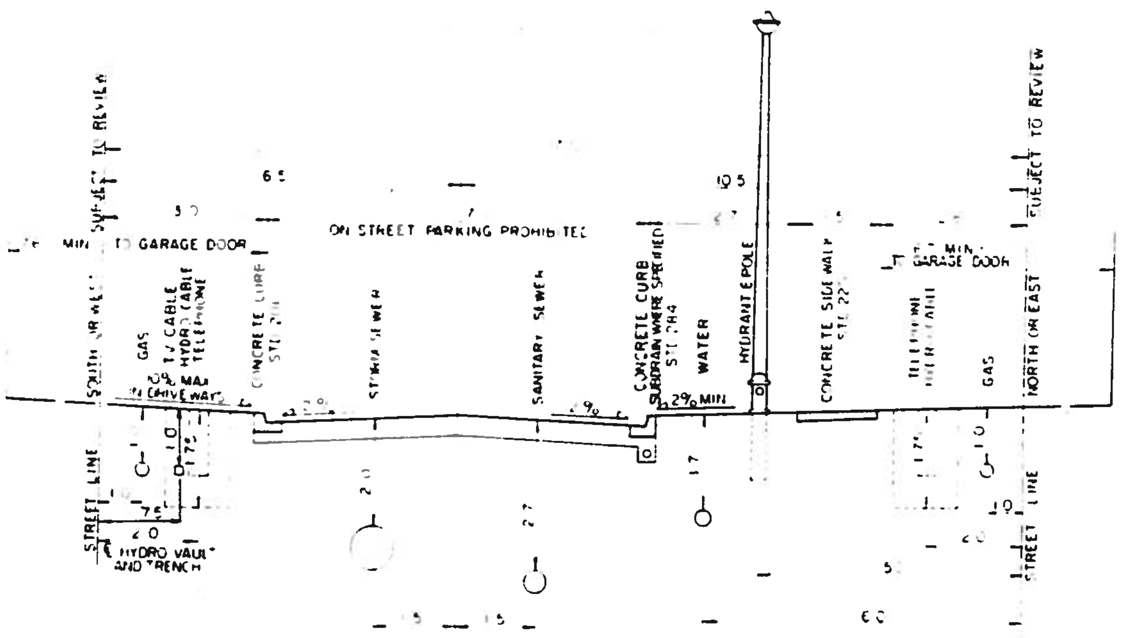
Typical standards for ROW and road widths and location of utilities

Fig. No.	Type of road and drainage system	ROW widths (m)	Pavement widths (m)
E-1	Private residential street with swales and infiltration trenches (includes underground utilities, water main and street lighting)	17	6.7
E-2	Minor local residential streets (Innovative Housing) with curb & gutter, (includes one sidewalk, underground utilities and street lighting)	17	7
E-3	Minor local streets with curb & gutter, (includes below ground utilities and street lighting)	18	8.5
E-4	Intermediate local residential street (Innovative Housing) with curb & gutter (includes one sidewalk, underground utilities and street lighting)	18.5	8.5
E-5	Urban or rural residential with grass swales and perforated pipes	20	6.8
E-6	Local residential street with ditches (includes above or below ground utilities, two sidewalks, and street lighting)	20	7.2
E-7	Rural estate with curbs and ditches (includes below ground utilities, water main and street lighting)	20	7.3
E-8	Urban or rural residential with grass swales, perforated pipes and storm sewers (includes sanitary)	20	7.3
E-9	Rural residential street with ditches	20	7.5
E-10	Typical local street with curb & gutter (includes above or below ground utilities, water main, street lighting and two sidewalks)	20	8.5
E-11	Rural collector with ditches	20	8.5
E-12	Residential collector with curb & gutter (includes below ground utilities, water main, street lighting and two sidewalks)	20	11
E-13	Collector street (minor) with curb & gutter (includes below ground utilities, water main, street lighting and two sidewalks)	23	8.5
E-14	Collector street (major) with curb & gutter (includes below ground utilities, water main, street lighting and two sidewalks)	23	11
E-15	Minor arterial with curb & gutter (includes below ground utilities water main, street lighting and two sidewalks)	26	14.5
E-16	Primary collector and arterial streets with ditches (includes above or underground utilities, water main, street lighting and two sidewalks)	27	7.2
E-17	Median divided arterial street with curb & gutter (includes above or below ground utilities, water main, street lighting and two sidewalks)	36	15.6 + median

E-1



E-2



DIMENSIONS IN metres EXCEPT AS NOTED

CITY OF ETOBICOKE

INNOVATIVE HOUSING
MINOR LOCAL RESIDENTIAL STREET

DRAWN BY S B
CHK'D BY
APPROVED
DEPUTY BOROUGH ENGINEER
DATE 78 07
REVISION No
DATE 96/
SCALE N T S
STANDARD
122

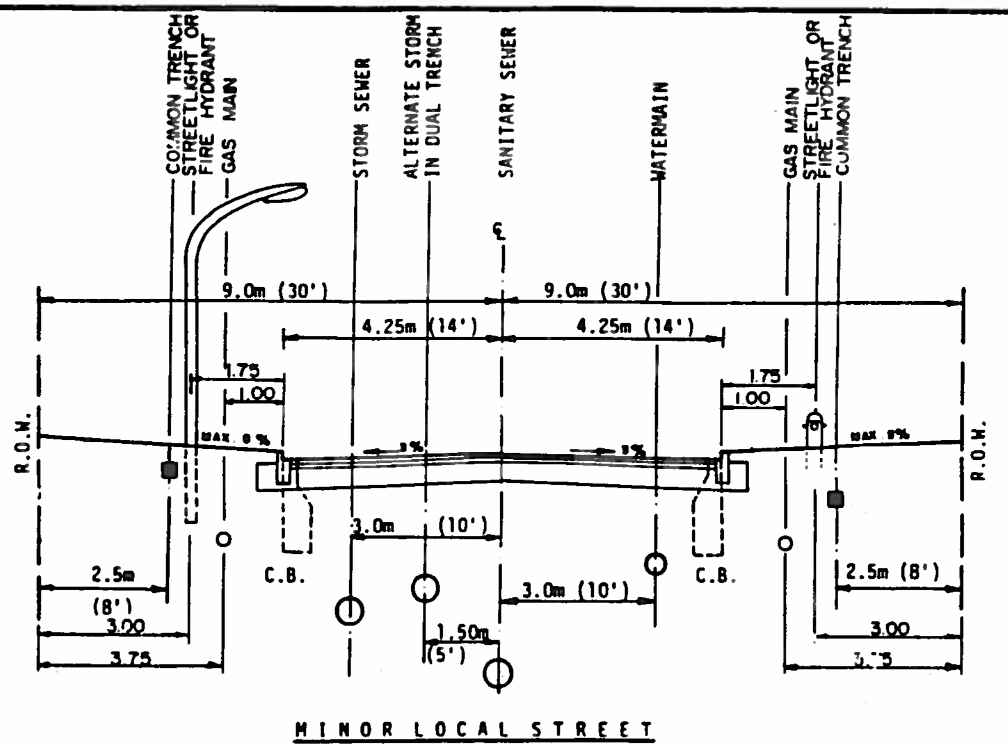
NOTES

THIS STANDARD TO BE USED ONLY IN "INNOVATIVE HOUSING" SCHEMES ON SHORT CUL-DE-SACS (MAX LENGTH [illegible]) AND CRESCENTS (MAX LENGTH 230 m) WITH ADDITIONAL OFF STREET PARKING PROVIDED (eg 2 CAR GARAGES)

2. GEOMETRIC DESIGN STANDARDS TO BE IN ACCORDANCE WITH RECOMMENDATIONS OF THE ROADS AND TRANSPORTATION ASSOCIATION OF CANADA WITH A DESIGN SPEED OF 50 km/hr, MAX GRADIENT OF 5.0 %, MIN GRADIENT OF 0.35 %, MIN CURB RADII AT INTERSECTIONS OF 8.0 m MIN INSIDE CURB RADIUS ON BENDS OF 15.0 m WITH THE PAVEMENT WIDTH INCREASED AS NECESSARY TO MAINTAIN THE OUTSIDE CURB OFFSET FROM STREET LINE. THE INSIDE STREET LINE RADIUS AT INTERSECTIONS AND BENDS SHALL BE ADJUSTED TO ENSURE THAT THE REQUIRED BOULEVARD WIDTH FROM THE CURB TO THE STREET LINE IS MAINTAINED. MIN CURB RADII AT CUL-DE-SAC OF 9.0 m, WITH A MIN BLVD WIDTH TO THE STREET LINE OF 7.0 m WHERE A SIDEWALK IS CONTINUOUS AROUND THE END OF THE TURNING CIRCLE, AND A MIN BLVD WIDTH TO THE STREET LINE OF 4.6 m WHERE THERE IS NO SIDEWALK

3. ALL DIMENSIONS SHOWN FOR COVER ARE MINIMUM

E-3



NOTE:

1. SEE ALSO DRWG R-9.
2. COMMON TRENCH – TELEPHONE, CABLEVISION, HYDRO, STREETLIGHTING

SCALE: 1 : 100

REVISION DATE: OCT 1989

UTILITY LOCATIONS 18 m (60') RIGHT OF WAY

DRAWN : K.H.

CHECKED: R.W.W.

DRWG. NO: YELLO

SK-1

E-4

CITY OF ETOBICOKE

INNOVATIVE HOUSING
INTERMEDIATE LOCAL RESIDENTIAL STREET

DRAWN BY S B

CHK'D BY

APPROVED

DEPUTY BOROUGH ENGINEER

DATE: 78 07

REVISION Nº

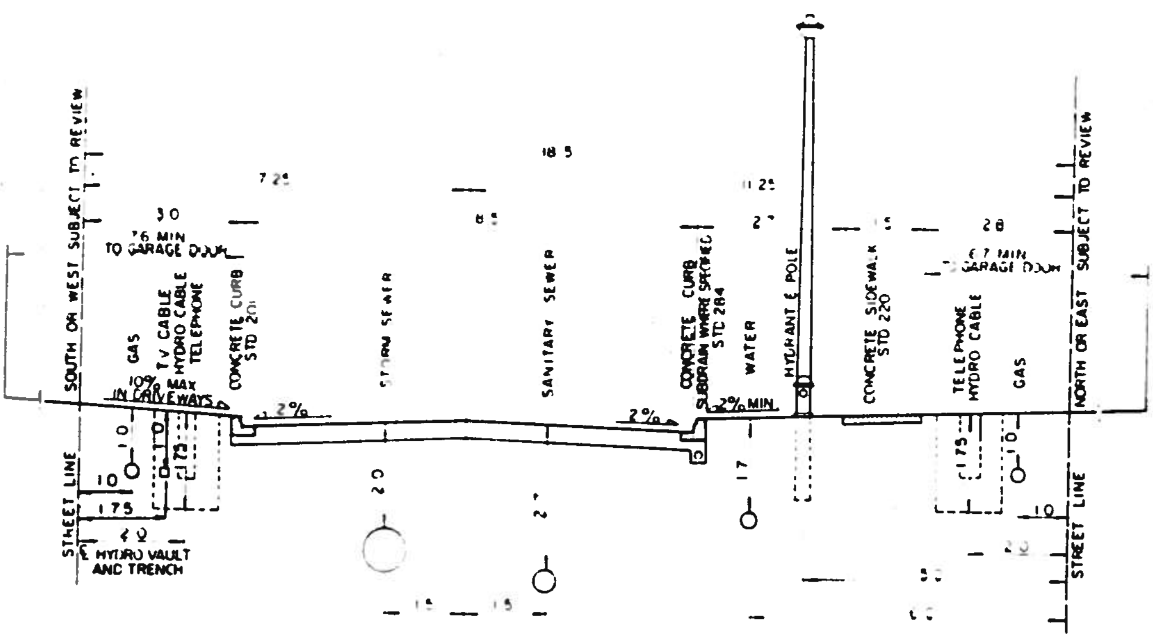
DATE: 96 /

SCALE: N T

STANDARD

121

DIMENSIONS IN metres EXCEPT AS NOTED



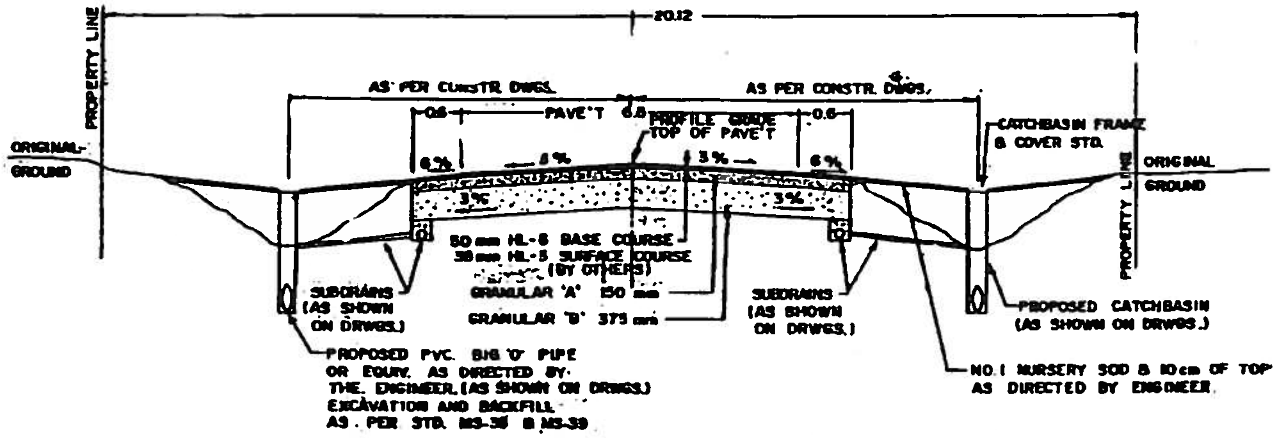
NOTES

1) THIS STANDARD TO BE USED ONLY IN "INNOVATIVE HOUSING" SCHEMES ON LONG CUL DE-SACS AND CRESCENTS WHICH DO NOT PROVIDE ACCESS TO OTHER INTERMEDIATE LOCAL STREETS, MINOR LOCAL CRESCENT STREETS, OR MORE THAN TWO SHORT CUL-DE-SACS (SUBJECT TO REVIEW BY THE CITY ENGINEER)

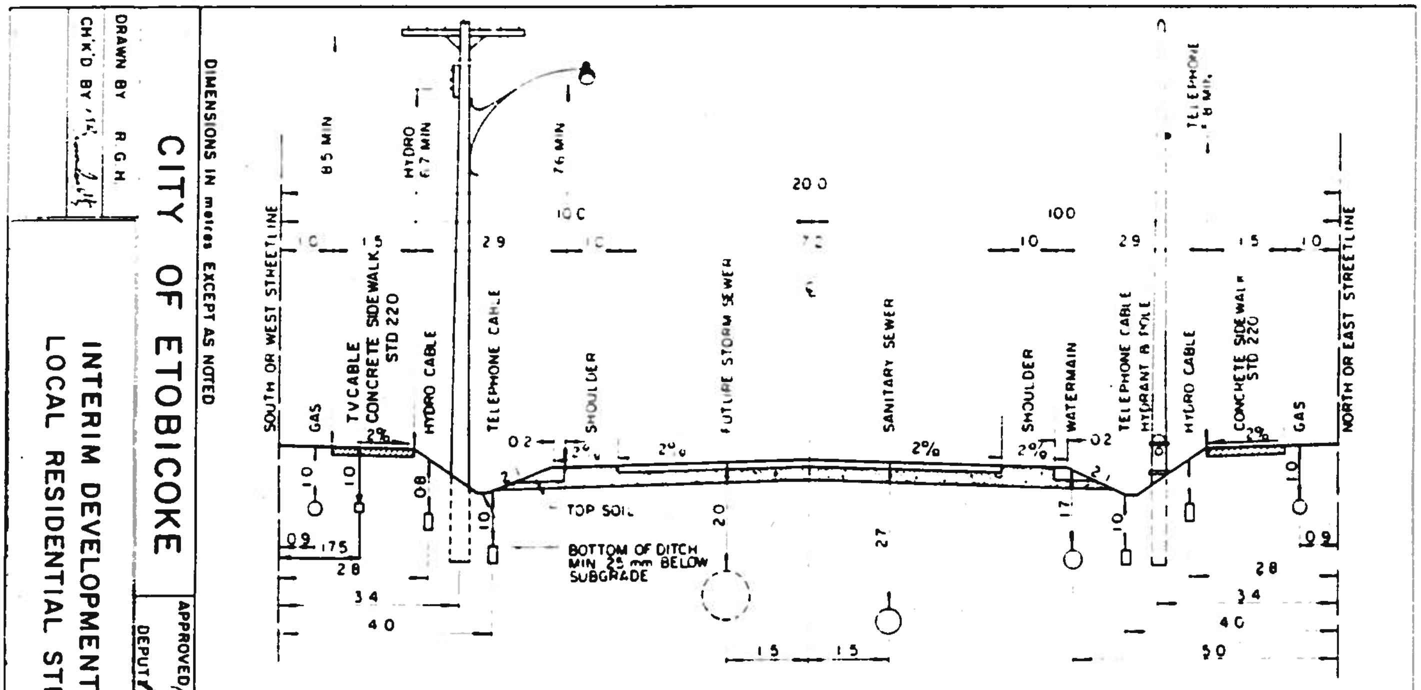
2) GEOMETRIC DESIGN STANDARDS TO BE IN ACCORDANCE WITH RECOMMENDATIONS OF THE ROADS AND TRANSPORTATION ASSOCIATION OF CANADA WITH A DESIGN SPEED OF 50 km/h, MAX GRADIENT OF 5.0%, MIN GRADIENT OF 0.35% MIN CURB RADII AT INTERSECTIONS OF 8.0 m MINIMUM INSIDE CURB RADIUS ON BENDS OF 15.0 m WITH THE PAVEMENT WIDTH INCREASED AS NECESSARY TO MAINTAIN THE OUTSIDE CURB OFFSET FROM STREET LINE THE INSIDE STREET LINE RADIUS AT INTERSECTIONS AND BENDS SHALL BE ADJUSTED TO ENSURE THAT THE REQUIRED BOULEVARD WIDTH FROM THE CURB TO THE STREET LINE IS MAINTAINED MIN CURB RADII AT CUL-DE-SAC OF 9.0 m WITH A MIN BLVD WIDTH TO THE STREET LINE OF 7.0 m WHERE A SIDEWALK IS CONTINUOUS AROUND THE END OF THE TURNING CIRCLE AND A MIN BLVD WIDTH TO THE STREET LINE OF 4.6 m WHERE THERE IS NO SIDEWALK

3) ALL DIMENSIONS SHOWN FOR COVER ARE MINIMUM

E-5



E-6



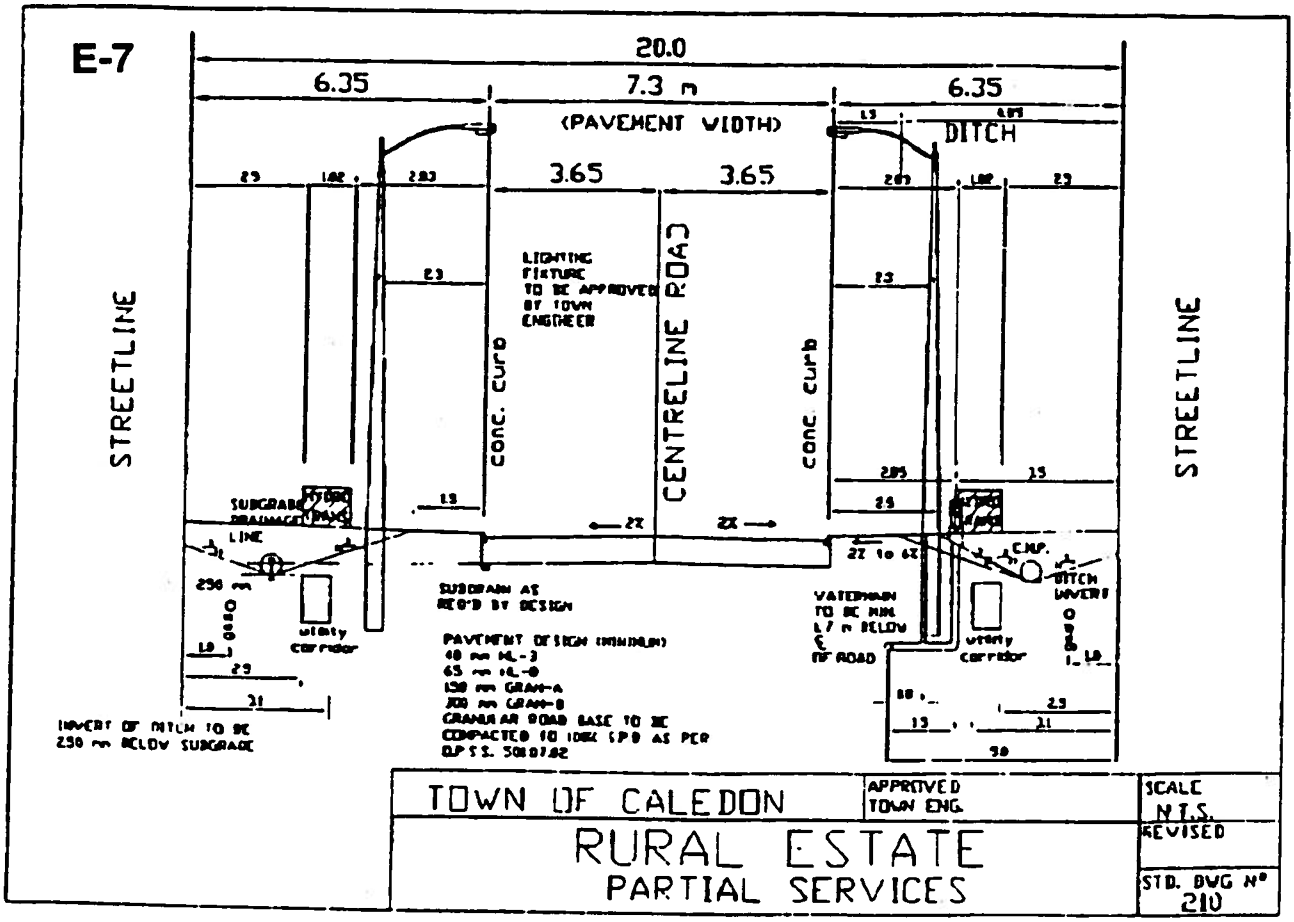
NOTES

1 ALL DIMENSIONS SHOWN FOR COVER ARE MINIMUM AND SHALL TAKE INTO CONSIDERATION THE ULTIMATE GRADING OF THE ROAD ALLOWANCE UTILITY LOCATIONS IN ACCORDANCE WITH ETOBICOKE PROCEDURE No E9-8

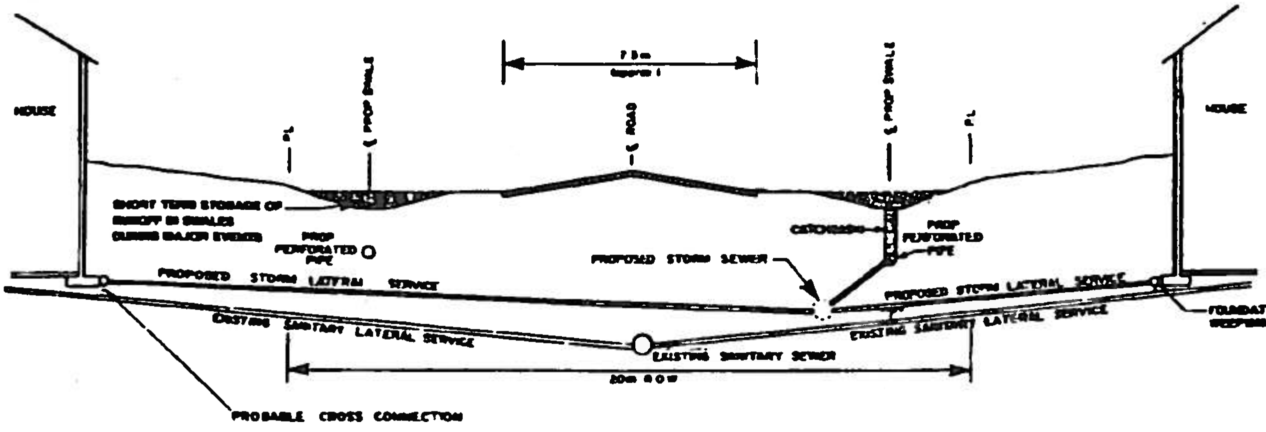
2 GEOMETRIC DESIGN STANDARDS TO BE IN ACCORDANCE WITH RECOMMENDATIONS OF THE ROADS AND TRANSPORTATION ASSOCIATION OF CANADA WITH A DESIGN SPEED OF 50 km/hr , MAX GRADIENT OF 5.0 % , MIN GRADIENT OF 0.35%
MIN ASPHALT RADII AT INTERSECTIONS OF 9.0 m , MIN INSIDE ASPHALT RADIUS ON BENDS OF SHORT CRESCENT STREETS AND CUL-DE-SACS OF 15.0 m , WITH THE PAVEMENT WIDTH INCREASED AS NECESSARY TO MAINTAIN THE OUTSIDE PAVEMENT OFFSET FROM STREET LINE
THE INSIDE STREET LINE RADIUS AT INTERSECTIONS AND BENDS SHALL BE ADJUSTED TO ENSURE THAT THE REQUIRED BOULEVARD WIDTH FROM THE FUTURE CURB TO THE STREET LINE IS MAINTAINED
MINIMUM INSIDE ASPHALT RADIUS ON BENDS OF OTHER LOCAL STREETS OF 79.0 m
MINIMUM ASPHALT RADII AT CUL-DE-SAC OF 9.0 m , WITH MINIMUM BOULEVARD WIDTH TO STREET LINE OF 5.75 m

3 SIDEWALK ELEVATIONS SHALL SATISFY EXISTING DRAINAGE REQUIREMENTS AND TAKE INTO CONSIDERATION THE ULTIMATE ROAD GRADE WHEN CURBS ARE CONSTRUCTED

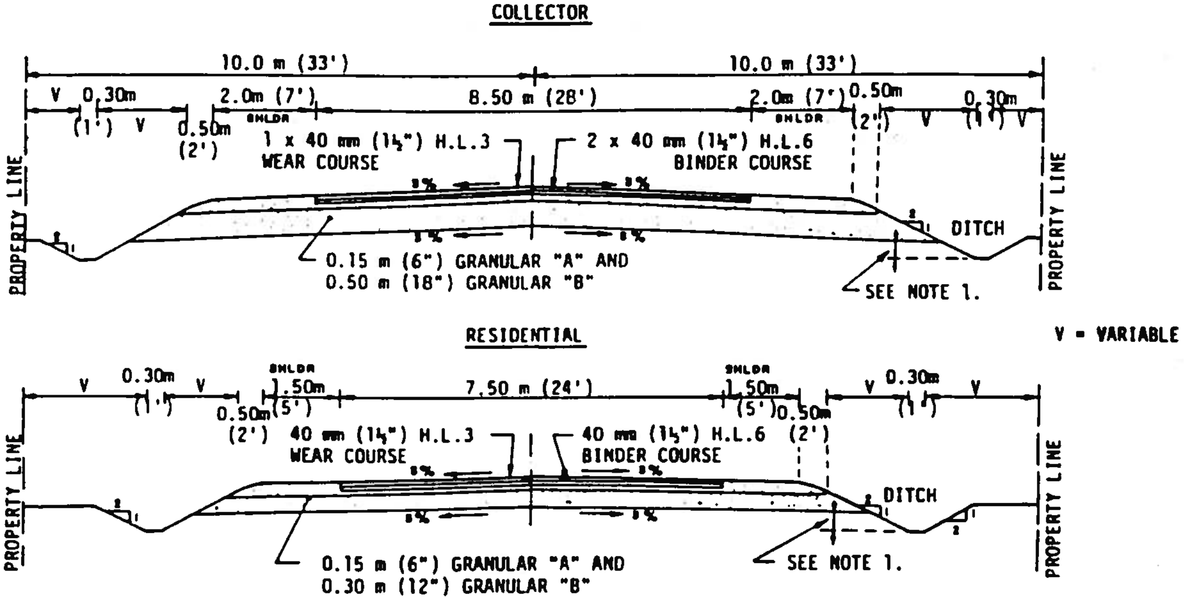
E-7


20.0
6.35
7.3 m
6.35
(PAVEMENT WIDTH)
DITCH
3.65
3.65
LIGHTING FIXTURE TO BE APPROVED BY TOWN ENGINEER
CENTRELINE ROAD
STREETLINE
STREETLINE
conc. curb
conc. curb
SUBGRADE DRAINAGE LINE
HYDRO
250 mm
utility corridor
2%
2%
2% to 6%
C.M.P.
DITCH INVERT
SUBDRAIN AS REQ'D BY DESIGN
PAVEMENT DESIGN (MINIMUM)
40 mm HL-3
65 mm HL-8
150 mm GRAN-A
300 mm GRAN-B
GRANULAR ROAD BASE TO BE COMPACTED TO 100% S.P.D AS PER O.P.S.S. 501.07.02
WATERMAIN TO BE MIN 1.7 m BELOW ℄ OF ROAD
INVERT OF DITCH TO BE 250 mm BELOW SUBGRADE
TOWN OF CALEDON
APPROVED TOWN ENG.
SCALE N.T.S.
REVISED
RURAL ESTATE
PARTIAL SERVICES
STD. DWG Nº 210

E-8


HOUSE
HOUSE
7.3m
PL
℄ PROP SWALE
℄ ROAD
℄ PROP SWALE
PL
SHORT TERM STORAGE OF RUNOFF IN SWALES DURING MAJOR EVENTS
PROP PERFORATED PIPE
CATCHBASIN
PROP PERFORATED PIPE
PROPOSED STORM SEWER
PROPOSED STORM LATERAL SERVICE
PROPOSED STORM LATERAL SERVICE
EXISTING SANITARY LATERAL SERVICE
EXISTING SANITARY LATERAL SERVICE
EXISTING SANITARY SEWER
FOUNDATION WEEPING TILES
20m R.O.W
PROBABLE CROSS CONNECTION

E-9



NOTES:

1. BOTTOM OF DITCH TO BE MINIMUM 0.30 m (1') BELOW GRANULAR SUBGRADE.
2. SHOULDER ON COLLECTOR STREET TO BE SURFACE TREATED, WHERE REQUIRED BY THE TWP. ENGINEER.
3. SUB-EXCAVATE SOFT AREAS IN SUBBASE AND FILL WITH GRANULAR "B" COMPACTED IN 0.15 m (6") LAYERS.
4. ALL MATERIALS TO BE SUPPLIED AND PLACED AS PER M.T.C. STANDARDS AND SPECIFICATIONS.
5. DEPTH OF GRANULAR "B" TO BE INCREASED AS REQUIRED BY SOIL CONDITIONS.
6. WEAR COURSE TO BE PLACED AFTER T.V. INSPECTION OF SEWERS AND ALL RESULTING REPAIRS CARRIED OUT BUT NO SOONER THAN 12 MONTH AFTER BINDER COURSE IN NEW SUBDIVISIONS.

SCALE 1 100	TOWNSHIP OF GLOUCESTER	DRAWN K.H. CHECKED: R.W. W.
REVISION DATE JULY 79	ROADWAY CROSS - SECTION IN RURAL AREAS	DRWG NO. R - 6

E-10

CITY OF ETOBICOKE

LOCAL RESIDENTIAL STREET

DRAWN BY S B

CHK'D BY

APPROVED

DEPUTY BOROUGH ENGINEER

DATE 78

REVISION

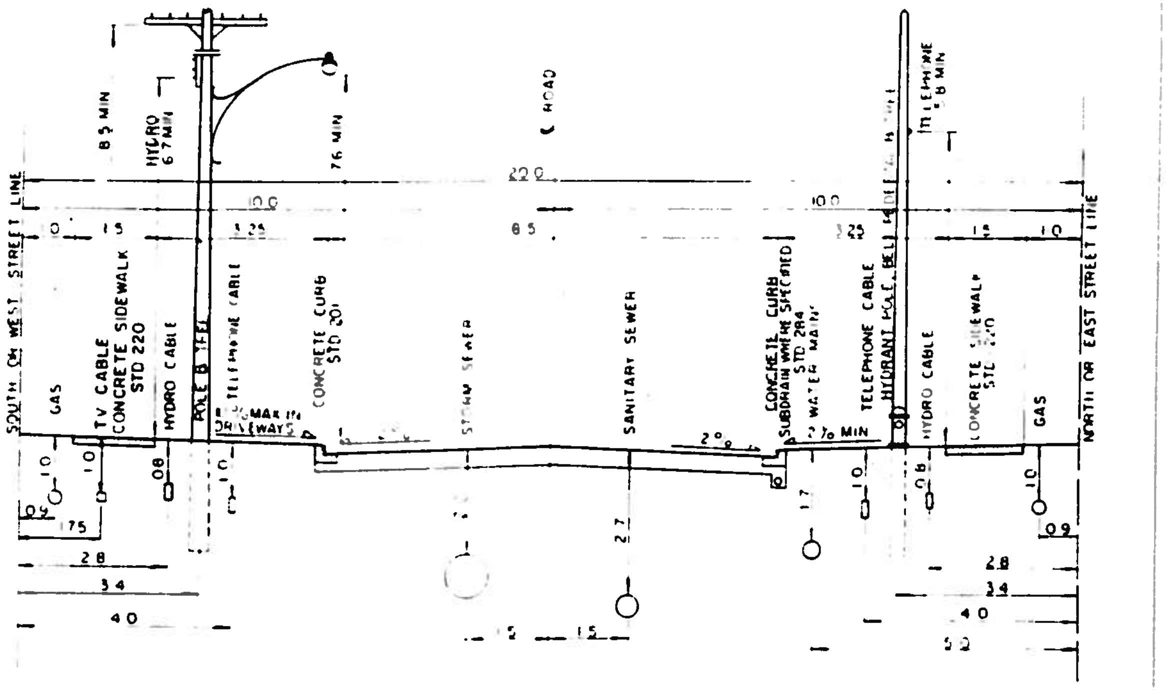
DATE

SCALE

STANDARD

120

DIMENSIONS IN metres EXCEPT AS NOTED



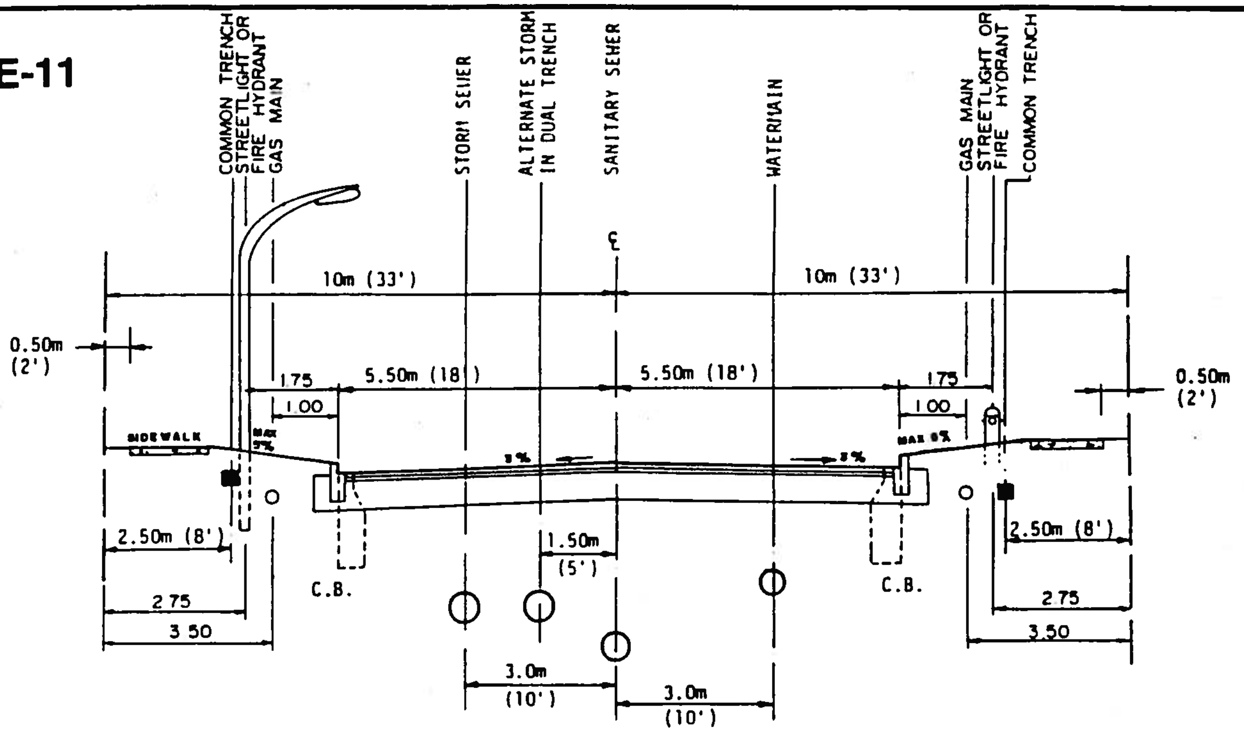
NOTES

ALL DIMENSIONS SHOWN FOR COVER ARE MINIMUM UTILITY LOCATIONS IN ACCORDANCE WITH M T P U C C DAG MA 412 SHT 1 B 2) AND ETOBICOKE PROCEDURE E9 8

2) GEOMETRIC DESIGN STANDARDS TO BE IN ACCORDANCE WITH RECOMMENDATIONS OF THE ROADS AND TRANSPORTATION ASSOCIATION OF CANADA WITH A DESIGN SPEED OF 50 km/hr, MAX GRADIENT OF 5.0%, MIN GRADIENT OF 0.35%. MIN CURB RADII AT INTERSECTIONS OF 8.0 m MIN INSIDE CURB RADIUS ON BENDS OF SHORT CRESCENT STREETS AND CUL DE-SACS OF 15.0 m WITH THE PAVEMENT WIDTH INCREASED AS NECESSARY TO MAINTAIN THE OUTSIDE CURB OFFSET FROM STREET LINE. THE INSIDE STREET LINE RADIUS AT INTERSECTIONS AND BENDS SHALL BE ADJUSTED TO ENSURE THAT THE REQUIRED BOULEVARD WIDTH FROM THE CURB TO THE STREET LINE IS MAINTAINED. MINIMUM INSIDE CURB RADIUS ON BENDS OF OTHER LOCAL STREETS OF 73.0 m. MINIMUM CURB RADII AT CUL-DE-SAC OF 9.0 m, WITH MINIMUM BLVD WIDTH TO STREET LINE OF 5.75 m

3) THIS SECTION ASSUMES A NORMAL [illegible] FROM THE STREET LINE AND NORMAL PEDESTRIAN NEEDS

E-11

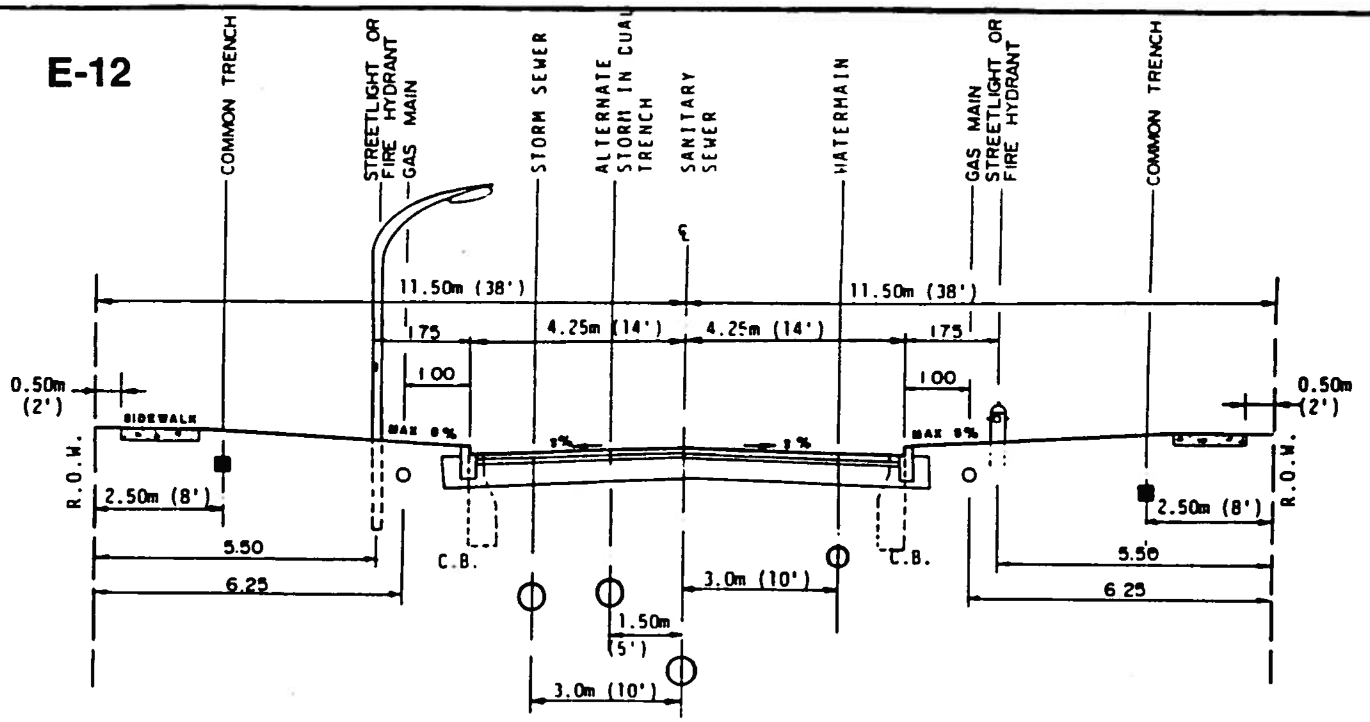


RESIDENTIAL COLLECTOR

NOTE: 1. SEE ALSO DRWG. R-9. 2. COMMON TRENCH - TELEPHONE, CABLEVISION, HYDRO, STREETLIGHTING

SCALE 1 : 100
REVISION DATE OCT 1989
UTILITY LOCATIONS 20m (66') RIGHT OF WAY
DRAWN K.H.
CHECKED: R.W.W.
DRWG NO SK-3

E-12

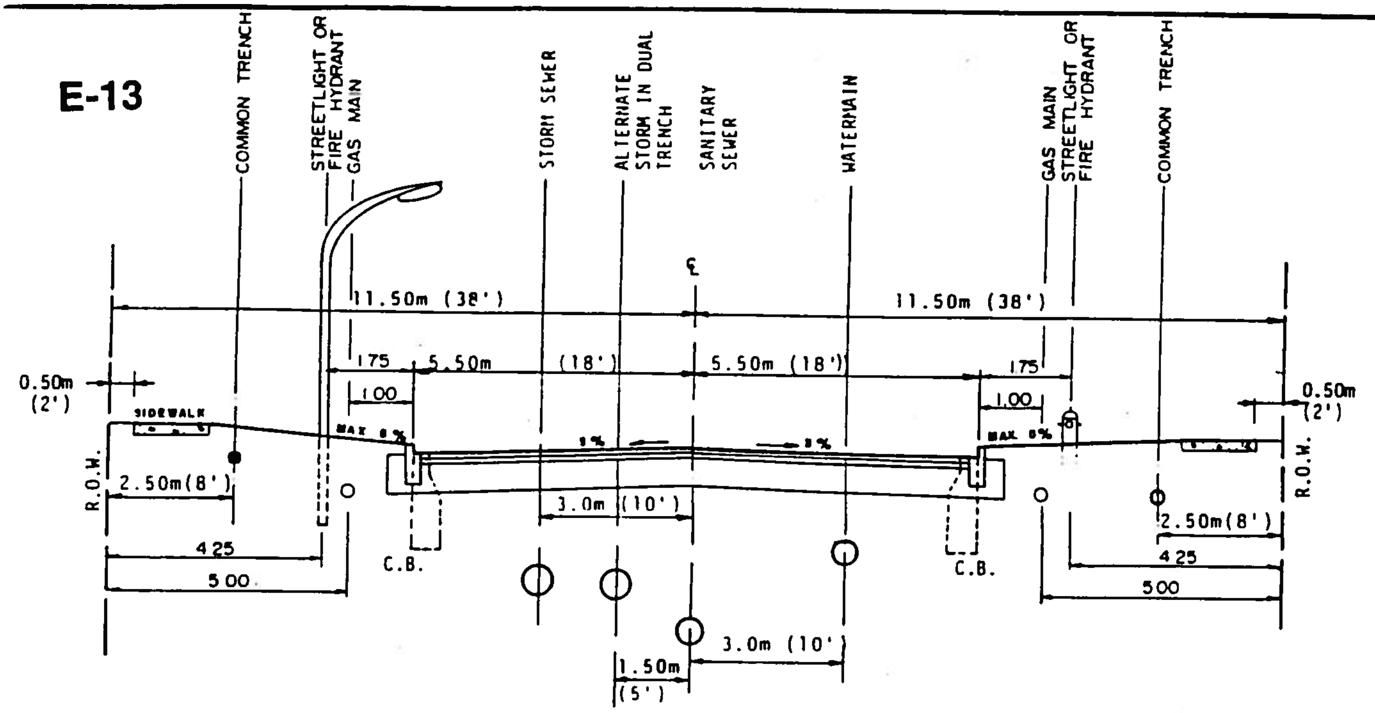


NOTE:
1. SEE ALSO DRWG. S-9.

COLLECTOR STREET - 8.50m (28') OF PAVEMENT
2. COMMON TRENCH - TELEPHONE, CABLEVISION, HYDRO, STREETLIGHTING

SCALE 1 : 100
REVISION DATE OCT 1989
UTILITY LOCATIONS 23m (76') RIGHT OF WAY
DRAWN K.H.
CHECKED: R.W.W.
DRWG NO SK-4

E-13

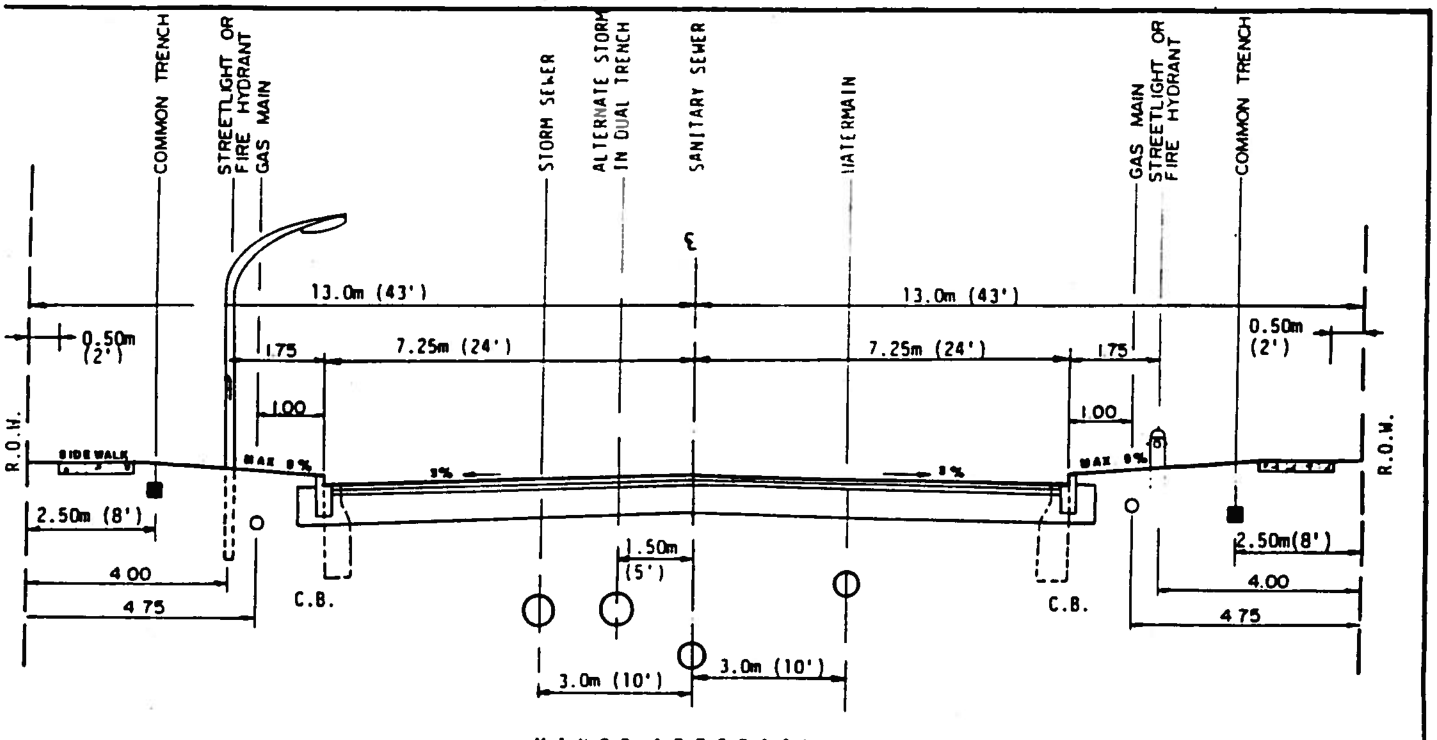


COLLECTOR STREET - 11m (36') OF PAVEMENT

NOTE:
1. SEE ALSO DRWG. S-9.
2. COMMON TRENCH - TELEPHONE, CABLEVISION, HYDRO, STREETLIGHTING

SCALE 1 100		DRAWN : K.H. CHECKED: R.W.W.
REVISION DATE OCT 1989	UTILITY LOCATIONS 23m(76') RIGHT OF WAY	DRWG NO: SK-5

E-14



MINOR ARTERIAL

NOTE:
1. SEE ALSO DRWG. S-9.
2 COMMON TRENCH - TELEPHONE, CABLEVISION, HYDRO, STREETLIGHTING

SCALE 1 100		DRAWN K.H. CHECKED: R.W.W
REVISION DATE OCT 1989	UTILITY LOCATIONS 26m(86') RIGHT OF WAY	DRWG NO: SK-6

E-15

CITY OF ETOBICOKE

INTERIM DEVELOPMENT ON PRIMARY COLLECTOR AND ARTERIAL STREETS

DIMENSIONS IN metres EXCEPT AS NOTED

DRAWN BY S B

CH'K'D BY T.B.

APPROVED

DEPUTY BOROUGH ENGINEER

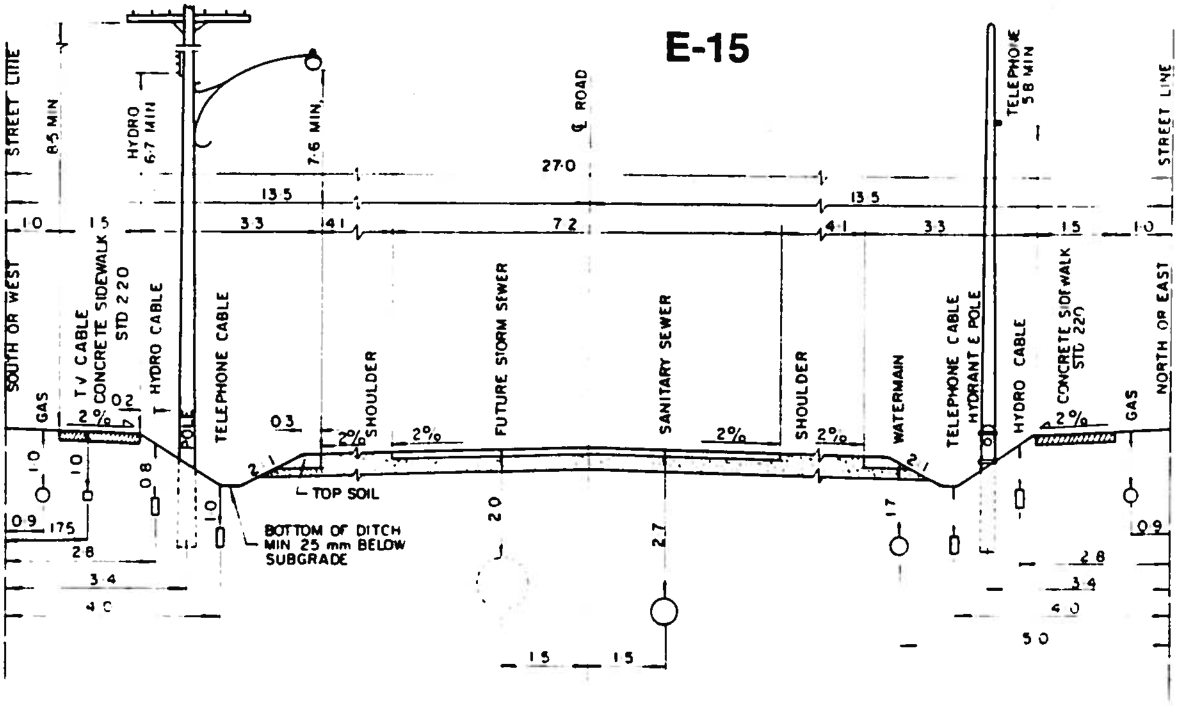
DATE: 78-07-28

REVISION Nº 2

DATE: 96/02/1

SCALE: N.T.S.

STANDARD Nº 128



NOTES

1) ALL DIMENSIONS SHOWN FOR COVER ARE MINIMUM AND SHALL TAKE INTO CONSIDERATION THE ULTIMATE GRADING OF THE ROAD ALLOWANCE UTILITY LOCATIONS IN ACCORDANCE WITH ETOBICOKE PROCEDURE Nº E9-8

2) GEOMETRIC DESIGN STANDARDS TO BE IN ACCORDANCE WITH RECOMMENDATIONS OF THE ROADS AND TRANSPORTATION ASSOCIATION OF CANADA WITH A DESIGN SPEED OF 60 km/hr FOR PRIMARY COLLECTORS AND 80 km/hr FOR ARTERIALS MAX GRADIENT OF 5.0 %. MIN GRADIENT OF 0.35 % MIN ASPHALT RADII AT INTERSECTIONS OF OTHER ARTERIAL STREETS SHALL BE 15.0 m; WITH PRIMARY COLLECTOR AND INDUSTRIAL STREETS SHALL BE 11.0 m, WITH ALL OTHER STREETS SHALL BE 9.0 m THE INSIDE STREET LINE RADIUS AT INTERSECTIONS AND BENDS SHALL BE ADJUSTED TO ENSURE THAT THE REQUIRED BOULEVARD WIDTH FROM THE FUTURE CURB TO THE STREET LINE IS MAINTAINED LEFT TURN LANES AND BUS BAYS MAY BE REQUIRED SUBJECT TO DETAIL DESIGN REVIEW

3) SIDEWALK ELEVATIONS SHALL SATISFY EXISTING DRAINAGE REQUIREMENTS AND TAKE INTO CONSIDERATION THE ULTIMATE ROAD GRADE WHEN CURBS ARE CONSTRUCTED

E-16

CITY OF ETOBICOKE

MEDIAN DIVIDED ARTERIAL STREET

DIMENSIONS IN metres EXCEPT AS NOTED

DRAWN BY S B

CH'K'D BY T.B.

APPROVED

DEPUTY BOROUGH ENGINEER

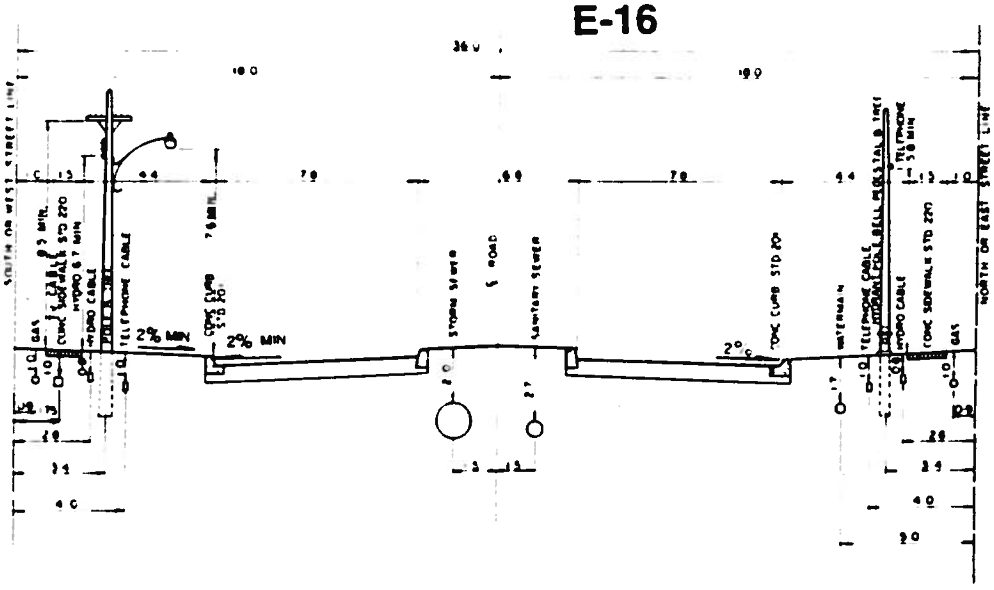
DATE: 78-07-

REVISION Nº

DATE: 96/02

SCALE: N T S

STANDARD Nº 127



NOTES

1) ALL DIMENSIONS SHOWN FOR COVER ARE MINIMUM UTILITY LOCATIONS IN ACCORDANCE WITH M T P U C C (DWG MA 9112 SH 1 & 2) AND ETOBICOKE PROCEDURE E9-8

2) GEOMETRIC DESIGN STANDARDS TO BE IN ACCORDANCE WITH RECOMMENDATIONS OF THE ROADS AND TRANSPORTATION ASSOCIATIATION OF CANADA WITH A DESIGN SPEED OF 80 km/hr, MAX GRADIENT OF 5.0 %; MIN GRADIENT OF 0.35 % MIN CURB RADII AT INTERSECTION WITH 15.0 m PAVEMENTS SHALL BE 15.0 m; WITH 13.8 m PAVEMENTS OR 9.7 m PAVEMENTS SHALL BE 11.0 m, WITH 8.5 m RESIDENTIAL PAVEMENTS SHALL BE 9.0 m MIN INSIDE CURB RADIUS ON BENDS SHALL BE 251 m THE INSIDE STREET LINE RADIUS AT INTERSECTIONS AND BENDS SHALL BE ADJUSTED TO ENSURE THAT THE REQURED BOULEVARD WIDTH FROM CURB TO STREET LINE IS MAINTAINED LEFT TURN CHANNELIZATION TO BE PROVIDED AT THE INTERSECTION OF ALL STREETS BUS BAYS TO BE PROVIDED AT ALL EXISTING OR PROPOSED BUS STOPS

3) THE RIGHT OF WAY SHALL BE INCREASED TO ACCOMODATE ADDITIONAL TRAVELLED LANES eg 45.0 m RIGHT OF WAY FOR A 6 LANE ROAD

4) THIS SECTION ASSUMES A NORMAL BUILDING SET BACK FROM STREET LINE AND NORMAL PEDESTRIAN NEEDS

APPENDIX F

Background Data for Economic Evaluation

SAMPLE GROUP :

The sources of information used to prepare this section include:
City of Ajax, City of Oshawa, City of Etobicoke, York Region, City of Ottawa, City of Nepean,
City of Kanata, City of Vanier, City of Gatineau, Markborough Properties Inc., Sorbara Group (Vaughan).

CONSTRUCTION COSTS

Road Drainage System Components	Construction / replacement		
	Lower Cost ($ / km)	Higher Cost ($ / km)	Average Cost ($ / km)
Road surface included curbs and gutters (width = 8.5 m)	$276,000.00	$1,100,000.00	$597,166.67
Ditches or swales system (both sides) culverts included	$150,000.00	$450,000.00	$242,800.00
Swale with perforated pipe	$570,000.00	$1,046,000.00	$808,000.00
Storm sewer system	$300,000.00	$700,000.00	$517,000.00
Curbs and gutters (one side)	$37,000.00	$108,000.00	$56,250.00
Sidewalk ($ / square meter) =>	$36.70	$50.00	$43.35

MAINTENANCE COSTS

Maintenance operations	Maintenance and repairs		
	Lower Cost ($ / km)	Higher Cost ($ / km)	Average Cost ($ / km)
Catch basin repairs	$35.00	$676.00	$363.67
Storm sewers repairs	$93.00	$774.00	$264.00
Streets sweeping and cleaning	$96.00	$997.00	$486.83
Curb and gutter repairs	$105.00	$511.00	$267.00
Ditch regrading / cleaning	$263.00	$3,625.00	$986.17
Shoulder / edge of road (twice / year)	$406.00	$406.00	$406.00
Grass cutting (two sides)	$276.00	$1,200.00	$608.75
Culvert repair / reset (100 units / km)	$179.00	$1,000.00	$364.83
Culvert thawing / winter drainage (100 units/ km)	$80.00	$456.00	$268.00
Catch basins cleaning ($ / unit) =>	$1.45	$10.80	$5.42

APPENDIX G

Copies of Relevant References
Provided Separate Binders - 6 Volumes

APPENDIX H

USER GUIDE

Drainage System Selection Tool
Microsoft Excel Version

"Evaluation of Roadside Ditches and other Stormwater Management Practices"

Prepared for:

**The Toronto and Region
Conservation Authority**

Prepared by:

**J.F. Sabourin and Associates Inc.
Ottawa, Ontario**

February 2000

1111 Prince of Wales Drive, suite 401, Ottawa, Ontario, K2C 3T2, tel (613) 727-5199, Fax (613) 727-5699, web www.jfsa.com

Table of Contents

General Information

Specific Details of Each Worksheet

ANNEX A: Sample Print-outs from Drainage System Selection Tool

Introduction

This is an electronic version of the selection tool developed as part of the study, "Evaluation of Roadside Ditches and other related Stormwater Management Practices" (1997, J.F. Sabourin and Associates Inc.)

Using the flexibility of a spreadsheet and the power of the Visual Basic programming language, "Report-Ready" analysis and recommendations can be made with the click of a few buttons.

The electronic version of the tool was developed for Microsoft Excel, and has been optimized for version 7. A spreadsheet was chosen as the tool naturally lent itself to this type of application because of it's tabular layout. Microsoft Excel was chosen as it is capable of sustaining VBA modules and can link form objects such as check boxes and buttons to Visual Basic programming code.

Methodology

- The selection tool allows for an efficient identification of drainage system features which are compatible with site and development characteristics.
- The user simply checks a series of boxes, and clicks a few buttons to conceptualize and cost various potential drainage systems.
- A complete set of capital and related maintenance costs are provided in tables, which are used to evaluate the total "Present Value" of potential alternatives.
- A complete set of performance tables is included to identify the environmental and social benefits of one system over another.
- An intuitive "build" algorithm is used to approximate the quantities of the various elements required to build the system (how many meters of pipes are required, how many catchbasins need to be installed etc.)

Results

- The tool can identify whether or not a drainage feature is compatible with the site and development characteristics.
- The tool can be used to calculate the quantities of materials needed to build a proposed drainage system based on drainage area and imperviousness.
- The use of this tool can speed up the evaluation of various drainage system design proposals.
- The tool can quickly and accurately produce a cost/benefit comparison of one system over another.

System Requirements

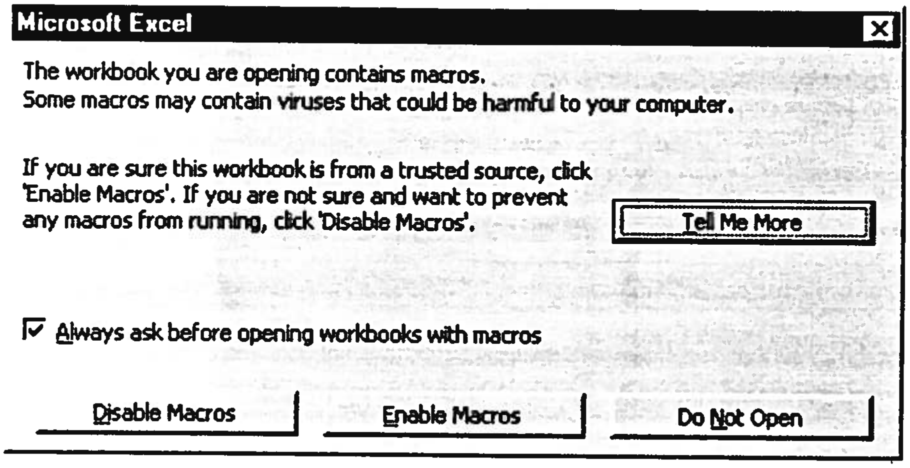
- Microsoft Excel, (version 7 or better) for Windows 95/98/NT
- Minimum screen resolution: 800 x 600 x 256 colours
- Recommended screen resolution: 1024 x 768 x 256 colours or better

Viewing Each Page

Each table has been designed so that the hard copy print-out covers the majority of a standard 8-1/2" x 11" page leaving adequate room for margins, headers and footers. To view each table properly, it is suggested that full-screen mode be employed and that all toolbars are turned off. This is accomplished by selecting "Full-Screen" from the "View" menu, and deselecting the toolbars listed under "Toolbars", also on the "View" menu.

Start Up

To start the tool, open the file, "DSST_V1.XLS" (Drainage System Selection Tool, Version 1), with Microsoft Excel (version 7 or better). This file contains VBA modules that are encoded as Macros. The latest version of Excel may produce a warning screen such as the one below. In order for the tool to run you need to Enable Macros. The macros contained within this tool are not malicious in nature, nor do they contain viruses.

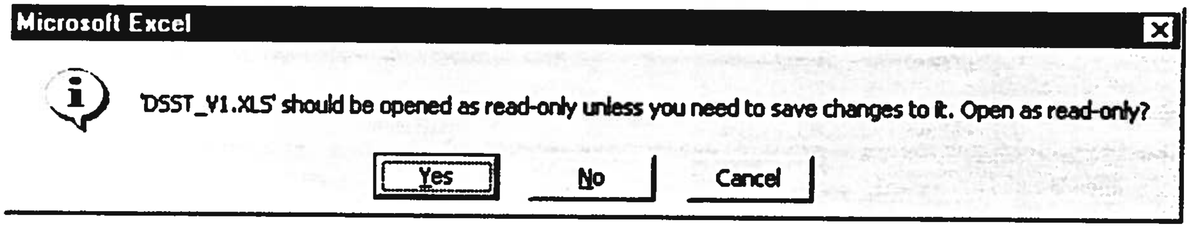


The workbook you are opening contains macros.
Some macros may contain viruses that could be harmful to your computer.

If you are sure this workbook is from a trusted source, click 'Enable Macros'. If you are not sure and want to prevent any macros from running, click 'Disable Macros'.

☑ Always ask before opening workbooks with macros

It is suggested that you open the file as read-only. This way, any changes made to the file will have to be saved with a new filename. This ensures that the original values contained within the selection tool will remain intact.

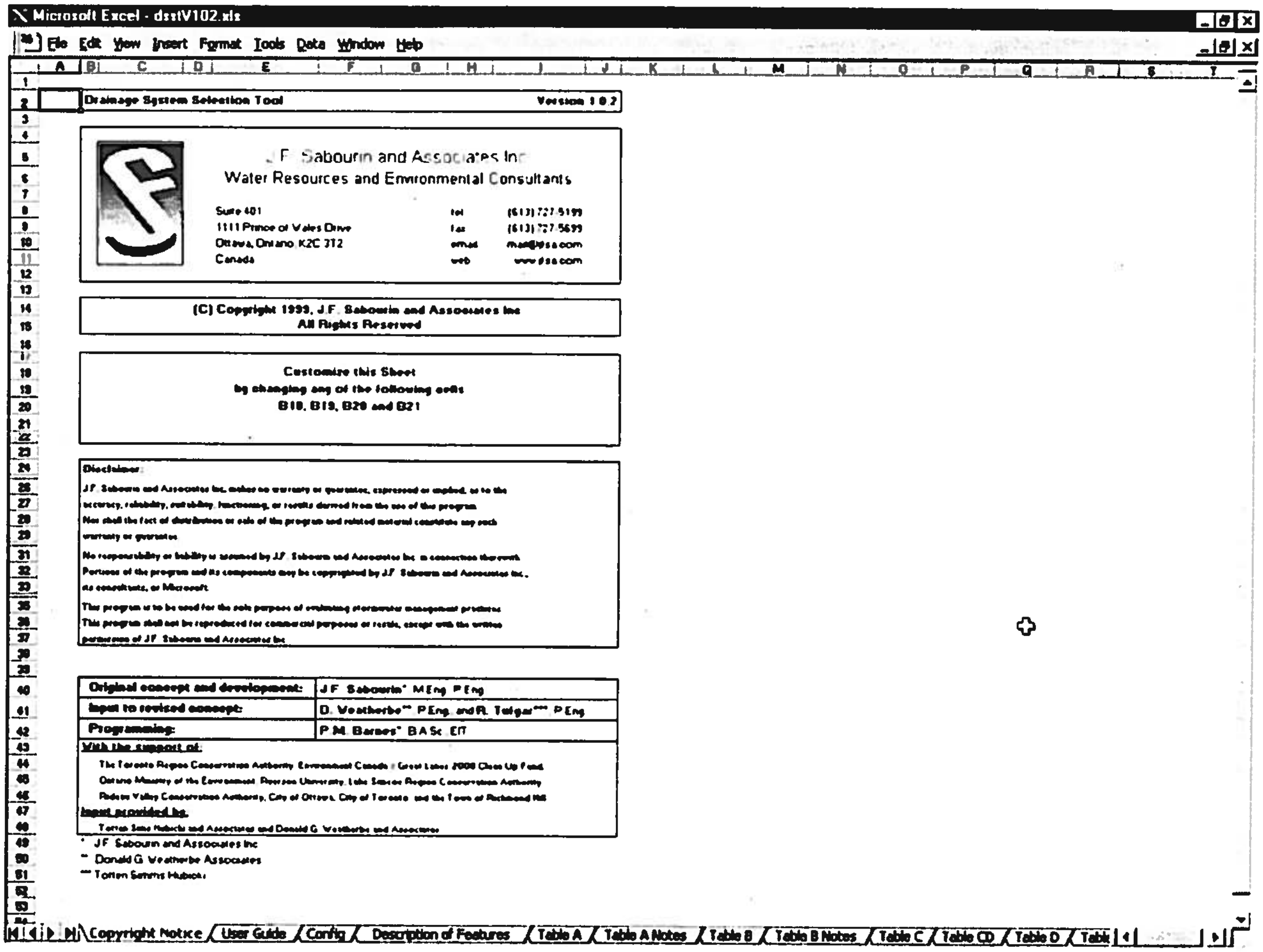


'DSST_V1.XLS' should be opened as read-only unless you need to save changes to it. Open as read-only?

Note:

Although other spreadsheet programs such as Quattro Pro or Lotus 1-2-3 may be able to open an Excel workbook, these programs do not have the ability to properly open and process the VBA code contained within the macros. This code is required for the tool to work. Microsoft provides a free viewer for Excel files; however, the viewer is not capable of executing VBA code contained within macros. The tool will not operate properly if opened in the viewer.

Copyright Notice



Drainage System Selection Tool Version 1.0.2

J.F. Sabourin and Associates Inc.
Water Resources and Environmental Consultants

Suite 401		tel	(613) 727-5199
1111 Prince of Wales Drive		fax	(613) 727-5699
Ottawa, Ontario K2C 3T2		email	mail@jfsa.com
Canada		web	www.jfsa.com

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Customize this Sheet
by changing any of the following cells
B18, B19, B20 and B21

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This program is to be used for the sole purpose of evaluating stormwater management practices. This program shall not be reproduced for commercial purposes or resale, except with the written permission of J.F. Sabourin and Associates Inc.

Original concept and development:	J.F. Sabourin* M.Eng. P.Eng.
Input to revised concept:	D. Weatherbe** P.Eng. and R. Telgar*** P.Eng.
Programming:	P.M. Barnes* B.A.Sc. EIT

With the support of:

The Toronto Region Conservation Authority, Environment Canada / Great Lakes 2000 Clean Up Fund, Ontario Ministry of the Environment, Ryerson University, Lake Simcoe Region Conservation Authority, Rideau Valley Conservation Authority, City of Ottawa, City of Toronto, and the Town of Richmond Hill

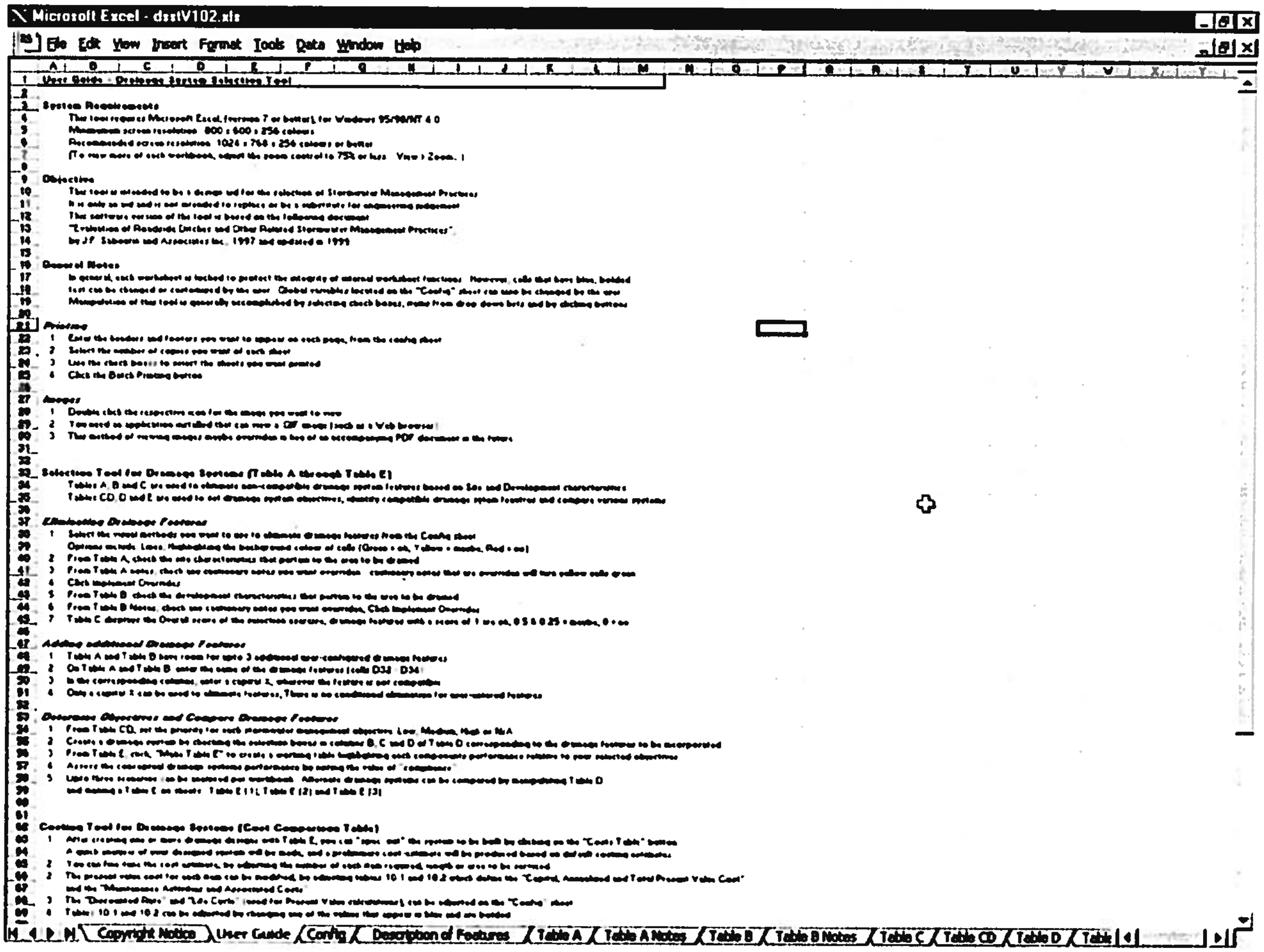
Input provided by:

Totten Sims Hubicki and Associates and Donald G. Weatherbe and Associates

* J.F. Sabourin and Associates Inc
** Donald G. Weatherbe Associates
*** Totten Sims Hubicki

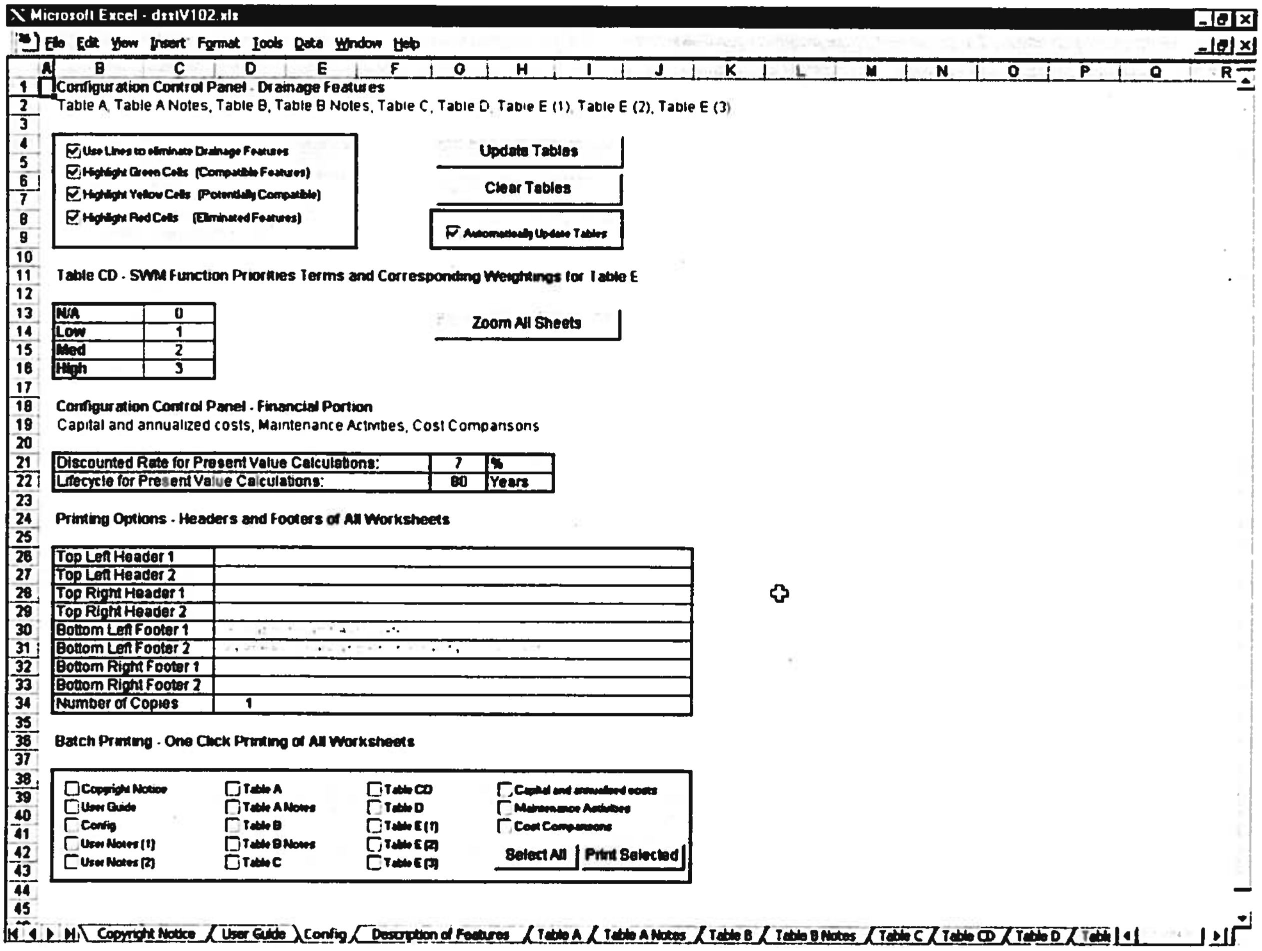
This page is used as a "Splash Screen", and is the first worksheet the user sees when opening up the workbook. It gives credit to the authors, and provides a general disclaimer on the tool's use. Changing cells "B18" to "B21" can customize this page. It is recommended that this customized page be used as a front page, or first page, of a report in which this tool is used.

User Guide



Additional user-help is available on this sheet.

Config



Configuration Control Panel - Drainage Features
Table A, Table A Notes, Table B, Table B Notes, Table C, Table D, Table E (1), Table E (2), Table E (3)

☑ Use Lines to eliminate Drainage Features
☑ Highlight Green Cells (Compatible Features)
☑ Highlight Yellow Cells (Potentially Compatible)
☑ Highlight Red Cells (Eliminated Features)

☑ Automatically Update Tables

Table CD - SWM Function Priorities Terms and Corresponding Weightings for Table E

N/A	0
Low	1
Med	2
High	3

Configuration Control Panel - Financial Portion
Capital and annualized costs, Maintenance Activities, Cost Comparisons

Discounted Rate for Present Value Calculations:	7	%
Lifecycle for Present Value Calculations:	80	Years

Printing Options - Headers and Footers of All Worksheets

Top Left Header 1	
Top Left Header 2	
Top Right Header 1	
Top Right Header 2	
Bottom Left Footer 1	
Bottom Left Footer 2	
Bottom Right Footer 1	
Bottom Right Footer 2	
Number of Copies	1

Batch Printing - One Click Printing of All Worksheets

☐ Copyright Notice
☐ User Guide
☐ Config
☐ User Notes (1)
☐ User Notes (2)
☐ Table A
☐ Table A Notes
☐ Table B
☐ Table B Notes
☐ Table C
☐ Table CD
☐ Table D
☐ Table E (1)
☐ Table E (2)
☐ Table E (3)
☐ Capital and annualized costs
☐ Maintenance Activities
☐ Cost Comparisons

This page is the most critical page of the tool as it is used to set up certain default values, and controls how the tool operates.

The first series of check boxes in the top left corner are used to control how compatible and non-compatible drainage features are highlighted. Background colours can be turned on and off, so can lines that strike out non-compatible features. Some experimenting with this may be necessary to optimize outputs for screen and printer.

Update Tables

This button is used when Automatic Updates is turned off. It recalculates each table, and changes the background colours as necessary.

Clear Tables

This button is used to remove any of the user input from Tables A through E and from the Cost Comparisons table.

[ ] Automatically Update Tables

This check box toggles the worksheet's auto-update mode. Working with this feature turned off, can speed up data-entry; however, the user should always use the **Update Tables** feature before making drainage system selections and printing output.

Zoom All Sheets

This button will cycle through each worksheet and select an appropriate Zoom factor so that the entire sheet will fit on the screen. This is useful as each table is quite large, and not all monitors are the same. For data input and detailed viewing, you may have to zoom in, and use the scroll bars to navigate each page.

SWM FUNCTION PRIORITIES

You can set the numeric weighting associated with the text value of each SWM Function Priority. These values are used in TABLE CD and TABLE E.

Discounted Rate

You can enter in a discounted rate in cell "G21". This value will be used for present value and payment functions in the "Capital and Annualized Costs" table.

Lifecycle

The lifecycle that is used for the financial calculations in the "Capital and Annualized Costs" table can be configured in cell "G22".

Batch Printing

Printing of the entire workbook can be automated through the batch printing utility at the bottom of the "CONFIG" page. Select which pages you want to print, and enter in the header and footer information you wish to appear.

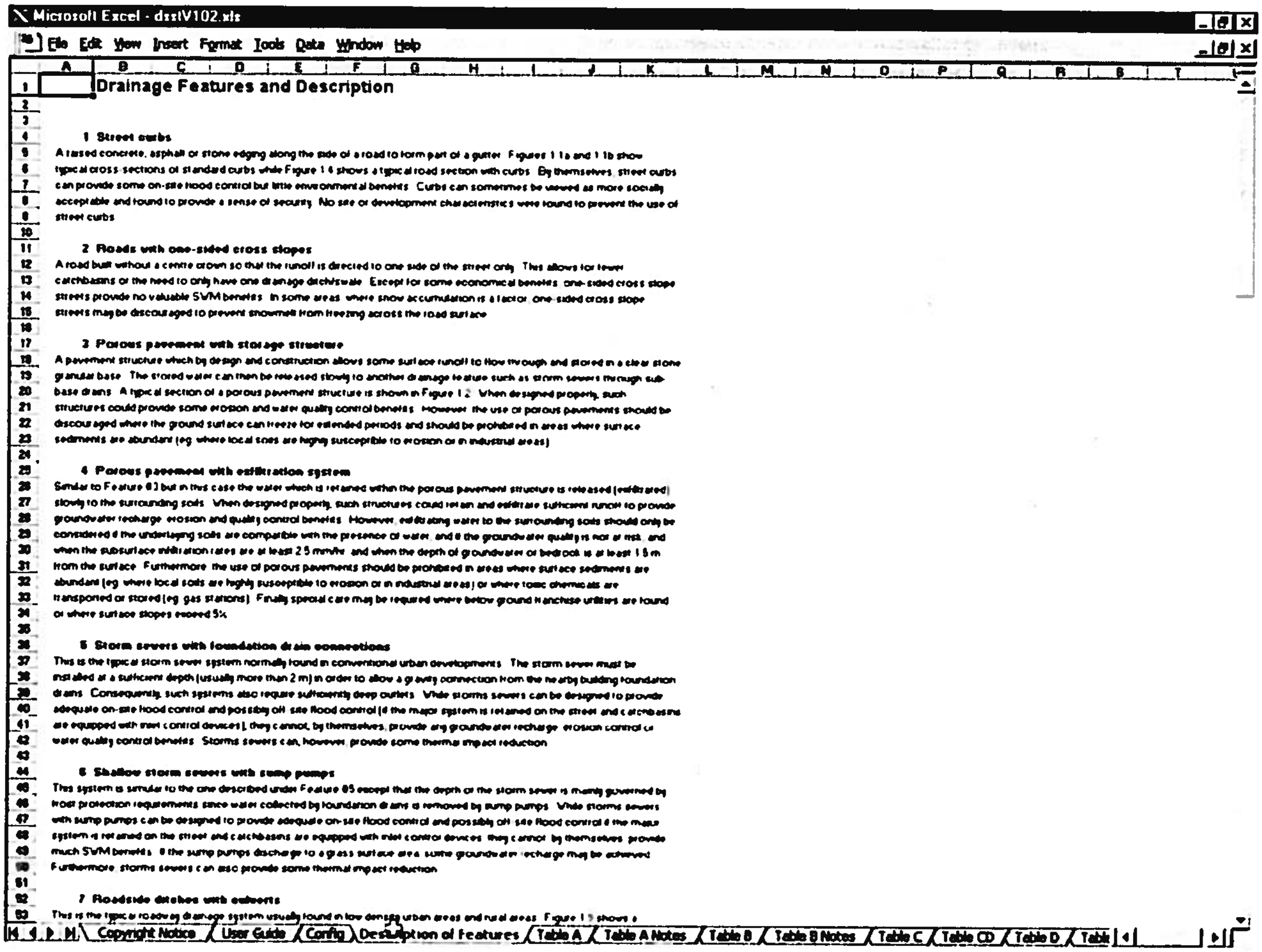
Select All

This button selects all of the worksheets in the workbook to be printed.

Print Selected

This button prints all of the worksheets that have been selected.

Drainage Features and Description



Drainage Features and Description

1 Street curbs

A raised concrete, asphalt or stone edging along the side of a road to form part of a gutter Figures 1 1a and 1 1b show typical cross sections of standard curbs while Figure 1 4 shows a typical road section with curbs By themselves, street curbs can provide some on-site flood control but little environmental benefits Curbs can sometimes be viewed as more socially acceptable and found to provide a sense of security No site or development characteristics were found to prevent the use of street curbs

2 Roads with one-sided cross slopes

A road built without a centre crown so that the runoff is directed to one side of the street only This allows for fewer catchbasins or the need to only have one drainage ditch/swale Except for some economical benefits one-sided cross slope streets provide no valuable SWM benefits In some areas where snow accumulation is a factor one-sided cross slope streets may be discouraged to prevent snowmelt from freezing across the road surface

3 Porous pavement with storage structure

A pavement structure which by design and construction allows some surface runoff to flow through and stored in a clear stone granular base The stored water can then be released slowly to another drainage feature such as storm sewers through sub-base drains A typical section of a porous pavement structure is shown in Figure 1 2 When designed properly, such structures could provide some erosion and water quality control benefits However the use of porous pavements should be discouraged where the ground surface can freeze for extended periods and should be prohibited in areas where surface sediments are abundant (eg where local soils are highly susceptible to erosion or in industrial areas)

4 Porous pavement with exfiltration system

Similar to Feature #3 but in this case the water which is retained within the porous pavement structure is released (exfiltrated) slowly to the surrounding soils When designed properly, such structures could retain and exfiltrate sufficient runoff to provide groundwater recharge erosion and quality control benefits However, exfiltrating water to the surrounding soils should only be considered if the underlaying soils are compatible with the presence of water and if the groundwater quality is not at risk and when the subsurface infiltration rates are at least 2 5 mm/hr and when the depth of groundwater or bedrock is at least 1 5 m from the surface Furthermore the use of porous pavements should be prohibited in areas where surface sediments are abundant (eg where local soils are highly susceptible to erosion or in industrial areas) or where toxic chemicals are transported or stored (eg gas stations) Finally special care may be required where below ground franchise utilities are found or where surface slopes exceed 5%

5 Storm sewers with foundation drain connections

This is the typical storm sewer system normally found in conventional urban developments The storm sewer must be installed at a sufficient depth (usually more than 2 m) in order to allow a gravity connection from the nearby building foundation drains Consequently, such systems also require sufficiently deep outlets While storms sewers can be designed to provide adequate on-site flood control and possibly off site flood control (if the major system is retained on the street and catchbasins are equipped with inlet control devices), they cannot, by themselves, provide any groundwater recharge erosion control or water quality control benefits Storms sewers can, however, provide some thermal impact reduction

6 Shallow storm sewers with sump pumps

This system is similar to the one described under Feature #5 except that the depth of the storm sewer is mainly governed by frost protection requirements since water collected by foundation drains is removed by sump pumps While storms sewers with sump pumps can be designed to provide adequate on-site flood control and possibly off site flood control if the major system is retained on the street and catchbasins are equipped with inlet control devices they cannot by themselves provide much SWM benefits If the sump pumps discharge to a grass surface area some groundwater recharge may be achieved Furthermore storms sewers can also provide some thermal impact reduction

7 Roadside ditches with culverts

This is the typical roadway drainage system usually found in low density urban areas and rural areas Figure 1 5 shows a

This sheet provides you with a complete description of the alternative drainage features considered by the Selection Tool.

Table A

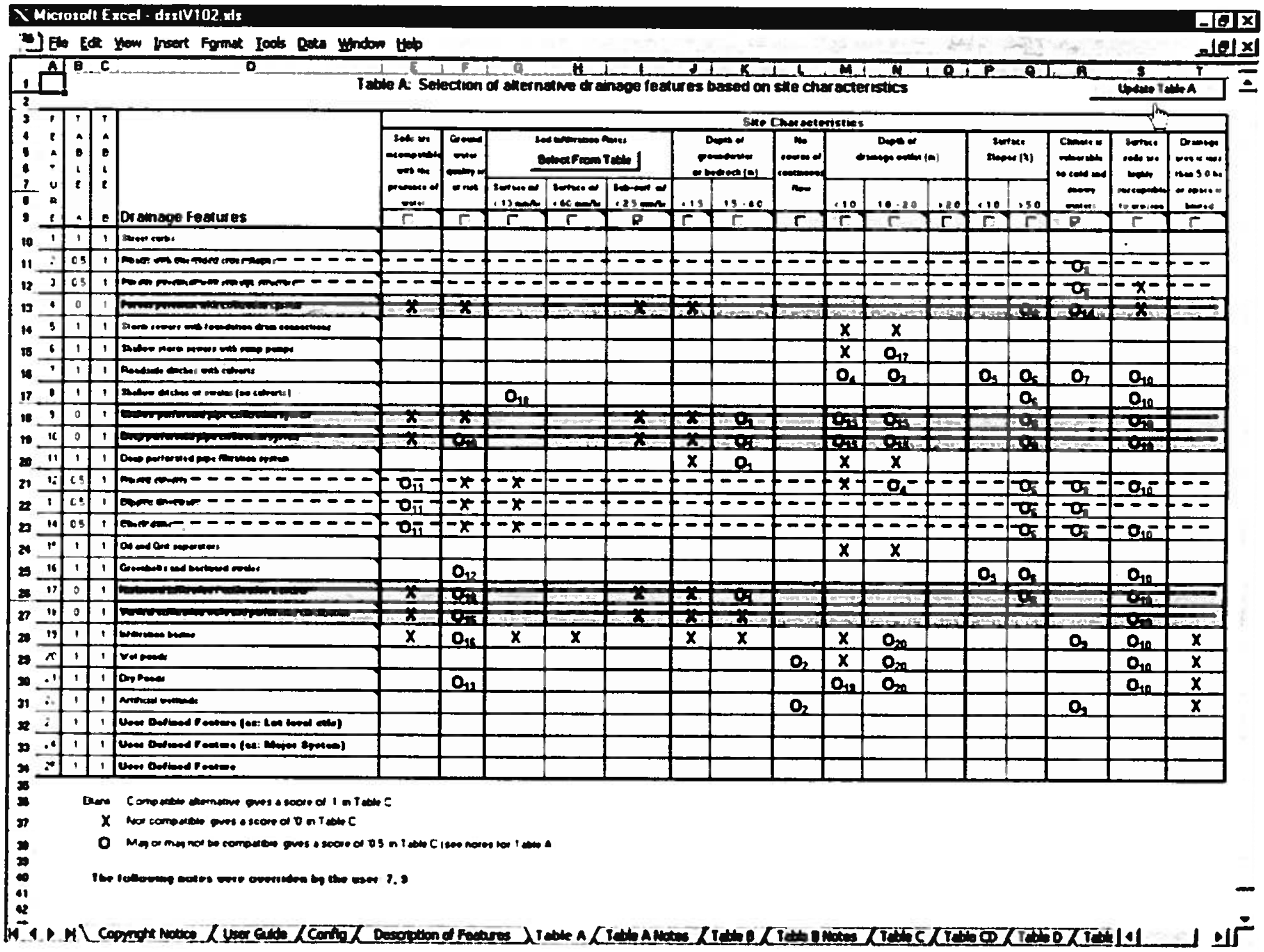


Table A: Selection of alternative drainage features based on site characteristics

Blank Compatible alternative gives a score of 1 in Table C

X Not compatible gives a score of 0 in Table C

O May or may not be compatible gives a score of 0.5 in Table C (see notes for Table A)

The following notes were overridden by the user 7, 9

This table is used to determine which features are compatible and which are not based on site characteristics. Not all drainage features are compatible with all site characteristics. Features that are not compatible are eliminated here.

Using the check boxes in Row 9, select the characteristics that match your site. If a feature has an "X" in the column relating to a specific site characteristic, it is not compatible, and that feature is highlighted (Red background, with solid line through it), this eliminates the drainage feature. If a feature has an "O" in the column relating to a specific site characteristic, it is potentially not compatible, and is highlighted as conditional (Yellow background, with dashed line through it). A table of notes is associated with each conditional "O", "TABLE A NOTES". You can "reinstate" a drainage feature by overriding the associated note in "TABLE A NOTES". Any notes that are overridden will be listed at the bottom of "TABLE A."

User defined drainage features can be added in rows 23, 24 and 25. "X's" can be placed in the site characteristics column where appropriate. Conditional "O's" may not be used for user-defined drainage features.

Select From Table

A pop-up menu has been included with "TABLE A" to help determine the soil infiltration rate. This table lists common soil-types and values of hydraulic conductivity. Choosing a soil type from this pop-up menu will select the appropriate surface infiltration rate of the site.

Update Table A

Clicking this button updates "TABLE A". This is only necessary if "Automatically Update Tables" is not checked on the "CONFIG" sheet.

Table A Notes

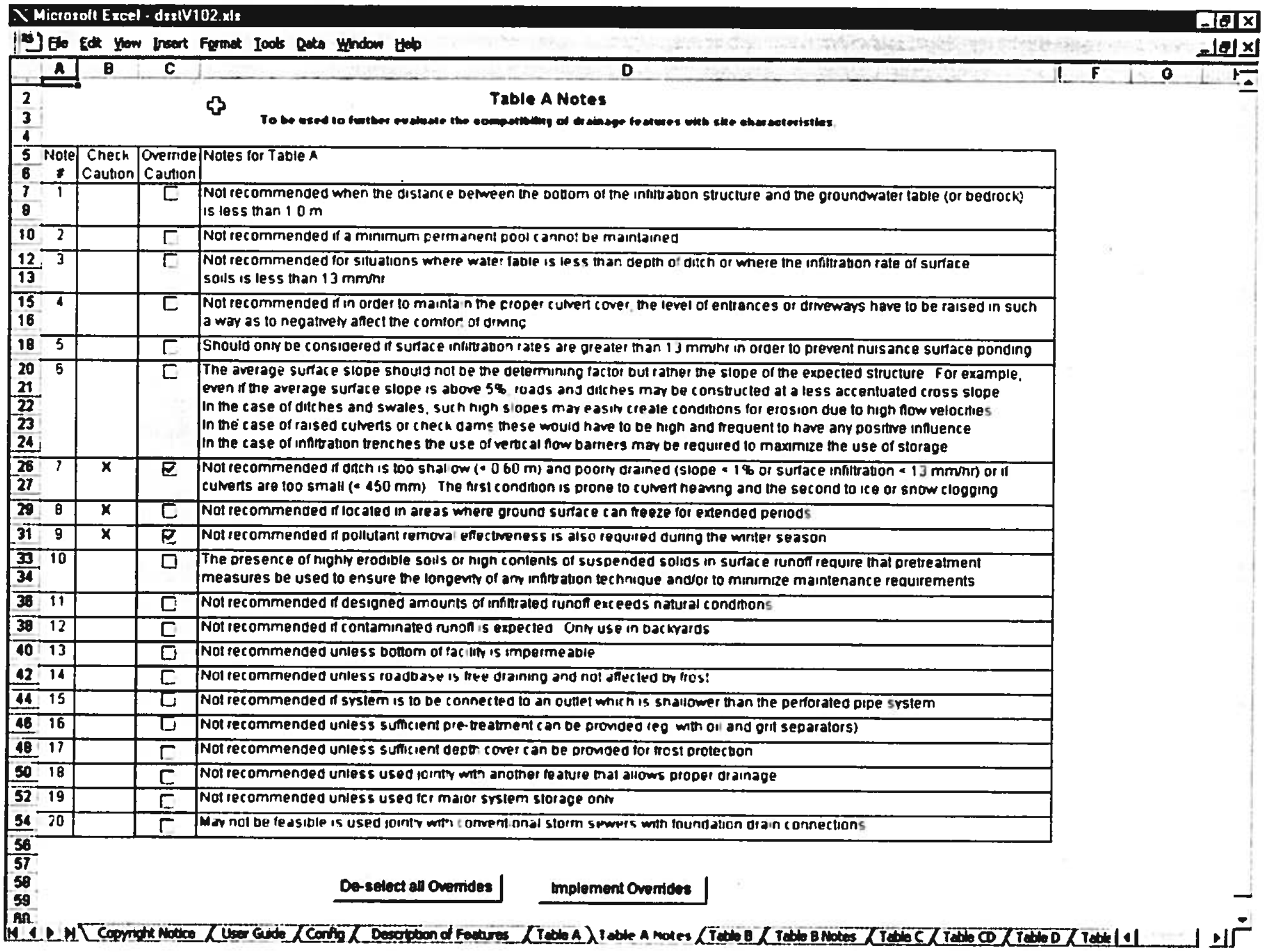


Table A Notes

To be used to further evaluate the compatibility of drainage features with site characteristics.

Note #	Check Caution	Override Caution	Notes for Table A
1		☐	Not recommended when the distance between the bottom of the infiltration structure and the groundwater table (or bedrock) is less than 1.0 m
2		☐	Not recommended if a minimum permanent pool cannot be maintained
3		☐	Not recommended for situations where water table is less than depth of ditch or where the infiltration rate of surface soils is less than 13 mm/hr
4		☐	Not recommended if in order to maintain the proper culvert cover, the level of entrances or driveways have to be raised in such a way as to negatively affect the comfort of driving
5		☐	Should only be considered if surface infiltration rates are greater than 13 mm/hr in order to prevent nuisance surface ponding
6		☐	The average surface slope should not be the determining factor but rather the slope of the expected structure. For example, even if the average surface slope is above 5%, roads and ditches may be constructed at a less accentuated cross slope In the case of ditches and swales, such high slopes may easily create conditions for erosion due to high flow velocities In the case of raised culverts or check dams these would have to be high and frequent to have any positive influence In the case of infiltration trenches the use of vertical flow barriers may be required to maximize the use of storage
7	X	☑	Not recommended if ditch is too shallow (< 0.60 m) and poorly drained (slope < 1% or surface infiltration < 13 mm/hr) or if culverts are too small (< 450 mm). The first condition is prone to culvert heaving and the second to ice or snow clogging
8	X	☐	Not recommended if located in areas where ground surface can freeze for extended periods
9	X	☑	Not recommended if pollutant removal effectiveness is also required during the winter season
10		☐	The presence of highly erodible soils or high contents of suspended solids in surface runoff require that pretreatment measures be used to ensure the longevity of any infiltration technique and/or to minimize maintenance requirements
11		☐	Not recommended if designed amounts of infiltrated runoff exceeds natural conditions
12		☐	Not recommended if contaminated runoff is expected. Only use in backyards
13		☐	Not recommended unless bottom of facility is impermeable
14		☐	Not recommended unless roadbase is free draining and not affected by frost
15		☐	Not recommended if system is to be connected to an outlet which is shallower than the perforated pipe system
16		☐	Not recommended unless sufficient pre-treatment can be provided (eg. with oil and grit separators)
17		☐	Not recommended unless sufficient depth cover can be provided for frost protection
18		☐	Not recommended unless used jointly with another feature that allows proper drainage
19		☐	Not recommended unless used for major system storage only
20		☐	May not be feasible is used jointly with conventional storm sewers with foundation drain connections

This table is used to override the conditional "O's" on "TABLE A". Each "O" on "TABLE A" has a note attached to it as a sub-script. These notes are listed in "TABLE A NOTES". An explanation, recommendation or guideline is listed beside each note.

A red "X" will appear in the column marked, "CHECK CAUTION" if a conditional elimination exists on "TABLE A". If the note beside the caution number does not apply, or is not relevant, a conditional elimination can be "reinstated" by checking the corresponding box in the "OVERIDE CAUTION" column.

Each cautionary note that is overridden on this sheet will be printed at the bottom of "TABLE A".

De-select all Overrides

Clicking this button is a fast way to remove all of the selected overrides. Any check marks in the "OVERRIDE CAUTION" column will be removed.

Implement Overrides

Clicking this button updates "TABLE A" with the new overrides. This is only necessary if "Automatically Update Tables" is not checked on the "CONFIG" sheet.

Table B

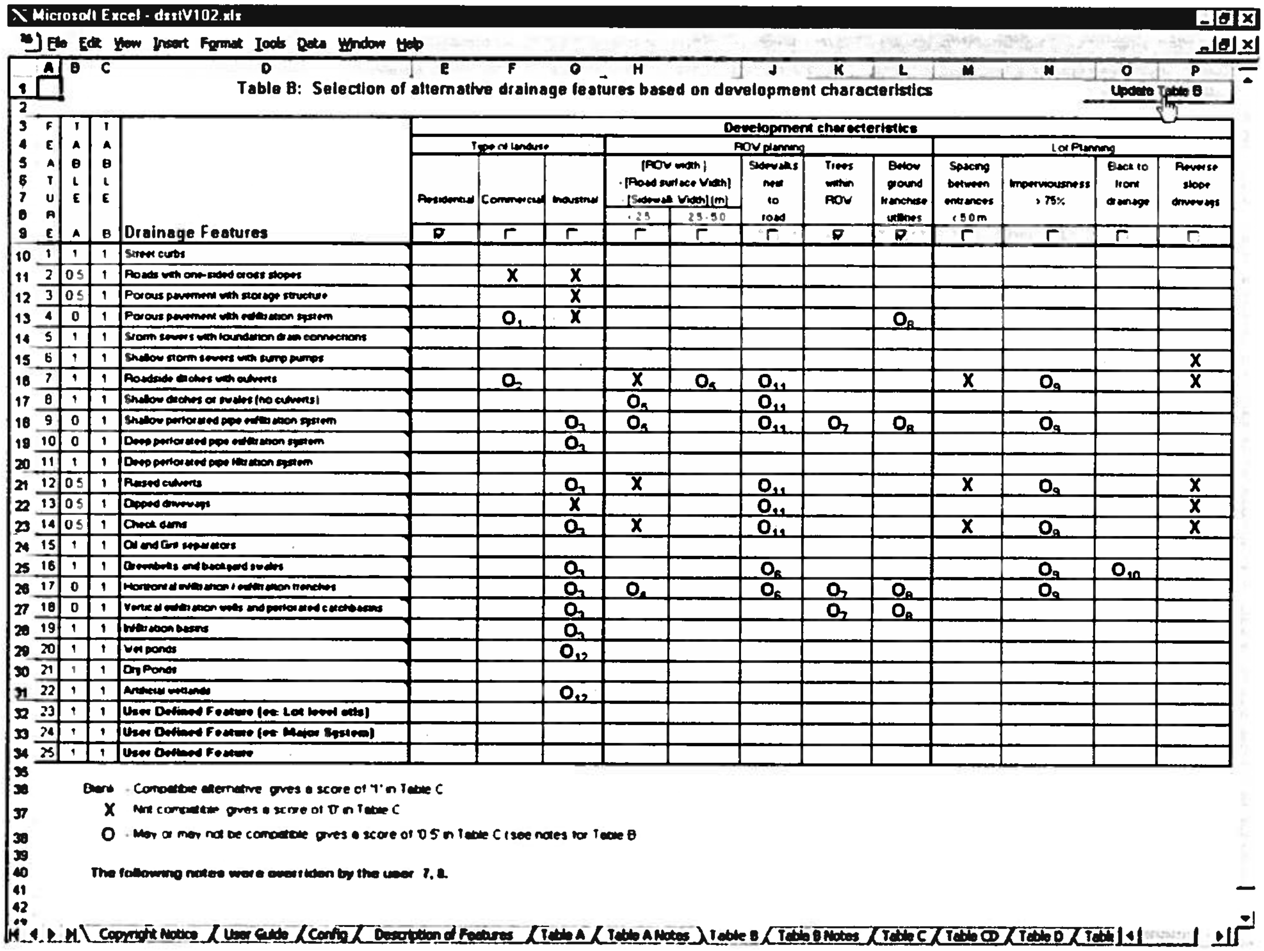


Table B: Selection of alternative drainage features based on development characteristics

FEATURE	TABLE A	TABLE B	Drainage Features	Development characteristics											
				Type of landuse			ROW planning					Lot Planning			
				Residential	Commercial	Industrial	(ROW width) - (Road surface Width) - (Sidewalk Width) (m)		Sidewalks next to road	Trees within ROW	Below ground franchise utilities	Spacing between entrances < 5.0 m	Imperviousness > 75%	Back to front drainage	Reverse slope driveways
							< 2.5	2.5 - 5.0							
				☑	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐
1	1	1	Street curbs												
2	0.5	1	Roads with one-sided cross slopes		X	X									
3	0.5	1	Porous pavement with storage structure			X									
4	0	1	Porous pavement with exfiltration system		O_{1}	X					O_{8}				
5	1	1	Storm sewers with foundation drain connections												
6	1	1	Shallow storm sewers with sump pumps												X
7	1	1	Roadside ditches with culverts		O_{2}		X	O_{5}	O_{11}			X	O_{9}		X
8	1	1	Shallow ditches or swales (no culverts)				O_{5}		O_{11}						
9	0	1	Shallow perforated pipe exfiltration system			O_{3}	O_{5}		O_{11}	O_{7}	O_{8}		O_{9}		
10	0	1	Deep perforated pipe exfiltration system			O_{3}									
11	1	1	Deep perforated pipe filtration system												
12	0.5	1	Raised culverts			O_{3}	X		O_{11}			X	O_{9}		X
13	0.5	1	Dipped driveways			X			O_{11}						X
14	0.5	1	Check dams			O_{3}	X		O_{11}			X	O_{9}		X
15	1	1	Oil and Grit separators												
16	1	1	Greenbelts and backyard swales			O_{3}			O_{6}				O_{9}	O_{10}	
17	0	1	Horizontal infiltration / exfiltration trenches			O_{3}	O_{4}		O_{6}	O_{7}	O_{8}		O_{9}		
18	0	1	Vertical exfiltration wells and perforated catchbasins			O_{3}				O_{7}	O_{8}				
19	1	1	Infiltration basins			O_{3}									
20	1	1	Wet ponds			O_{12}									
21	1	1	Dry Ponds												
22	1	1	Artificial wetlands			O_{12}									
23	1	1	User Defined Feature (ex: Lot level ctls)												
24	1	1	User Defined Feature (ex: Major System)												
25	1	1	User Defined Feature												

Blank - Compatible alternative gives a score of '1' in Table C
X - Not compatible gives a score of '0' in Table C
O - May or may not be compatible gives a score of '0.5' in Table C (see notes for Table B

The following notes were overridden by the user 7, 8.

This table is used to determine which features are compatible and which are not based on the development characteristics. Not all drainage features are compatible with all development characteristics. Features that are not compatible can be eliminated here.

This table follows the same principles as "TABLE A"

Table B Notes

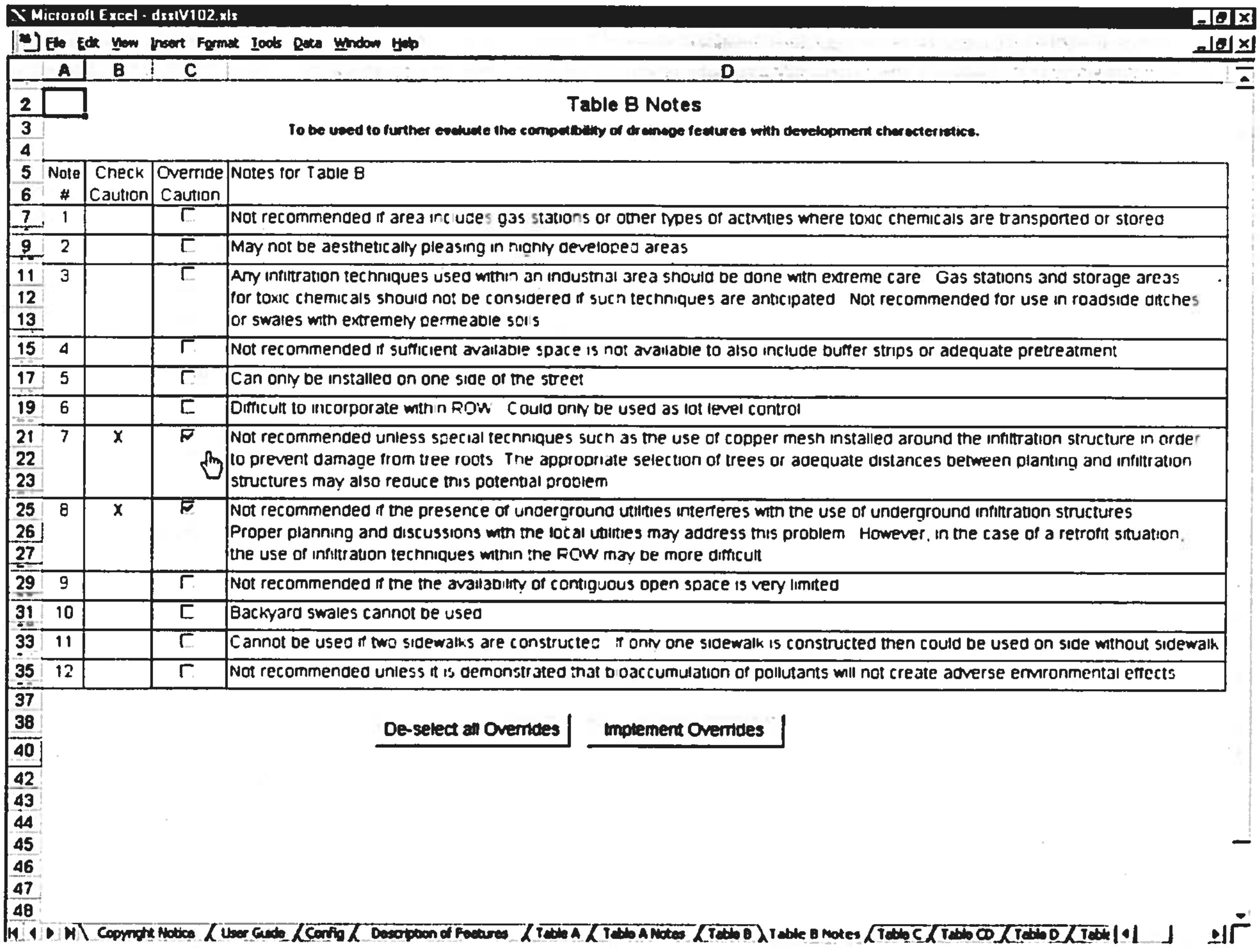


Table B Notes

To be used to further evaluate the compatibility of drainage features with development characteristics.

Note #	Check Caution	Override Caution	Notes for Table B
1		☐	Not recommended if area includes gas stations or other types of activities where toxic chemicals are transported or stored
2		☐	May not be aesthetically pleasing in highly developed areas
3		☐	Any infiltration techniques used within an industrial area should be done with extreme care Gas stations and storage areas for toxic chemicals should not be considered if such techniques are anticipated Not recommended for use in roadside ditches or swales with extremely permeable soils
4		☐	Not recommended if sufficient available space is not available to also include buffer strips or adequate pretreatment
5		☐	Can only be installed on one side of the street
6		☐	Difficult to incorporate within ROW Could only be used as lot level control
7	X	☑	Not recommended unless special techniques such as the use of copper mesh installed around the infiltration structure in order to prevent damage from tree roots The appropriate selection of trees or adequate distances between planting and infiltration structures may also reduce this potential problem
8	X	☑	Not recommended if the presence of underground utilities interferes with the use of underground infiltration structures Proper planning and discussions with the local utilities may address this problem However, in the case of a retrofit situation, the use of infiltration techniques within the ROW may be more difficult
9		☐	Not recommended if the the availability of contiguous open space is very limited
10		☐	Backyard swales cannot be used
11		☐	Cannot be used if two sidewalks are constructed If only one sidewalk is constructed then could be used on side without sidewalk
12		☐	Not recommended unless it is demonstrated that bioaccumulation of pollutants will not create adverse environmental effects

This table is used to override the conditional "O's" on "TABLE B".

This table follows the same principles as "TABLE A NOTES"

Table C

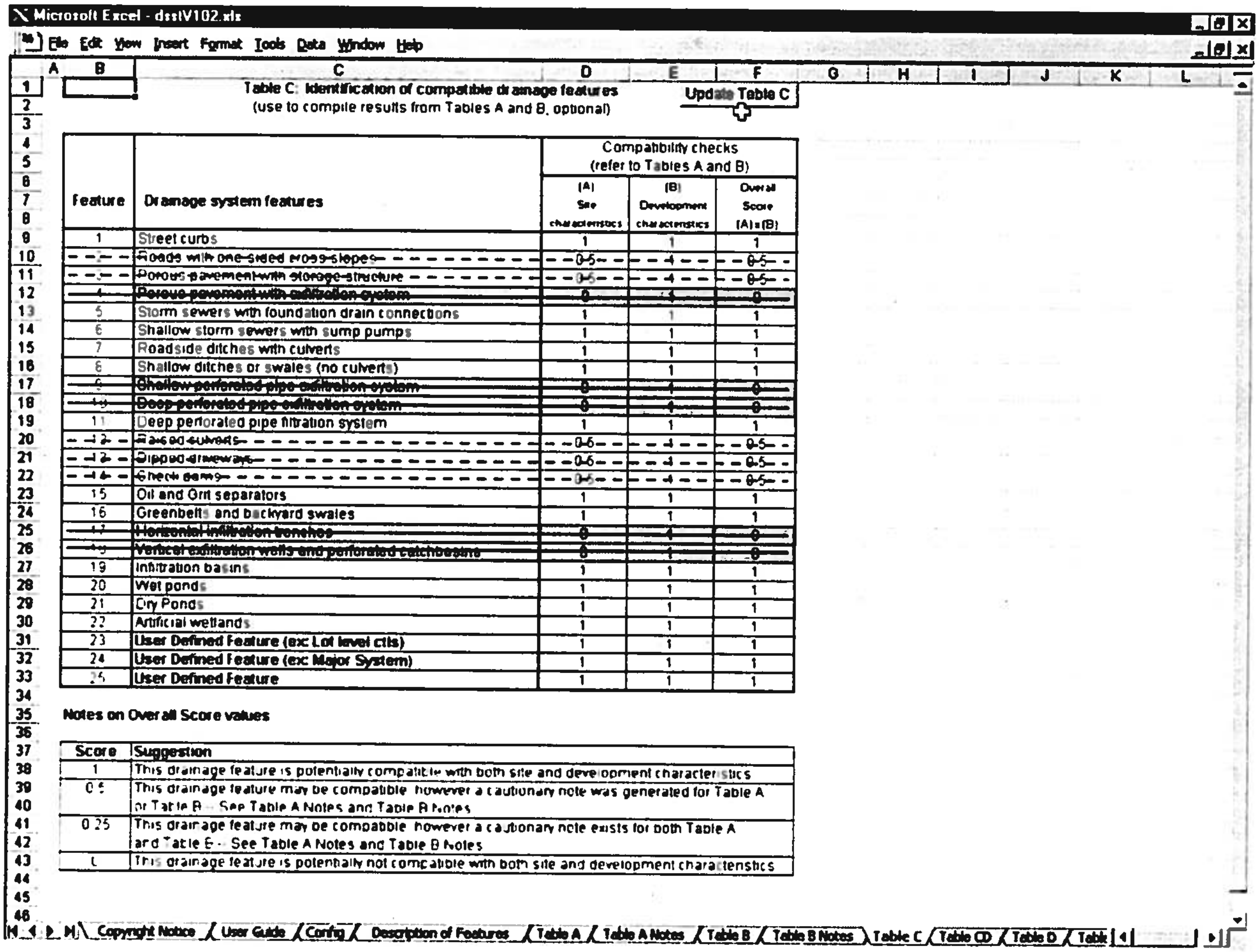


Table C: Identification of compatible drainage features
(use to compile results from Tables A and B, optional)

Feature	Drainage system features	Compatibility checks (refer to Tables A and B)		
		(A) Site characteristics	(B) Development characteristics	Overall Score (A)x(B)
1	Street curbs	1	1	1
~~2~~	~~Roads with one-sided cross-slopes~~	~~0.5~~	~~1~~	~~0.5~~
~~3~~	~~Porous pavement with storage structure~~	~~0.5~~	~~1~~	~~0.5~~
~~4~~	~~Porous pavement with exfiltration system~~	~~0~~	~~1~~	~~0~~
5	Storm sewers with foundation drain connections	1	1	1
6	Shallow storm sewers with sump pumps	1	1	1
7	Roadside ditches with culverts	1	1	1
8	Shallow ditches or swales (no culverts)	1	1	1
~~9~~	~~Shallow perforated pipe exfiltration system~~	~~0~~	~~1~~	~~0~~
~~10~~	~~Deep perforated pipe exfiltration system~~	~~0~~	~~1~~	~~0~~
11	Deep perforated pipe filtration system	1	1	1
~~12~~	~~Raised culverts~~	~~0.5~~	~~1~~	~~0.5~~
~~13~~	~~Dipped driveways~~	~~0.5~~	~~1~~	~~0.5~~
~~14~~	~~Check dams~~	~~0.5~~	~~1~~	~~0.5~~
15	Oil and Grit separators	1	1	1
16	Greenbelts and backyard swales	1	1	1
~~17~~	~~Horizontal infiltration trenches~~	~~0~~	~~1~~	~~0~~
~~18~~	~~Vertical exfiltration wells and perforated catchbasins~~	~~0~~	~~1~~	~~0~~
19	Infiltration basins	1	1	1
20	Wet ponds	1	1	1
21	Dry Ponds	1	1	1
22	Artificial wetlands	1	1	1
23	**User Defined Feature (ex: Lot level ctls)**	1	1	1
24	**User Defined Feature (ex: Major System)**	1	1	1
25	**User Defined Feature**	1	1	1

Notes on Overall Score values

Score	Suggestion
1	This drainage feature is potentially compatible with both site and development characteristics
0.5	This drainage feature may be compatible, however a cautionary note was generated for Table A or Table B -- See Table A Notes and Table B Notes
0.25	This drainage feature may be compatible, however a cautionary note exists for both Table A and Table B -- See Table A Notes and Table B Notes
0	This drainage feature is potentially not compatible with both site and development characteristics

This table is used to identify which drainage features are compatible based on the site and development characteristics identified on "TABLE A" and "TABLE B".

A score of 1 is given to each drainage feature on "TABLE A" and "TABLE B" that is compatible with the site and development characteristics. A score of 0.5 is given for each feature which has been conditionally eliminated and not reinstated by overriding the cautionary notes on either "TABLE A NOTES" or "TABLE B NOTES"

An overall score is computed for each drainage feature by multiplying the score from "TABLE A" with the "TABLE B" score. Drainage features that are suitable based on both site and development characteristics will be given an overall score of 1, and will be highlighted in green. Drainage features that are not suitable will have a total score of 0.5 or less, and will appear highlighted in yellow with a dashed line (where a conditional caution exists), or highlighted in red with a solid line (where no conditional cautions exist).

Update Table C

Clicking this button will re-compute the overall score of each drainage feature based on user input from "TABLE A", "TABLE A NOTES", "TABLE B" and "TABLE B NOTES". This is only necessary, if "Automatically Update Tables" is not checked on the "CONFIG" sheet.

Table CD

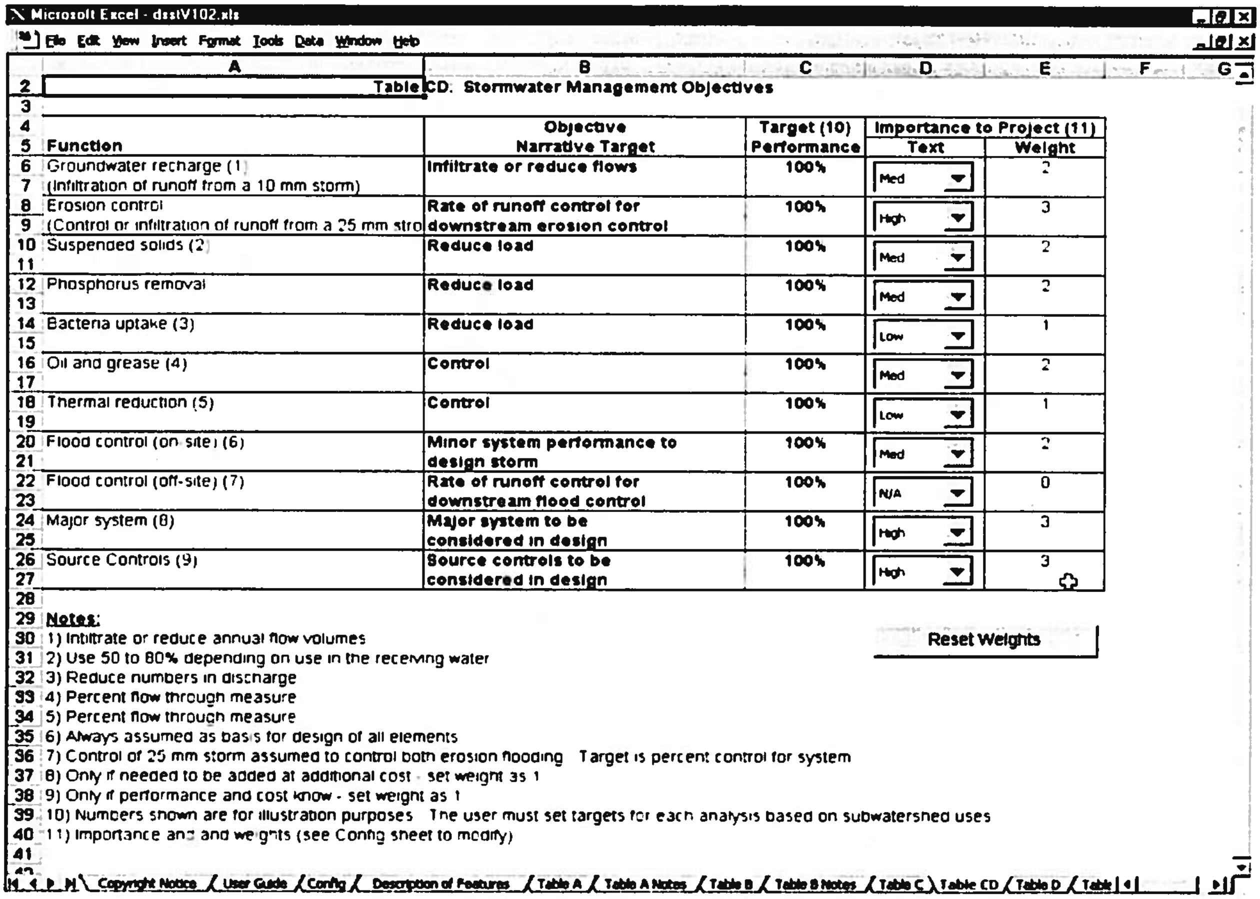


Table CD: Stormwater Management Objectives

Function	Objective Narrative Target	Target (10) Performance	Importance to Project (11) Text	Importance to Project (11) Weight
Groundwater recharge (1) (Infiltration of runoff from a 10 mm storm)	Infiltrate or reduce flows	100%	Med	2
Erosion control (Control or infiltration of runoff from a 25 mm stro	Rate of runoff control for downstream erosion control	100%	High	3
Suspended solids (2)	Reduce load	100%	Med	2
Phosphorus removal	Reduce load	100%	Med	2
Bacteria uptake (3)	Reduce load	100%	Low	1
Oil and grease (4)	Control	100%	Med	2
Thermal reduction (5)	Control	100%	Low	1
Flood control (on site) (6)	Minor system performance to design storm	100%	Med	2
Flood control (off-site) (7)	Rate of runoff control for downstream flood control	100%	N/A	0
Major system (8)	Major system to be considered in design	100%	High	3
Source Controls (9)	Source controls to be considered in design	100%	High	3

Notes:

1) Infiltrate or reduce annual flow volumes
2) Use 50 to 80% depending on use in the receiving water
3) Reduce numbers in discharge
4) Percent flow through measure
5) Percent flow through measure
6) Always assumed as basis for design of all elements
7) Control of 25 mm storm assumed to control both erosion flooding Target is percent control for system
8) Only if needed to be added at additional cost - set weight as 1
9) Only if performance and cost know - set weight as 1
10) Numbers shown are for illustration purposes The user must set targets for each analysis based on subwatershed uses
11) Importance and and weights (see Config sheet to modify)

Reset Weights

This table is used to identify the "Stormwater management objectives", and apply weightings and target performances for selected stormwater management functions. For each function, the user can enter a narrative target that identifies the objective (in column B); a target performance percentage (in Column C) and a weighting value (in Column D).

Objective Narrative Target

Words the user wants to describe the overall goal for the SWM function. Examples may include: "Reduce Load", "Strictly Control", "Maximize", "Minimize" etc.

Target Performance

This is a percentage value representing the goal for the SWM function. It will be used to compute a value for "SYSTEM COMPLIANCE" on "TABLE E".

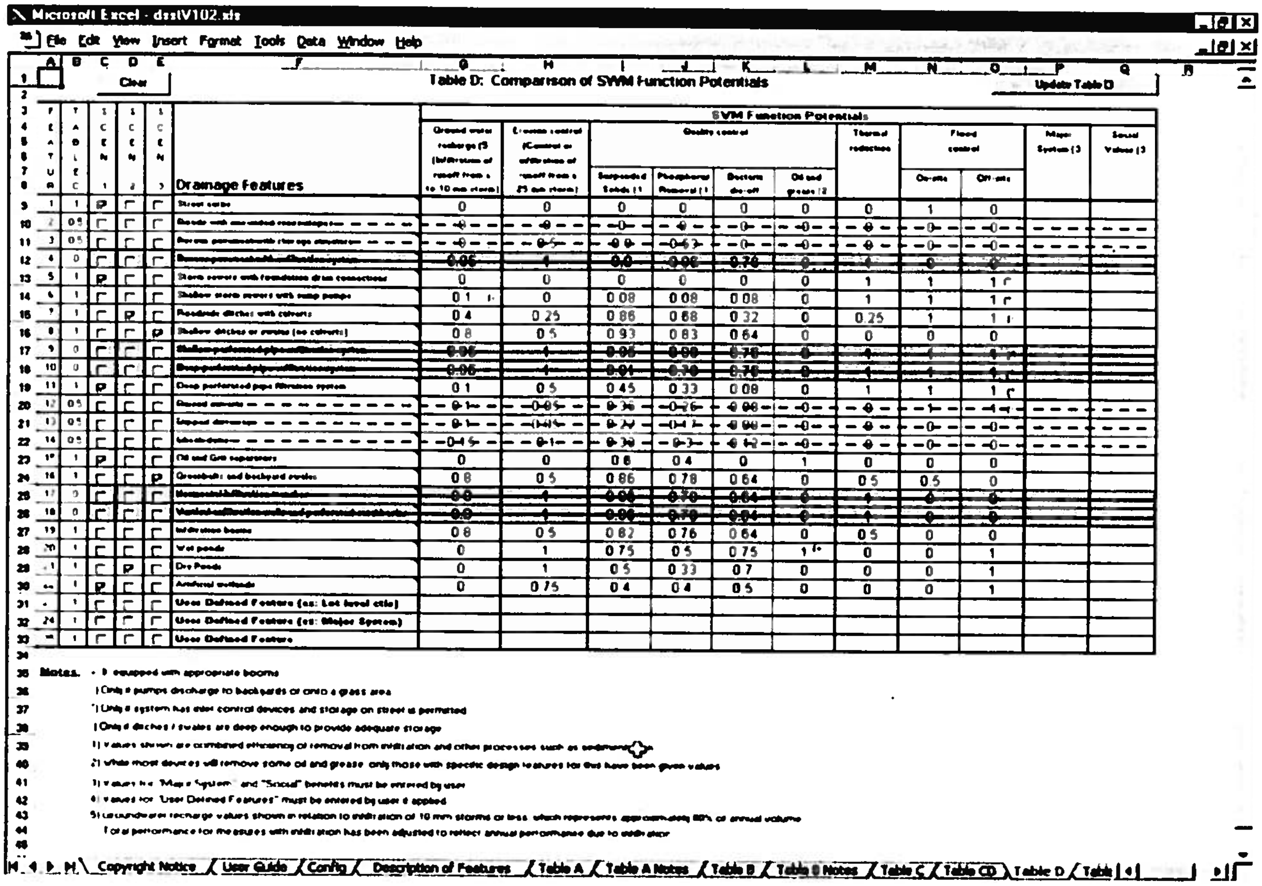
Importance to Project

This is a drop-down box, with text values: "N/A", "Low", "Med", or "High". A corresponding numeric value, "Weight" is linked to this selection box. The weighting will be used to compute a value for "Weighted Compliance as per SWM Priorities" on "TABLE E". The numeric weighting for each value in the drop-down boxes can be set on the "CONFIG" sheet.

Reset Weights

Clicking this button resets all of the drop-down boxes to "N/A" and sets the weight to the corresponding value for "N/A" as set on the "CONFIG" sheet.

Table D



The purpose of this table is two fold. It is first used to associate a numeric value to each drainage feature's SWM function potential. Secondly, it is used to select which drainage features will be used to design a conceptual drainage system for comparison purposes.

SWM Function Potential

A numeric value between 0 and 1 and is used to identify the effectiveness of each drainage feature with respect to a given stormwater management function (Ground water recharge, flood control, thermal reduction etc..). 0 is used for non-effectiveness and 1 is used for complete effectiveness. The SWM function potential is used to compute the "System Efficiency" on "TABLE E". Rows 23, 24 and 25 can be used to enter values for user-defined drainage features.

Conceptual Drainage System Design

Columns C, D and E, are used to identify three user-defined drainage system scenarios. Clicking the check boxes corresponding to the drainage features to be included in the design creates a drainage system scenario. The scenario may contain multiple drainage features. The selected drainage features, the SWM function potentials and the SWM objectives as identified on "TABLE CD" will be used to create "TABLE E".

Update Table D

Clicking this button will re-compute the overall score of each drainage feature based on user input from "TABLE A", "TABLE A NOTES", "TABLE B" and "TABLE B NOTES". The overall score from "TABLE C" will be placed in column "B", and the corresponding background color for the drainage feature's compatibility will be updated. This is only necessary, if "Automatically Update Tables" is not checked on the "CONFIG" sheet.

Table E

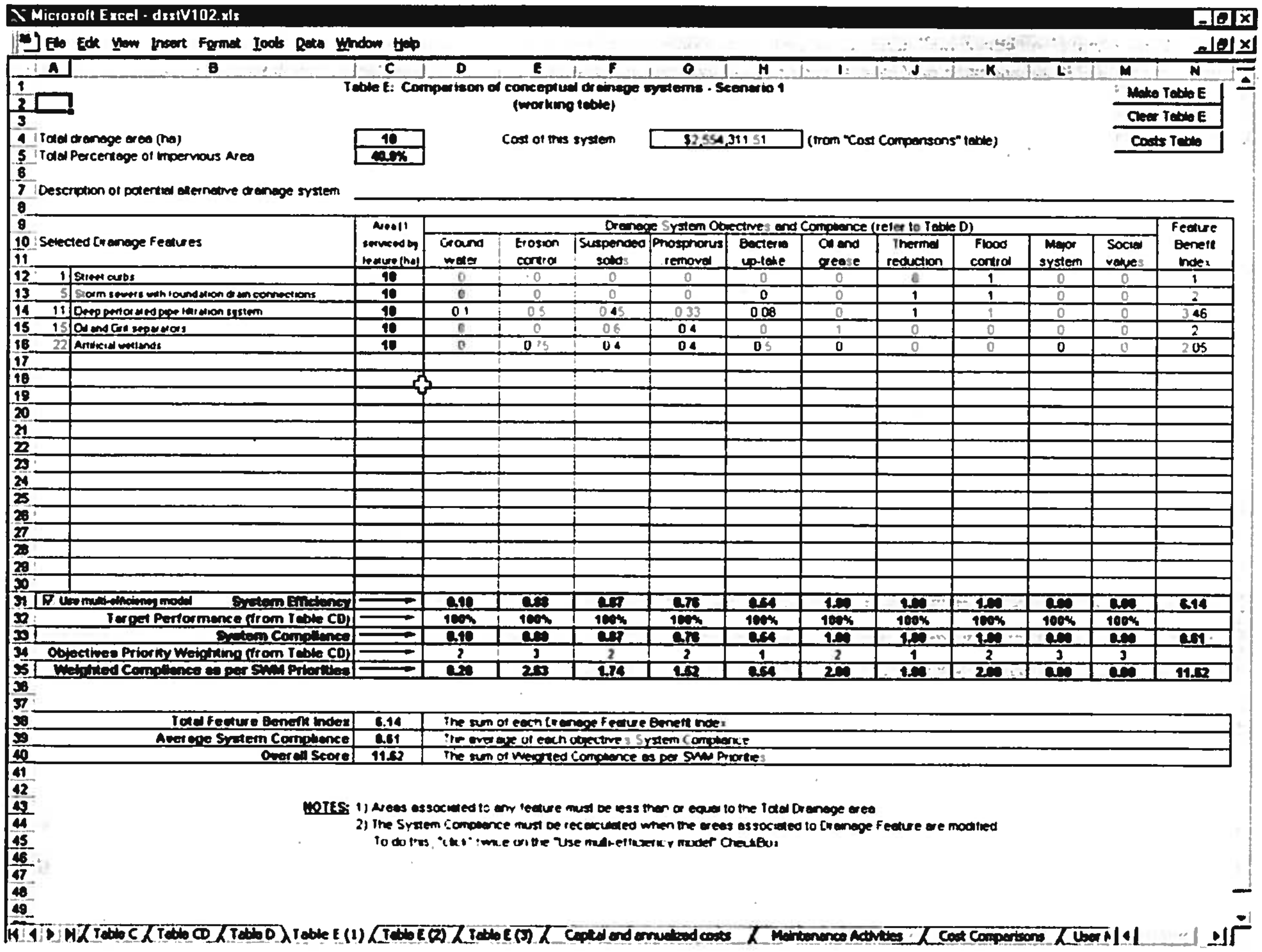


Table E: Comparison of conceptual drainage systems - Scenario 1
(working table)

Total drainage area (ha) 10

Total Percentage of Impervious Area 40.0%

Cost of this system $2,554,311.51 (from "Cost Comparisons" table)

Description of potential alternative drainage system

	Selected Drainage Features	Area(1) serviced by feature (ha)	Ground water	Erosion control	Suspended solids	Phosphorus removal	Bacteria up-take	Oil and grease	Thermal reduction	Flood control	Major system	Social values	Feature Benefit Index
			Drainage System Objectives and Compliance (refer to Table D)										
1	Street curbs	10	0	0	0	0	0	0	0	1	0	0	1
5	Storm sewers with foundation drain connections	10	0	0	0	0	0	0	1	1	0	0	2
11	Deep perforated pipe filtration system	10	0.1	0.5	0.45	0.33	0.08	0	1	1	0	0	3.46
15	Oil and Grit separators	10	0	0	0.6	0.4	0	1	0	0	0	0	2
22	Artificial wetlands	10	0	0.75	0.4	0.4	0.5	0	0	0	0	0	2.05
☑ Use multi-efficiency model	System Efficiency	→	0.10	0.88	0.87	0.76	0.64	1.00	1.00	1.00	0.00	0.00	6.14
	Target Performance (from Table CD)	→	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
	System Compliance	→	0.10	0.88	0.87	0.76	0.64	1.00	1.00	1.00	0.00	0.00	0.61
	Objectives Priority Weighting (from Table CD)	→	2	3	2	2	1	2	1	2	3	3	
	Weighted Compliance as per SWM Priorities	→	0.20	2.63	1.74	1.52	0.64	2.00	1.00	2.00	0.00	0.00	11.62

Total Feature Benefit Index	6.14	The sum of each Drainage Feature Benefit Index
Average System Compliance	0.61	The average of each objective's System Compliance
Overall Score	11.62	The sum of Weighted Compliance as per SWM Priorities

NOTES: 1) Areas associated to any feature must be less than or equal to the Total Drainage area
2) The System Compliance must be recalculated when the areas associated to Drainage Feature are modified
To do this, "click" twice on the "Use multi-efficiency model" CheckBox

This table is used to list the selected drainage features of a conceptual system, as selected from "TABLE D". The components of the conceptualized drainage system are analyzed and a series of comparative indices are computed based on SWM function objectives and potentials.

There are three copies of "TABLE E", one for each scenario as selected by the user on "TABLE D". To automate "TABLE E", click the button at the top right, **[Make Table E]**.

The total drainage area and percentage of impervious area are entered in cells "C4" and "C5" respectively. The area is used to compute a pro-weighted value of compliance in columns "D" through "M" (see **[MAKE TABLE E]**). The area and imperviousness are also used to compute the "Cost of System" (see **[COSTS TABLE]**)

Make Table E

Clicking this button fills columns "A" and "B", with the drainage features selected for the scenario in "TABLE D". Rows 10 and 11 of columns "D" through "M", will contain the headings of any SWM Function from "TABLE CD", which was given a text rating other than "N/A", for "Importance to Project".
The remaining rows in columns "D" through "M" will contain the numeric value (0 to 1) of the SWM function potential for the corresponding drainage feature listed in Column "B".

Values in columns "D" through "M" will be pro-weighted based on the ratio of "Area Serviced By Feature" (entered by the user in column "C"), and "Total Drainage Area" (entered by the user in cell "C4").

Feature Benefit Index

This value is reported in column "N" and is calculated as the sum of each pro-weighted value listed in columns "D" through "M". This value can be used to comparatively assess the effectiveness of each drainage feature with respect to all of the system objectives.

System Efficiency

The system efficiency is a comparative measure of the proposed drainage system's effectiveness with respect to each SWM function objective.

Use Multi-Efficiency Model ***not selected***

This value is the sum of each pro-weighted value reported for the various drainage system objectives.

Use Multi-Efficiency Model selected

This value uses the product summation as follows:

$$N_e = \left[1 - \prod_{i}^{n}(1 - n_e)\right] * 100\%$$

Where: N_e = the overall Efficiency
n_e = individual efficiency of a particular item

System Compliance

This value is a measure of the system efficiency with respect to the user's target performance objectives as specified on "TABLE CD", and reported on row 32.

System Compliance = System Efficiency / Target Performance.

Weighted Compliance as per SWM Priorities

This value is a measure of the system's compliance with respect to the user's objective priorities as specified on "TABLE CD", and reported on row 34.

Weighted Compliance = System Compliance x Objectives Priority Weighting

Total Feature Benefit Index

This is the sum of each individual "Feature Benefit Index". This value can be used for comparing the effectiveness of one proposed system (or scenario) with another.

Average System Compliance

This is the average value of "System Compliance". This value can be used for comparing the effectiveness of one proposed system (or scenario) with another.

Overall Score

This is the sum of each "Weighted Compliance as per SWM Priorities". This value can be used for comparing the effectiveness of one proposed system (or scenario) with another.

Clear Table E

Clicking this button removes all of the data from "TABLE E".

( ) Use Multi-Efficiency Model

Checking this box changes the calculation method for "System Efficiency" (see **System Efficiency**).

Costs Table

Clicking this button invokes a costing sub-routine that approximates the cost of the proposed drainage system by computing the quantities of materials needed to construct the system. The quantities are placed in the appropriate column of the "COST COMPARISONS" table. A present value item cost is computed based on the "Cost Per Unit" and a total present value cost is computed as the sum of each item cost. (See **"Costs Comparisons", "Capital and Annualized Costs" and "Maintenance Activities"**).

The value of "Total Cost (Present Value)" is placed in cell "G4" and labeled, "Cost of this System". This value can be used to compare the cost-benefit of each proposed scenario.

Note: This cost is an approximation only. For a detailed breakdown of how this feature works, see the text for the "COST COMPARISONS" table.

Maintenance Activities

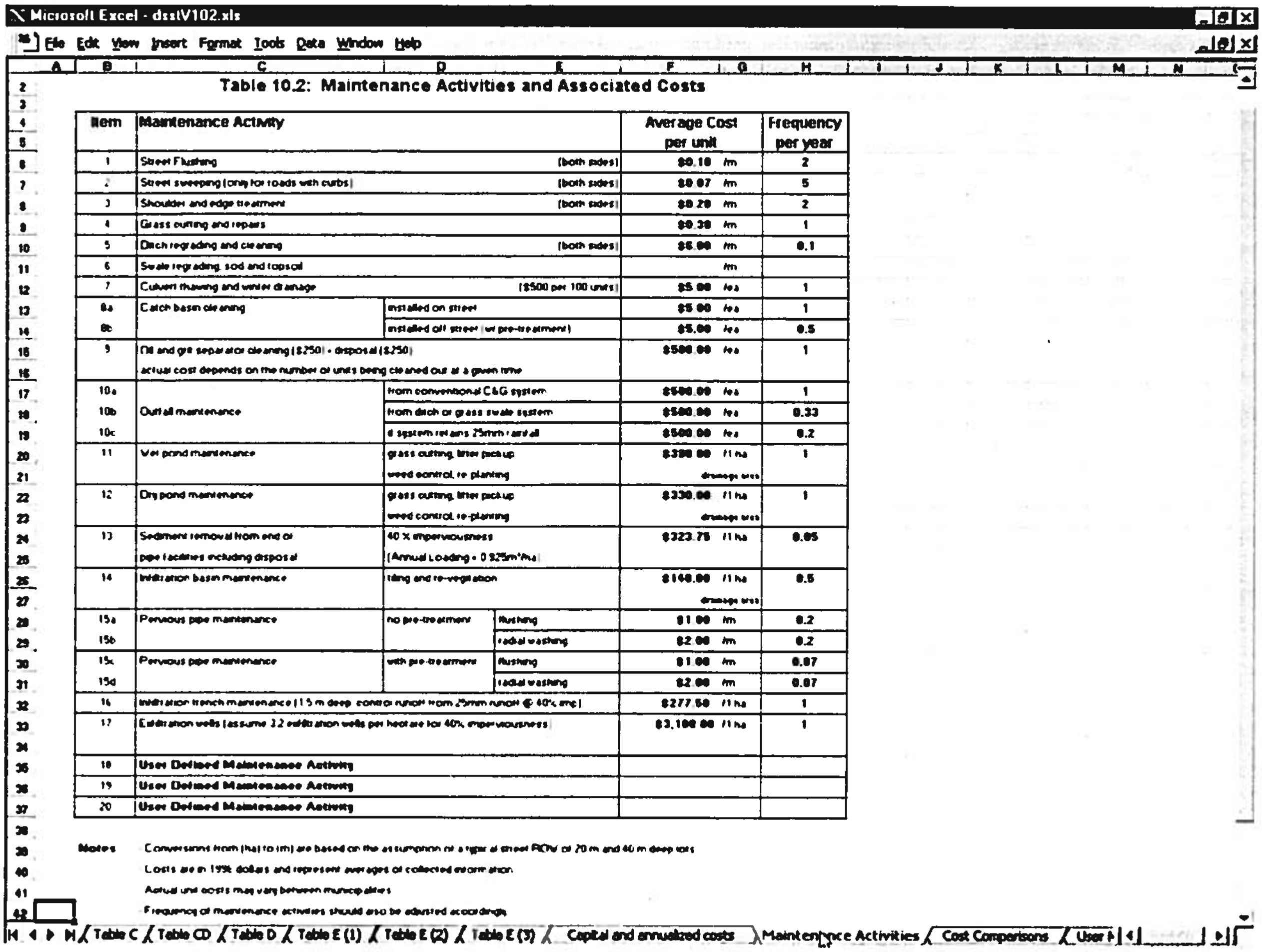


Table 10.2: Maintenance Activities and Associated Costs

Item	Maintenance Activity			Average Cost per unit	Frequency per year
1	Street Flushing (both sides)			$0.10 /m	2
2	Street sweeping (only for roads with curbs) (both sides)			$0.07 /m	5
3	Shoulder and edge treatment (both sides)			$0.20 /m	2
4	Grass cutting and repairs			$0.30 /m	1
5	Ditch regrading and cleaning (both sides)			$6.00 /m	0.1
6	Swale regrading, sod and topsoil			/m	
7	Culvert thawing and winter drainage ($500 per 100 units)			$5.00 /ea	1
8a	Catch basin cleaning	installed on street		$5.00 /ea	1
8b		installed off street (w/ pre-treatment)		$5.00 /ea	0.5
9	Oil and grit separator cleaning ($250) + disposal ($250) actual cost depends on the number of units being cleaned out at a given time			$500.00 /ea	1
10a	Outfall maintenance	from conventional C&G system		$500.00 /ea	1
10b		from ditch or grass swale system		$500.00 /ea	0.33
10c		if system retains 25mm rainfall		$500.00 /ea	0.2
11	Wet pond maintenance	grass cutting, litter pickup weed control, re-planting		$390.00 /1 ha drainage area	1
12	Dry pond maintenance	grass cutting, litter pickup weed control, re-planting		$330.00 /1 ha drainage area	1
13	Sediment removal from end of pipe facilities including disposal	40 % imperviousness (Annual Loading = 0.325m³/ha)		$323.75 /1 ha	0.05
14	Infiltration basin maintenance	tilling and re-vegetation		$140.00 /1 ha drainage area	0.5
15a	Pervious pipe maintenance	no pre-treatment	flushing	$1.00 /m	0.2
15b			radial washing	$2.00 /m	0.2
15c	Pervious pipe maintenance	with pre-treatment	flushing	$1.00 /m	0.07
15d			radial washing	$2.00 /m	0.07
16	Infiltration trench maintenance (1.5 m deep, control runoff from 25mm runoff @ 40% imp)			$277.50 /1 ha	1
17	Exfiltration wells (assume 3.2 exfiltration wells per hectare for 40% imperviousness)			$3,100.00 /1 ha	1
18	**User Defined Maintenance Activity**				
19	**User Defined Maintenance Activity**				
20	**User Defined Maintenance Activity**				

Notes: Conversions from (ha) to (m) are based on the assumption of a typical street ROW of 20 m and 40 m deep lots
Costs are in 1996 dollars and represent averages of collected information.
Actual unit costs may vary between municipalities
Frequency of maintenance activities should also be adjusted accordingly

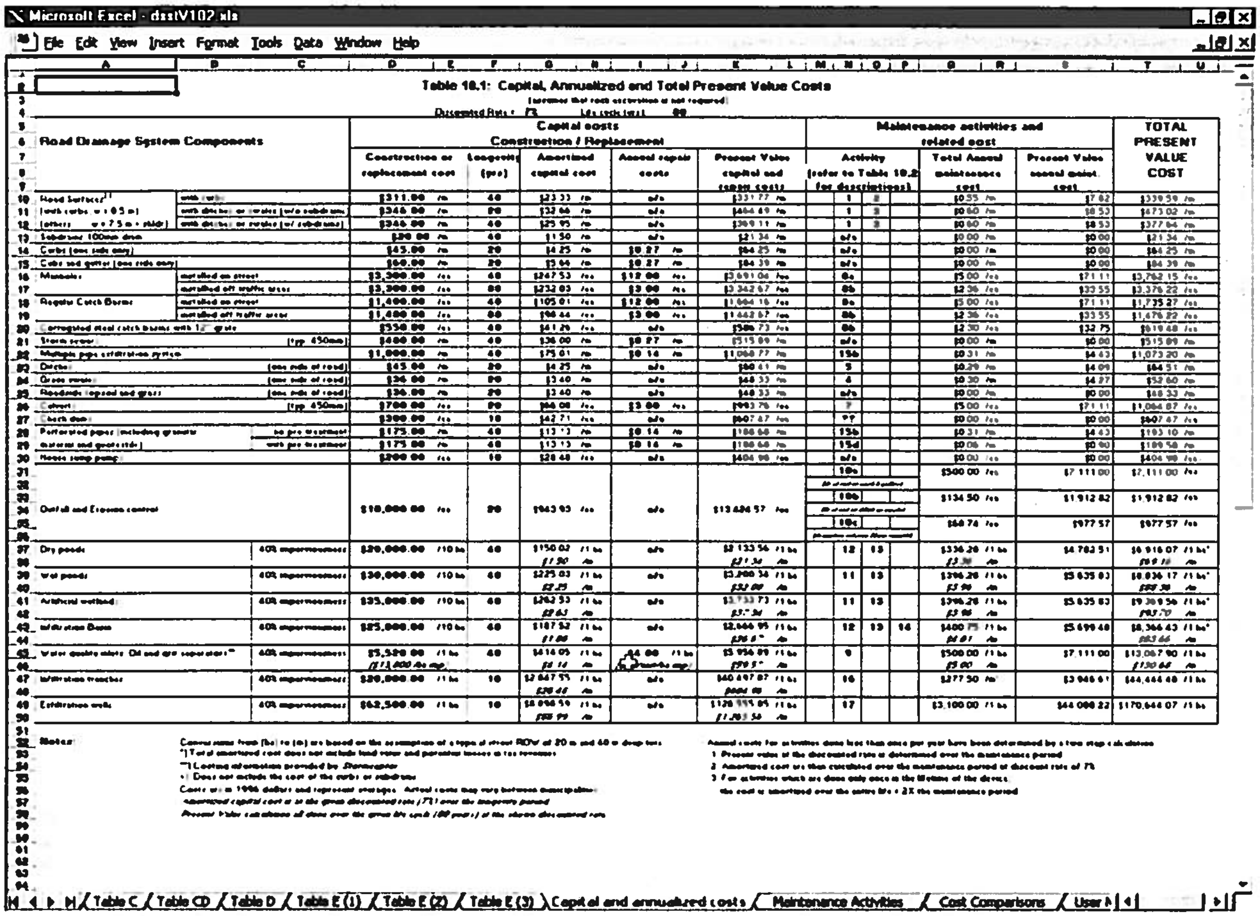
This table is used to define the frequency and cost per unit of various maintenance activities. This table is referenced by the "CAPTIAL AND ANNUALIZED COSTS" table to compute a "Total Present Value Cost" for each drainage feature.

Common maintenance activities are listed as Items 1 through 17. Default values for "Average Cost Per Unit" and "Frequency Per Year" have been entered based on, "Evaluation of Roadside Ditches and other Stormwater management Practices" (J.F. Sabourin and Associates Inc., 1997). The user is free to change the values in these columns to better match the costs and practices in their area.

Items 18, 19 and 20 are left blank for three additional user-defined maintenance activities.

Note on Frequency per Year values: If a maintenance activity is performed less than once per year, such as once every 5 years, a value of 1/5 or 0.2 is used as the frequency.

Capital and Annualized Costs



This table is used to compute a "Total Present Value Cost" for each road drainage system component. This cost is then transferred to the "COST COMPARISONS" table, for costing comparisons of various drainage system scenarios. The "Total Present Value Cost", takes into account, the construction and replacement cost, the longevity of the component, the annual repair cost, and the total maintenance cost. Present value computations are made using a specified Discounted Rate and Lifecycle (these values are entered on the "CONFIG" sheet).

Default values are provided for each field based on "Evaluation of Roadside Ditches and other Stormwater management Practices" (J.F. Sabourin and Associates Inc., 1997); however, any value that appears in blue, bolded text can be changed by the user.

Note: This table uses the Excel functions, **PV** and **PMT**, for "Present Value" and "Payment" calculations.

Construction or replacement cost

The cost per unit to construct or replace the drainage system component.

Longevity

The number of years the drainage system component is expected to last before being replaced.

Amortized Capital Cost

The construction or replacement cost of the drainage system component amortized over the longevity at the user specified discounted rate.

*Amortized Capital Cost = - **PMT**(Discounted Rate, Longevity, Construction or replacement cost)*

Annual Repair Costs

The value in dollars per unit expected for annual repairs to the drainage system component.

Present Value capital and repair costs

The present value of amortized capital costs plus annual repair costs for the drainage system component.

*Present Value capital and repair costs = - **PV**(Discounted Rate, Lifecycle, Amortized Capital Cost +Annual Repair Costs)*

Activity

The maintenance activities associated with the drainage system component. Four columns, "M", "N", "O" and "P" can be used to identify four different maintenance activities from the "MAINTENANCE ACTIVITIES" table.

Total Annual Maintenance Cost

For Each Maintenance Activity Identified in columns "M", "N", "O" and "P", an individual maintenance cost must first be calculated.

Frequency = Maintenance Frequency from "MAINTENANCE ACTIVITIES" sheet.
Avg. Maint. Cost = Average cost per unit from "MAINTENANCE ACTIVITIES" sheet.

If Frequency >= once per year then
Maintenance Cost = Avg. Maintenance Cost x Frequency

Otherwise,
*Present Value = - **PV** (Discounted Rate, Integer value of (1 / Frequency), 0, Avg. Maint. cost)*
*Maint. Cost = -**PMT** (Discounted Rate, (Longevity / (Longevity x Frequency - 1)), Present Value)*

Total Annual Maintenance Cost = sum of the Maintenance Costs for each activity identified in columns "M", "N", "O" and "P".

Present Value Annual Maintenance Cost

The present value of the annual maintenance costs taking into account the Discounted Rate and the Lifecylce.

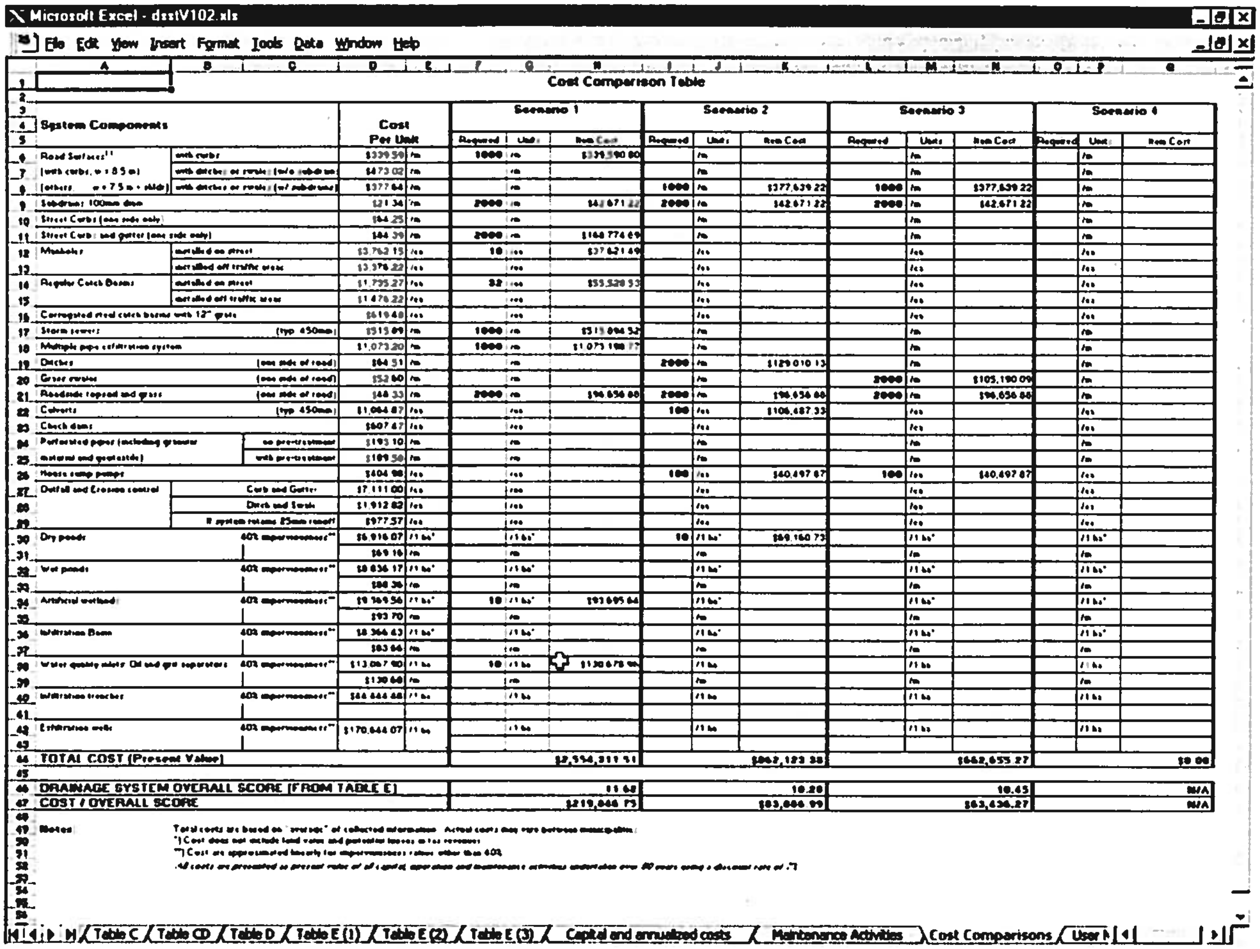
*Present Value annual maint. cost = -**PV**(Discounted Rate, Lifecycle, Total Annual Maintenance Cost)*

Total Present Value Cost

The total present value cost of the item taking into account the capital costs, repair costs and maintenance costs.

Total Present Value Cost = Present Value Capital and Repair Costs + Present Value Annual Maint. Cost.

Cost Comparisons



Cost Comparison Table

	System Components		Cost Per Unit		Scenario 1			Scenario 2			Scenario 3			Scenario 4		
					Required	Units	Item Cost	Required	Units	Item Cost	Required	Units	Item Cost	Required	Units	Item Cost
6	Road Surfaces(1)	with curbs	$339.59	/m	1000	/m	$339,590.00		/m			/m			/m	
7	(with curbs, w = 8.5 m)	with ditches or swales (w/o subdrains)	$473.02	/m		/m			/m			/m			/m	
8	(others w = 7.5 m + shldr)	with ditches or swales (w/ subdrains)	$377.64	/m		/m		1000	/m	$377,639.22	1000	/m	$377,639.22		/m	
9	Subdrains 100mm diam		$21.34	/m	2000	/m	$42,671.22	2000	/m	$42,671.22	2000	/m	$42,671.22		/m	
10	Street Curbs (one side only)		$64.25	/m		/m			/m			/m			/m	
11	Street Curbs and gutter (one side only)		$84.39	/m	2000	/m	$168,774.69		/m			/m			/m	
12	Manholes	installed on street	$3,762.15	/ea	10	/ea	$37,621.49		/ea			/ea			/ea	
13		installed off traffic areas	$3,378.22	/ea		/ea			/ea			/ea			/ea	
14	Regular Catch Basins	installed on street	$1,735.27	/ea	32	/ea	$55,528.53		/ea			/ea			/ea	
15		installed off traffic areas	$1,470.22	/ea		/ea			/ea			/ea			/ea	
16	Corrugated steel catch basins with 12" grate		$619.40	/ea		/ea			/ea			/ea			/ea	
17	Storm sewers	(typ. 450mm)	$515.09	/m	1000	/m	$515,094.52		/m			/m			/m	
18	Multiple pipe exfiltration system		$1,073.20	/m	1000	/m	$1,073,198.77		/m			/m			/m	
19	Ditches	(one side of road)	$64.51	/m		/m		2000	/m	$129,010.13		/m			/m	
20	Grass swales	(one side of road)	$52.60	/m		/m			/m		2000	/m	$105,190.09		/m	
21	Roadside topsoil and grass	(one side of road)	$48.33	/m	2000	/m	$96,656.66	2000	/m	$96,656.66	2000	/m	$96,656.66		/m	
22	Culverts	(typ. 450mm)	$1,064.87	/ea		/ea		100	/ea	$106,487.33		/ea			/ea	
23	Check dams		$607.47	/ea		/ea			/ea			/ea			/ea	
24	Perforated pipes (including granular	no pre-treatment	$193.10	/m		/m			/m			/m			/m	
25	material and geotextile)	with pre-treatment	$189.50	/m		/m			/m			/m			/m	
26	House sump pumps		$404.98	/ea		/ea		100	/ea	$40,497.87	100	/ea	$40,497.87		/ea	
27	Outfall and Erosion control	Curb and Gutter	$7,111.00	/ea		/ea			/ea			/ea			/ea	
28		Ditch and Swale	$1,912.82	/ea		/ea			/ea			/ea			/ea	
29		If system retains 25mm runoff	$977.57	/ea		/ea			/ea			/ea			/ea	
30	Dry ponds	40% imperviousness**	$6,916.07	/1 ha*		/1 ha*		10	/1 ha*	$69,160.73		/1 ha*			/1 ha*	
31			$69.16	/m		/m			/m			/m			/m	
32	Wet ponds	40% imperviousness**	$8,836.17	/1 ha*		/1 ha*			/1 ha*			/1 ha*			/1 ha*	
33			$88.36	/m		/m			/m			/m			/m	
34	Artificial wetlands	40% imperviousness**	$9,369.56	/1 ha*	10	/1 ha*	$93,695.64		/1 ha*			/1 ha*			/1 ha*	
35			$93.70	/m		/m			/m			/m			/m	
36	Infiltration Basin	40% imperviousness**	$8,366.43	/1 ha*		/1 ha*			/1 ha*			/1 ha*			/1 ha*	
37			$83.66	/m		/m			/m			/m			/m	
38	Water quality inlets: Oil and grit separators	40% imperviousness**	$13,067.90	/1 ha	10	/1 ha	$130,678.[illegible]		/1 ha			/1 ha			/1 ha	
39			$130.68	/m		/m			/m			/m			/m	
40	Infiltration trenches	40% imperviousness**	$44,444.48	/1 ha		/1 ha			/1 ha			/1 ha			/1 ha	
41																
42	Exfiltration wells	40% imperviousness**	$170,644.07	/1 ha		/1 ha			/1 ha			/1 ha			/1 ha	
43																
44	TOTAL COST (Present Value)						$2,554,311.51			$862,123.38			$662,655.27			$0.00
46	DRAINAGE SYSTEM OVERALL SCORE (FROM TABLE E)						11.64			10.28			10.45			N/A
47	COST / OVERALL SCORE						$219,446.73			$83,886.99			$63,436.27			N/A

Notes:

Total costs are based on "average" of collected information. Actual costs may vary between municipalities.
*) Cost does not include land value and potential losses in tax revenues
**) Cost are approximated linearly for imperviousness values other than 40%
All costs are presented as present value of all capital, operation and maintenance activities undertaken over [illegible] years using a discount rate of [illegible]

This table is used to compare the costs of each drainage system scenario, as built using "TABLE D" and "TABLE E". The "Cost per Unit", for each drainage system component has been transferred from the "CAPITAL AND ANNUALIZED COSTS" table. A total present value cost is computed by multiplying each unit cost by the number of units required per drainage system component, and summing up the values for each scenario.

This table is automatically filled in by clicking [COSTS TABLE] from "TABLE E". Alternatively, you can manually enter in a "Shopping List" of items required for a conceptual drainage system.

A description of the scenario, as entered by the user (Cell "C7" on "TABLE E"), is placed atop each column. If the description is longer than 28 characters, it is truncated followed by "...".

The following procedure is applied to determine the required quantities of the system components, when the [COSTS TABLE] button is clicked from "TABLE E"...

Road Surfaces with curbs

If any of the following drainage features are selected: Street curbs, Roads with one-sided cross slopes, Porous pavement with storage structure, Porous pavement with exfiltration system, Storm sewers with foundation drain connections, Shallow storm sewers with sump pumps, Deep perforated pipe filtration system.

Road Surfaces with curbs = Area (ha) x 100 m of road per hectare

Road Surfaces with swales (Sub-drains are assumed)

If any of the following drainage features are selected: Roadside ditches with culverts, Shallow ditches or swales (no culverts), Shallow perforated pipe exfiltration system.

Road Surfaces with swales = Area (ha) x 100 m of road per hectare

Subdrains

Subdrains are assumed for all Road Surfaces. Subdrains are required for each side of the road.

Subdrains = Length of Road Surfaces (m) x 2 lengths of subdrain per length of road

Street Curbs

If Street curbs are selected as a drainage feature, street curbs are assumed for each side of the road.

Street Curbs = Length of Road Surfaces with curbs (m) x 2 street curbs per road length

If Storm sewers with foundation drains are selected, then street curbs with gutters are then assumed to be included.

Street Curbs with Gutters = Length of Road Surfaces with curbs (m) x 2 curbs and gutters per road length

Manholes installed on street and off traffic areas

If any of the following drainage features are selected: Storm sewers with foundation drain connections, Deep perforated pipe exfiltration system or Deep perforated pipe filtration system, then all of the manholes are installed on the street.

Manholes installed on street = Length of Road Surfaces (m) / 100 m per Man Hole installation
Manholes installed off traffic areas = 0

If a shallow perforated pipe exfiltration system is selected then, half of the manholes are installed on the street and half are installed off the street.

Manholes installed on street = Length of Road Surfaces (m) / 100 m per Man Hole installation / 2
Manholes installed off traffic areas = Length of Road Surfaces (m) / 100 m per Man Hole / 2

Regular Catch Basins installed on street or off traffic areas

If any of the following drainage features are selected: Storm sewers with foundation drain connections, Shallow storm sewers with sump pumps, Deep perforated pipe exfiltration system, Deep perforated pipe filtration system. If Street curbs have been selected, the catch basins are installed on street, otherwise they are installed off traffic areas.

Regular Catch Basins = Area (ha) x 3.2 Catch Basins per hectare

If Roads with one-sided cross slopes have been selected, only have the number of catch basins are required.

Regular Catch Basins = Area (ha) x 3.2 Catch Basins per hectare / 2

Corrugated steel catch basins

If shallow perforated pipe exfiltration system is selected, one corrugated steel catch basin is installed per lot.

Corrugated steel catch basins = Area (ha) x 10 Lots per hectare x 1 CB per lot

Storm sewers

If Storm sewers with foundation drain connections are selected.

Storm sewers = Length of Road Surfaces (m)

Multiple pipe exfiltration system

If Deep perforated pipe exfiltration system or Deep perforated pipe filtration system are selected.

Multiple pipe exfiltration system = Length of Road Surfaces (m)

Ditches

If Roadside ditches with culverts are selected.

Ditches = Length of Road Surfaces (m) x 2 ditches per length of road

Grass Swales

If Shallow ditches or swales (no culverts) or Shallow perforated pipe exfiltration system are selected.

Grass Swales = Length of Road Surfaces (m) x 2 swales per length of road

If Greenbelts and backyard swales are selected, an additional length of swale is required equivalent to the lot frontage (which is approximated as the length of road surfaces).

Additional Length of Swale for Greenbelts/backyard swales = Length of Road Surfaces (m)

Roadside topsoil and grass

This is generally required for all drainage systems, except for roadside ditches with culverts. For the latter system, it is assumed that the existing roadside topsoil and grass will be used.

Roadside topsoil and grass = Length of Road Surfaces (m) x 2 sides of road

Culverts

Culverts are required for Roadside ditches with culverts. One culvert per lot is assumed.

Culverts = Area (ha) x 10 Lots per hectare x 1 Culvert per lot

Check Dams

If Check dams are selected, one check dam per lot is assumed.

Check dams = Area (ha) x 10 Lots per hectare x 1 Check dam per lot

Perforated Pipes (including granular material and geotextile (with or without pre-treatment)

If Shallow perforated pipe exfiltration system is selected then perforated pipes are required.

If Oil and grit separators or grass swales are selected:

Perforated Pipes with pretreatment = Length of Road Surfaces (m) x 2 pipes per road length

Otherwise:

Perforated Pipes without pretreatment = Length of Road Surfaces (m) x 2 pipes per road length

House sump pumps

If any of: Shallow storm sewers with sump pumps, Roadside ditches with culverts, Shallow ditches or swales (no culverts) or Shallow perforated pipe exfiltration system are selected, one sump pump per lot is required.

House sump pumps = Area (ha) x 10 Lots per hectare x 1 Sump pump per lot

Dry Ponds, Wet Ponds, Artificial Wetlands, Infiltration Basins, Oil and Grit Separators and Exfiltration Wells

If any of the following: Dry Ponds, Wet Ponds, Artificial Wetlands, Infiltration Basins, Oil and Grit Separators and Exfiltration Wells are selected, a calculation is made to determine an equivalent contributing area at 40% imperviousness to the respective facility. This calculation is necessary as the unit costing is done based on an assumed imperviousness of 40%.

Equivalent Area @ 40% Imperviousness = Contributing area to the facility (ha) x Imperviousness (As given in "TABLE E") / Costing Imperviousness (40 %).

Infiltration Trenches

If Porous pavement with storage structure, Porous pavement with exfiltration system or Horizontal infiltration trenches are selected, then an equivalent contributing area at 40% imperviousness is required. (The same reasoning and procedure is followed as above).

Equivalent Area @ 40% Imperviousness = Contributing area to the facility (ha) x Imperviousness (As given on "TABLE E") / Costing Imperviousness (40 %).

ANNEX A

Sample Print-outs from Drainage System Selection Tool

User Guide - Drainage System Selection Tool

System Requirements

This tool requires Microsoft Excel, (version 7 or better), for Windows 95/98/NT 4.0.
Minimumum screen resolution: 800 x 600 x 256 colours.
Recommended screen resolution: 1024 x 768 x 256 colours or better.
(To view more of each workbook, adjust the zoom control to 75% or less. View > Zoom...)

Objective

This tool is intended to be a design aid for the selection of Stormwater Management Practices.
It is only an aid and is not intended to replace or be a substitute for engineering judgement.
This software version of the tool is based on the following document:
"Evaluation of Roadside Ditches and Other Related Stormwater Management Practices",
by J.F. Sabourin and Associates Inc., 1997 and updated in 1999.

General Notes

In general, each worksheet is locked to protect the integrity of internal worksheet functions. However, cells that have blue, bolded text can be changed or customized by the user. Global variables located on the "Config" sheet can also be changed by the user. Manipulation of this tool is generally accomplished by selecting check boxes, items from drop down lists and by clicking buttons.

Printing

1. Enter the headers and footers you want to appear on each page, from the config sheet
2. Select the number of copies you want of each sheet
3. Use the check boxes to select the sheets you want printed
4. Click the Batch Printing button

Images

1. Double click the respective icon for the image you want to view
2. You need an application installed that can view a .GIF image (such as a Web browser)
3. This method of viewing images maybe overriden in lieu of an accompanying PDF document in the future

Selection Tool for Drainage Systems (Table A through Table E)

Tables A, B and C are used to eliminate non-compatible drainage system features based on Site and Development characteristics.
Tables CD, D and E are used to set drainage system objectives, identify compatible drainage sytem feautres and compare various systems.

Eliminating Drainage Features

1. Select the visual methods you want to use to eliminate drainage features from the Config sheet

Options include, Lines, Highlighting the background colour of cells (Green = ok, Yellow = maybe, Red = no)
2 From Table A, check the site characteristics that pertain to the area to be drained
3 From Table A notes, check any cautionary notes you want overriden - cautionary notes that are overriden will turn yellow cells green
4 Click Implement Overrides
5 From Table B, check the development characteristics that pertain to the area to be drained
6 From Table B Notes, check any cautionary notes you want overriden, Click Implement Overrides
7 Table C displays the Overall score of the selection exercise, drainage features with a score of 1 are ok, 0.5 & 0.25 = maybe, 0 = no

Adding additional Drainage Features

1 Table A and Table B have room for upto 3 additional user-configured drainage features
2 On Table A and Table B, enter the name of the drainage features (cells D32 - D34)
3 In the corresponding columns, enter a capital X, wherever the feature is not compatible
4 Only a capital X can be used to eliminate features, There is no conditional elimination for user-entered features

Determine Objectives and Compare Drainage Features

1 From Table CD, set the priority for each stormwater management objective: Low, Medium, High or N/A
2
3 From Table E, click, "Make Table E" to create a working table highlighting each components performance relative to your selected objectives
4 Assess the conceptual drainage systems performance by noting the value of "compliance"
5 Upto three scenarios can be analysed per workbook. Alternate drainage systems can be compared by manipulating Table D
and making a Table E on sheets: Table E (1), Table E (2) and Table E (3).

Costing Tool for Drainage Systems (Cost Comparison Table)

1 After creating one or more drainage designs with Table E, you can "spec. out" the system to be built by clicking on the "Costs Table" button.
A quick analysis of your designed system will be made, and a preliminary cost-estimate will be produced based on default costing estimates.
2 You can fine-tune the cost estimate, by adjusting the number of each item required, length or area to be serviced.
2 The present value cost for each item can be modified, by adjusting tables 10.1 and 10.2 which define the "Capital, Annualized and Total Present Valu
and the "Maintenance Activities and Associated Costs".
3 The "Discounted Rate" and "Life Cycle" (used for Present Value calculations), can be adjusted on the "Config" sheet.
4 Tables 10.1 and 10.2 can be adjusted by changing any of the values that appear in blue and are bolded.

Configuration Control Panel - Drainage Features

Table A, Table A Notes, Table B, Table B Notes, Table C, Table D, Table E (1), Table E (2), Table E (3

☑ Use Lines to eliminate Drainage Features
☑ Highlight Green Cells (Compatible Features)
☑ Highlight Yellow Cells (Potentially Compatible)
☑ Highlight Red Cells (Eliminated Features)

Update Tables

Clear Tables

☑ Automatically Update Tables

Table CD - SWM Function Priorities Terms and Corresponding Weightings for Table E

N/A	0
Low	1
Med	2
High	3

Zoom All Sheets

Configuration Control Panel - Financial Portion

Capital and annualized costs, Maintenance Activities, Cost Comparisons

Discounted Rate for Present Value Calculations:	7	%
Lifecycle for Present Value Calculations:	80	Years

Printing Options - Headers and Footers of All Worksheets

Top Left Header 1	**Drainage System Selection Tool**
Top Left Header 2	
Top Right Header 1	**User Guide**
Top Right Header 2	**Example Output**
Bottom Left Footer 1	J.F. Sabourin and Associates Inc.
Bottom Left Footer 2	Water Resources and Environmental Consultants
Bottom Right Footer 1	**Ref.: # 9800220**
Bottom Right Footer 2	**Annex A**
Number of Copies	1

Batch Printing - One Click Printing of All Worksheets

☑ Copyright Notice
☑ User Guide
☑ Config
☑ User Notes (1)
☑ User Notes (2)
☑ Table A
☑ Table A Notes
☑ Table B
☑ Table B Notes
☑ Table C
☑ Table CD
☑ Table D
☑ Table E (1)
☑ Table E (2)
☑ Table E (3)
☑ Capital and annualized costs
☑ Maintenance Activities
☑ Cost Comparisons

Select All

Print Selected

Table A: Selection of alternative drainage features based on site characteristics

FEATURE	TABLE A	TABLE B	Drainage Features	Site Characteristics															
				Soils are incompatible with the presence of water	Ground water quality is at risk	Soil Infiltration Rates			Depth of groundwater or bedrock (m)		No source of continuous flow	Depth of drainage outlet (m)			Surface Slopes (%)		Climate is vulnerable to cold and snowy winters	Surface soils are highly susceptible to erosion	Drainage area is less than 5.0 ha or space is limited
						Surface inf < 13 mm/hr	Surface inf < 60 mm/hr	Sub-surf inf < 2.5 mm/hr	< 1.5	1.5 - 4.0		< 1.0	1.0 - 2.0	> 2.0	< 1.0	> 5.0			
				☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐
1	1	1	Street curbs																
2	0.5	1	~~Roads with [illegible] crossslopes~~														~~O_8~~		
3	0.5	1	~~Porous pavement with storage structure~~														~~O_8~~	~~X~~	
4	0	1	~~[illegible]~~	~~X~~	~~X~~			~~X~~	~~X~~							~~O_6~~	~~O_{14}~~	~~X~~	
5	1	1	Storm sewers with foundation drain connections									X	X						
6	1	1	Shallow storm sewers with sump pumps									X	O_{17}						
7	1	1	Roadside ditches with culverts									O_4	O_3		O_5	O_6	O_7	O_{10}	
8	1	1	Shallow ditches or swales (no culverts)			O_{18}										O_6		O_{10}	
9	0	1	~~Shallow perforated pipe [illegible] system~~	~~X~~	~~X~~			~~X~~	~~X~~	~~O_1~~		~~O_{15}~~	~~O_{15}~~			~~O_6~~		~~O_{10}~~	
10	0	1	~~Deep perforated pipe [illegible] system~~	~~X~~	~~O_{16}~~			~~X~~	~~X~~	~~O_1~~		~~O_{15}~~	~~O_{15}~~			~~O_6~~		~~O_{10}~~	
11	1	1	Deep perforated pipe filtration system						X	O_1		X	X						
12	0.5	1	~~Raised culverts~~	~~O_{11}~~	~~X~~	~~X~~						~~X~~	~~O_3~~			~~O_6~~	~~O_8~~	~~O_{10}~~	
13	0.5	1	~~Dipped driveways~~	~~O_{11}~~	~~X~~	~~X~~										~~O_6~~	~~O_8~~		
14	0.5	1	~~Check dams~~	~~O_{11}~~	~~X~~	~~X~~										~~O_6~~	~~O_8~~	~~O_{10}~~	
15	1	1	Oil and Grit separators									X	X						
16	1	1	Greenbelts and backyard swales		O_{12}										O_5	O_6		O_{10}	
17	0	1	~~Horizontal [illegible] trenches~~	~~X~~	~~O_{16}~~			~~X~~	~~X~~	~~O_1~~						~~O_6~~		~~O_{10}~~	
18	0	1	~~Vertical [illegible]~~	~~X~~	~~O_{16}~~			~~X~~	~~X~~	~~X~~								~~O_{10}~~	
19	1	1	Infiltration basins	X	O_{16}	X	X		X	X		X	O_{20}				O_9	O_{10}	X
20	1	1	Wet ponds								O_2	X	O_{20}					O_{10}	X
21	1	1	Dry Ponds		O_{13}							O_{19}	O_{20}					O_{10}	X
22	1	1	Artificial wetlands								O_2						O_9		X
23	1	1	User Defined Feature (ex: Lot level ctls)																
24	1	1	User Defined Feature (ex: Major System)																
25	1	1	User Defined Feature																

Blank - Compatible alternative, gives a score of '1 in Table C

X - Not compatible, gives a score of '0 in Table C

O - May or may not be compatible, gives a score of '0.5 in Table C (see notes for Table A)

The following notes were overriden by the user 7, 9.

Table A Notes

To be used to further evaluate the compatibility of drainage features with site characteristics.

Note #	Check Caution	Override Caution	Notes for Table A
1		☐	Not recommended when the distance between the bottom of the infiltration structure and the groundwater table (or bedrock) is less than 1.0 m.
2		☐	Not recommended if a minimum permanent pool cannot be maintained.
3		☐	Not recommended for situations where water table is less than depth of ditch or where the infiltration rate of surface soils is less than 13 mm/hr.
4		☐	Not recommended if in order to maintain the proper culvert cover, the level of entrances or driveways have to be raised in such a way as to negatively affect the comfort of driving.
5		☐	Should only be considered if surface infiltration rates are greater than 13 mm/hr in order to prevent nuisance surface ponding.
6		☐	The average surface slope should not be the determining factor but rather the slope of the expected structure. For example, even if the average surface slope is above 5%, roads and ditches may be constructed at a less accentuated cross slope. In the case of ditches and swales, such high slopes may easily create conditions for erosion due to high flow velocities. In the case of raised culverts or check dams these would have to be high and frequent to have any positive influence. In the case of infiltration trenches the use of vertical flow barriers may be required to maximize the use of storage.
7	X	☑	Not recommended if ditch is too shallow (< 0.60 m) and poorly drained (slope < 1% or surface infiltration < 13 mm/hr) or if culverts are too small (< 450 mm). The first condition is prone to culvert heaving and the second to ice or snow clogging.
8	X	☐	Not recommended if located in areas where ground surface can freeze for extended periods.
9	X	☑	Not recommended if pollutant removal effectiveness is also required during the winter season.
10		☐	The presence of highly erodible soils or high contents of suspended solids in surface runoff require that pretreatment measures be used to ensure the longevity of any infiltration technique and/or to minimize maintenance requirements.
11		☐	Not recommended if designed amounts of infiltrated runoff exceeds natural conditions.
12		☐	Not recommended if contaminated runoff is expected. Only use in backyards.
13		☐	Not recommended unless bottom of facility is impermeable.
14		☐	Not recommended unless roadbase is free draining and not affected by frost.
15		☐	Not recommended if system is to be connected to an outlet which is shallower than the perforated pipe system.
16		☐	Not recommended unless sufficient pre-treatment can be provided (eg. with oil and grit separators).
17		☐	Not recommended unless sufficient depth cover can be provided for frost protection.
18		☐	Not recommended unless used jointly with another feature that allows proper drainage.
19		☐	Not recommended unless used for major system storage only.
20		☐	May not be feasible is used jointly with conventional storm sewers with foundation drain connections.

Table B: Selection of alternative drainage features based on development characteristics

FEATURE	TABLE A	TABLE B	Drainage Features	Development characteristics											
				Type of landuse			ROW planning					Lot Planning			
				Residential	Commercial	Industrial	[ROW width] - [Road surface Width] - [Sidewalk Width] (m)		Sidewalks next to road	Trees within ROW	Below ground franchise utilities	Spacing between entrances < 5 0 m	Imperviousness > 75%	Back to front drainage	Reverse slope driveways
							< 2 5	2 5 - 5 0							
E	A	B	**Drainage Features**	☑	☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☐
1	1	1	Street curbs												
2	0 5	1	Roads with one-sided cross slopes		X	X									
3	0 5	1	Porous pavement with storage structure			X									
4	0	1	Porous pavement with exfiltration system		O_1	X					O_8				
5	1	1	Storm sewers with foundation drain connections												
6	1	1	Shallow storm sewers with sump pumps												X
7	1	1	Roadside ditches with culverts		O_2		X	O_5	O_{11}			X	O_9		X
8	1	1	Shallow ditches or swales (no culverts)				O_5		O_{11}						
9	0	1	Shallow perforated pipe exfiltration system			O_3	O_5		O_{11}	O_7	O_8		O_9		
10	0	1	Deep perforated pipe exfiltration system			O_3									
11	1	1	Deep perforated pipe filtration system												
12	0 5	1	Raised culverts			O_3	X		O_{11}			X	O_9		X
13	0 5	1	Dipped driveways			X			O_{11}						X
14	0 5	1	Check dams			O_3	X		O_{11}			X	O_9		X
15	1	1	Oil and Grit seperators												
16	1	1	Greenbelts and backyard swales			O_3			O_6				O_9	O_{10}	
17	0	1	Horizontal infiltration / exfiltration trenches			O_3	O_4		O_6	O_7	O_8		O_9		
18	0	1	Vertical exfiltration wells and perforated catchbasins			O_3				O_7	O_8				
19	1	1	Infiltration basins			O_3									
20	1	1	Wet ponds			O_{12}									
21	1	1	Dry Ponds												
22	1	1	Artificial wetlands			O_{12}									
23	1	1	**User Defined Feature (ex: Lot level ctls)**												
24	1	1	**User Defined Feature (ex: Major System)**												
25	1	1	**User Defined Feature**												

Blank - Compatible alternative, gives a score of '1' in Table C
X - Not compatible, gives a score of '0' in Table C
O - May or may not be compatible, gives a score of '0 5' in Table C (see notes for Table B)

The following notes were overriden by the user: 7, 8.

Table B Notes

To be used to further evaluate the compatibility of drainage features with development characteristics.

Note #	Check Caution	Override Caution	Notes for Table B
1		☐	Not recommended if area includes gas stations or other types of activities where toxic chemicals are transported or stored.
2		☐	May not be aesthetically pleasing in highly developed areas.
3		☐	Any infiltration techniques used within an industrial area should be done with extreme care. Gas stations and storage areas for toxic chemicals should not be considered if such techniques are anticipated. Not recommended for use in roadside ditches or swales with extremely permeable soils.
4		☐	Not recommended if sufficient available space is not available to also include buffer strips or adequate pretreatment.
5		☐	Can only be installed on one side of the street.
6		☐	Difficult to incorporate within ROW. Could only be used as lot level control.
7	X	☑	Not recommended unless special techniques such as the use of copper mesh installed around the infiltration structure in order to prevent damage from tree roots. The appropriate selection of trees or adequate distances between planting and infiltration structures may also reduce this potential problem.
8	X	☑	Not recommended if the presence of underground utilities interferes with the use of underground infiltration structures. Proper planning and discussions with the local utilities may address this problem. However, in the case of a retrofit situation, the use of infiltration techniques within the ROW may be more difficult.
9		☐	Not recommended if the the availability of contiguous open space is very limited.
10		☐	Backyard swales cannot be used.
11		☐	Cannot be used if two sidewalks are constructed. If only one sidewalk is constructed then could be used on side without sidewalk.
12		☐	Not recommended unless it is demonstrated that bioaccumulation of pollutants will not create adverse environmental effects.

Table C: Identification of compatible drainage features
(use to compile results from Tables A and B, optional)

Feature	Drainage system features	Compatibility checks (refer to Tables A and B)		
		(A) Site characteristics	(B) Development characteristics	Overall Score (A) x (B)
1	Street curbs	1	1	1
~~2~~	~~Roads with one sided cross slopes~~	~~0.5~~	~~1~~	~~0.5~~
~~3~~	~~Porous pavement with storage structure~~	~~0.5~~	~~1~~	~~0.5~~
~~4~~	~~Porous pavement with exfiltration system~~	~~0~~	~~1~~	~~0~~
5	Storm sewers with foundation drain connections	1	1	1
6	Shallow storm sewers with sump pumps	1	1	1
7	Roadside ditches with culverts	1	1	1
8	Shallow ditches or swales (no culverts)	1	1	1
~~9~~	~~Shallow perforated pipe exfiltration system~~	~~0~~	~~1~~	~~0~~
~~10~~	~~Deep perforated pipe exfiltration system~~	~~0~~	~~1~~	~~0~~
11	Deep perforated pipe filtration system	1	1	1
~~12~~	~~Raised culverts~~	~~0.5~~	~~1~~	~~0.5~~
~~13~~	~~Dipped driveways~~	~~0.5~~	~~1~~	~~0.5~~
~~14~~	~~Check dams~~	~~0.5~~	~~1~~	~~0.5~~
15	Oil and Grit separators	1	1	1
16	Greenbelts and backyard swales	1	1	1
~~17~~	~~Horizontal infiltration trenches~~	~~0~~	~~1~~	~~0~~
~~18~~	~~Vertical exfiltration wells and perforated catchbasins~~	~~0~~	~~1~~	~~0~~
19	Infiltration basins	1	1	1
20	Wet ponds	1	1	1
21	Dry Ponds	1	1	1
22	Artificial wetlands	1	1	1
23	**User Defined Feature (ex: Lot level ctls)**	1	1	1
24	**User Defined Feature (ex: Major System)**	1	1	1
25	**User Defined Feature**	1	1	1

Notes on Overall Score values

Score	Suggestion
1	This drainage feature is potentially compatible with both site and development characteristics
0.5	This drainage feature may be compatible, however a cautionary note was generated for Table A or Table B – See Table A Notes and Table B Notes
0.25	This drainage feature may be compatible, however a cautionary note exists for both Table A and Table B – See Table A Notes and Table B Notes
0	This drainage feature is potentially not compatible with both site and development characteristics

Table CD: Stormwater Management Objectives

Function	Objective Narrative Target	Target (10) Performance	Importance to Project (11)	
			Text	Weight
Groundwater recharge (1) (Infiltration of runoff from a 10 mm storm)	**Infiltrate or reduce flows**	**100%**	Med ▼	2
Erosion control (Control or infiltration of runoff from a 25 mm strom)	**Rate of runoff control for downstream erosion control**	**100%**	High ▼	3
Suspended solids (2)	**Reduce load**	**100%**	Med ▼	2
Phosphorus removal	**Reduce load**	**100%**	Med ▼	2
Bacteria uptake (3)	**Reduce load**	**100%**	Low ▼	1
Oil and grease (4)	**Control**	**100%**	Med ▼	2
Thermal reduction (5)	**Control**	**100%**	Low ▼	1
Flood control (on-site) (6)	**Minor system performance to design storm**	**100%**	Med ▼	2
Flood control (off-site) (7)	**Rate of runoff control for downstream flood control**	**100%**	N/A ▼	0
Major system (8)	**Major system to be considered in design**	**100%**	High ▼	3
Source Controls (9)	**Source controls to be considered in design**	**100%**	High ▼	3

Notes:

1) Infiltrate or reduce annual flow volumes.
2) Use 50 to 80% depending on use in the receiving water.
3) Reduce numbers in discharge.
4) Percent flow through measure.
5) Percent flow through measure.
6) Always assumed as basis for design of all elements.
7) Control of 25 mm storm assumed to control both erosion flooding. Target is percent control for system.
8) Only if needed to be added at additional cost - set weight as 1.
9) Only if performance and cost know - set weight as 1.
10) Numbers shown are for illustration purposes. The user must set targets for each analysis based on subwatershed uses.
11) Importance and and weights (see Config sheet to modify).

Table D: Comparison of SWM Function Potentials

FEATUR	TABLEC	SCEN 1	SCEN 2	SCEN 3	Drainage Features	SWM Function Potentials										
						Ground water recharge (5 (Infiltration of runoff from a to 10 mm storm)	Erosion control (Control or infiltration of runoff from a 25 mm storm)	Quality control				Thermal reduction	Flood control		Major System (3	Social Values (3
								Suspended Solids (1	Phosphorus Removal (1	Bacteria die-off	Oil and grease (2		On-site	Off-site		
1	1	☑	☐	☐	Street curbs	0	0	0	0	0	0	0	1	0		1
2	0 5	☐	☐	☐	~~Roads with one-sided cross slopes~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~		
3	0 5	☐	☐	☐	~~Porous pavement with storage structure~~	~~0~~	~~0.5~~	~~0.8~~	~~0.59~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~		
4	0	☐	☐	☐	~~Porous pavement with infiltration system~~	~~0.95~~	~~1~~	~~0.9~~	~~0.88~~	~~0.70~~	~~0~~	~~1~~	~~0~~	~~0~~		
5	1	☑	☐	☐	Storm sewers with foundation drain connections	0	0	0	0	0	0	1	1	1 (*		
6	1	☐	☐	☐	Shallow storm sewers with sump pumps	0.1 (-	0	0.08	0.08	0.08	0	1	1	1 (*		
7	1	☐	☑	☐	Roadside ditches with culverts	0.4	0.25	0.86	0.68	0.32	0	0.25	1	1 (		0.5
8	1	☐	☐	☑	Shallow ditches or swales (no culverts)	0.8	0.5	0.93	0.83	0.64	0	0	0	0		1
9	0	☐	☐	☐	~~Shallow perforated pipe infiltration system~~	~~0.95~~	~~1~~	~~0.95~~	~~0.89~~	~~0.70~~	~~0~~	~~1~~	~~1~~	~~1 (*~~		
10	0	☐	☐	☐	~~Deep perforated pipe infiltration system~~	~~0.95~~	~~1~~	~~0.81~~	~~0.79~~	~~0.70~~	~~0~~	~~1~~	~~1~~	~~1 (~~		
11	1	☑	☐	☐	Deep perforated pipe filtration system	0.1	0.5	0.45	0.33	0.08	0	1	1	1 (*		
12	0 5	☐	☐	☐	~~Raised culverts~~	~~0.1~~	~~0.05~~	~~0.96~~	~~0.20~~	~~0.08~~	~~0~~	~~0~~	~~1~~	~~1 +~~		
13	0 5	☐	☐	☐	~~Dipped driveways~~	~~0.1~~	~~0.05~~	~~0.22~~	~~0.17~~	~~0.08~~	~~0~~	~~0~~	~~0~~	~~0~~		
14	0 5	☐	☐	☐	~~Checkdams~~	~~0.45~~	~~0.4~~	~~0.98~~	~~0.3~~	~~0.42~~	~~0~~	~~0~~	~~0~~	~~0~~		
15	1	☑	☐	☐	Oil and Grit seperators	0	0	0.6	0.4	0	1	0	0	0		0.5
16	1	☐	☐	☑	Greenbelts and backyard swales	0.8	0.5	0.86	0.78	0.64	0	0.5	0.5	0		0.5
17	0	☐	☐	☐	~~Horizontal infiltration trenches~~	~~0.8~~	~~1~~	~~0.86~~	~~0.78~~	~~0.64~~	~~0~~	~~1~~	~~0~~	~~0~~		
18	0	☐	☐	☐	~~Vertical infiltration wells and perforated catch basins~~	~~0.8~~	~~1~~	~~0.88~~	~~0.70~~	~~0.64~~	~~0~~	~~1~~	~~0~~	~~0~~		
19	1	☐	☐	☐	Infiltration basins	0.8	0.5	0.82	0.76	0.64	0	0.5	0	0		
20	1	☐	☐	☐	Wet ponds	0	1	0.75	0.5	0.75	1 (+)	0	0	1		1
21	1	☐	☑	☐	Dry Ponds	0	1	0.5	0.33	0.7	0	0	0	1		1
22	1	☑	☐	☐	Artificial wetlands	0	0.75	0.4	0.4	0.5	0	0	0	1		1
23	1	☐	☐	☐	**User Defined Feature (ex: Lot level ctls)**											
24	1	☐	☐	☐	**User Defined Feature (ex: Major System)**											
25	1	☐	☐	☐	**User Defined Feature**											

Notes: +) If equipped with appropriate booms.

-) Only if pumps discharge to backyards or onto a grass area.

*) Only if system has inlet control devices and storage on street is permitted.

) Only if ditches / swales are deep enough to provide adequate storage.

1) Values shown are combined efficiency of removal from infiltration and other processes such as sedimentation

2) While most devices will remove some oil and grease, only those with specific design features for this have been given values.

3) Values for "Major System" and "Social" benefits must be entered by user.

4) Values for "User Defined Features" must be entered by user if applied

5) Groundwater recharge values shown in relation to infiltration of 10 mm storms or less, which represents approximately 80% of annual volume. Total performance for measures with infiltration has been adjusted to reflect annual performance due to infiltration.

Table E: Comparison of conceptual drainage systems - Scenario 1
(working table)

Total drainage area (ha):	10	Cost of this system	$2,554,311.51 (from "Cost Comparisons" table)
Total Percentage of Impervious Area	40.0%		

Description of potential alternative drainage system:

NOTE: To clear the Costs Table, first
clear Table E and Click on Costs Table

	Selected Drainage Features	Area (1 serviced by feature (ha)	Drainage System Objectives and Compliance (refer to Table D) Ground water	Erosion control	Suspended solids	Phosphorus removal	Bacteria up-take	Oil and grease	Thermal reduction	Flood control	Major system	Social values	Feature Benefit Index
1	Street curbs	10	0	0	0	0	0	0	0	1	0	1	2
5	Storm sewers with foundation drain connections	10	0	0	0	0	0	0	1	1	0	0	2
11	Deep perforated pipe filtration system	10	0.1	0.5	0.45	0.33	0.08	0	1	1	0	0	3.46
15	Oil and Grit separators	10	0	0	0.6	0.4	0	1	0	0	0	0.5	2.5
22	Artificial wetlands	10	0	0.75	0.4	0.4	0.5	0	0	0	0	1	3.05
☑ Use multi-efficiency model ;	**System Efficiency**	→	**0.10**	**0.88**	**0.87**	**0.76**	**0.54**	**1.00**	**1.00**	**1.00**	**0.00**	**1.00**	**7.14**
	Target Performance (from Table CD)	→	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
	System Compliance	→	**0.10**	**0.88**	**0.87**	**0.76**	**0.54**	**1.00**	**1.00**	**1.00**	**0.00**	**1.00**	**0.71**
	Objectives Priority Weighting (from Table CD)	→	**2**	**3**	**2**	**2**	**1**	**2**	**1**	**2**	**3**	**3**	
	Weighted Compliance as per SWM Priorities	→	**0.20**	**2.63**	**1.74**	**1.52**	**0.54**	**2.00**	**1.00**	**2.00**	**0.00**	**3.00**	**14.62**

Total Feature Benefit Index	7.14	The sum of each Drainage Feature Benefit Index
Average System Compliance	0.71	The average of each objective's System Compliance
Overall Score	14.62	The sum of Weighted Compliance as per SWM Priorities

NOTES: 1) Areas associated to any feature must be less than or equal to the Total Drainage area
2) The System Compliance must be recalculated when the areas associated to Drainage Feature are modified
To do this, "click" twice on the "Use multi-efficiency model" CheckBox next

Table E: Comparison of conceptual drainage systems - Scenario 2
(working table)

Total drainage area (ha)	10	Cost of this system	$862,123.38 (from "Cost Comparisons" table)
Total Percentage of Impervious Area	40.0%		

Description of potential alternative drainage system

NOTE To clear the Costs Table, first clear Table E and Click on Costs Table

	Selected Drainage Features	Area serviced by feature (ha)	Drainage System Objectives and Compliance (refer to Table D)										Feature Benefit Index
			Ground water	Erosion control	Suspended solids	Phosphorus removal	Bacteria up-take	Oil and grease	Thermal reduction	Flood control	Major system	Social values	
7	Roadside ditches with culverts	10	0.4	0.25	0.86	0.68	0.32	0	0.25	1	0	0.5	4.26
21	Dry Ponds	10	0	1	0.5	0.33	0.7	0	0	0	0	1	3.53
☑ Use multi-efficiency model	**System Efficiency**	→	**0.40**	**1.00**	**0.93**	**0.79**	**0.80**	**0.00**	**0.25**	**1.00**	**0.00**	**1.00**	**6.16**
	Target Performance (from Table CD)	→	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
	System Compliance	→	**0.40**	**1.00**	**0.93**	**0.79**	**0.80**	**0.00**	**0.25**	**1.00**	**0.00**	**1.00**	**0.62**
	Objectives Priority Weighting (from Table CD)	→	**2**	**3**	**2**	**2**	**1**	**2**	**1**	**2**	**3**	**3**	
	Weighted Compliance as per SWM Priorities	→	**0.80**	**3.00**	**1.86**	**1.57**	**0.80**	**0.00**	**0.25**	**2.00**	**0.00**	**3.00**	**13.28**

Total Feature Benefit Index	6.16	The sum of each Drainage Feature Benefit Index
Average System Compliance	0.62	The average of each objective's System Compliance
Overall Score	13.28	The sum of Weighted Compliance as per SWM Priorities

NOTES: 1) Areas associated to any feature must be less than or equal to the Total Drainage area.
2) The System Compliance must be recalculated when the areas associated to Drainage Feature are modified.
To do this, "click" twice on the "Use multi-efficiency model" CheckBox next.

Table E: Comparison of conceptual drainage systems - Scenario 3
(working table)

Total drainage area (ha)	10	Cost of this system	$662,655.27	(from "Cost Comparisons" table)
Total Percentage of Impervious Area	40.0%			

Description of potential alternative drainage system

NOTE: To clear the Costs Table, first
clear Table E and Click on Costs Table

	Selected Drainage Features	Area serviced by feature (ha)	Drainage System Objectives and Compliance (refer to Table D)										Feature Benefit Index
			Ground water	Erosion control	Suspended solids	Phosphorus removal	Bacteria up-take	Oil and grease	Thermal reduction	Flood control	Major system	Social values	
8	Shallow ditches or swales (no culverts)	10	0.8	0.5	0.93	0.83	0.64	0	0	0	0	1	4.7
16	Greenbelts and backyard swales	10	0.8	0.5	0.86	0.78	0.64	0	0.5	0.5	0	0.5	5.08
☑ Use multi-efficiency model	**System Efficiency**	→	**0.96**	**0.75**	**0.99**	**0.96**	**0.87**	**0.00**	**0.50**	**0.50**	**0.00**	**1.00**	**6.53**
	Target Performance (from Table CD)	→	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	
	System Compliance	→	**0.96**	**0.75**	**0.99**	**0.96**	**0.87**	**0.00**	**0.50**	**0.50**	**0.00**	**1.00**	**0.65**
	Objectives Priority Weighting (from Table CD)	→	**2**	**3**	**2**	**2**	**1**	**2**	**1**	**2**	**3**	**3**	
	Weighted Compliance as per SWM Priorities	→	**1.92**	**2.25**	**1.98**	**1.93**	**0.87**	**0.00**	**0.50**	**1.00**	**0.00**	**3.00**	**13.45**

Total Feature Benefit Index	6.53	The sum of each Drainage Feature Benefit Index
Average System Compliance	0.65	The average of each objective's System Compliance
Overall Score	13.45	The sum of Weighted Compliance as per SWM Priorities

NOTES: 1) Areas associated to any feature must be less than or equal to the Total Drainage area
2) The System Compliance must be recalculated when the areas associated to Drainage Feature are modified.
To do this, "click" twice on the "Use multi efficiency model" CheckBox next.

Table 10.1: Capital, Annualized and Total Present Value Costs

(assumes that rock excavation is not required)

Discounted Rate = 7% Life cycle (yrs) 80

Road Drainage System Components		Capital costs Construction / Replacement					Maintenance activities and related cost					TOTAL PRESENT VALUE COST
		Construction or replacement cost	Longevity (yrs)	Amortized capital cost	Annual repair costs	Present Value capital and repair costs	Activity (refer to Table 10.2 for descriptions)			Total Annual maintenance cost	Present Value annual maint. cost	
Road Surfaces *	with curbs	$311.00 /m	40	$23.33 /m	n/a	$331.77 /m	1	2		$0.55 /m	$7.82	$339.59 /m
(with curbs w = 8.5 m)	with ditches or swales (w/o subdrains)	$346.00 /m	20	$32.66 /m	n/a	$464.49 /m	1	3		$0.60 /m	$8.53	$473.02 /m
(others, w = 7.5 m + shldr)	with ditches or swales (w/ subdrains)	$348.00 /m	40	$25.95 /m	n/a	$369.11 /m	1	3		$0.60 /m	$8.53	$377.64 /m
Subdrains 100mm diam		$20.00 /m	40	$1.50 /m	n/a	$21.34 /m	n/a			$0.00 /m	$0.00	$21.34 /m
Curbs (one side only)		$45.00 /m	20	$4.25 /m	$0.27 /m	$64.25 /m	n/a			$0.00 /m	$0.00	$64.25 /m
Cubs and gutter (one side only)		$60.00 /m	20	$5.66 /m	$0.27 /m	$84.39 /m	n/a			$0.00 /m	$0.00	$84.39 /m
Manholes	installed on street	$3,300.00 /ea	40	$247.53 /ea	$12.00 /ea	$3,691.04 /ea	8a			$5.00 /ea	$71.11	$3,762.15 /ea
	installed off traffic areas	$3,300.00 /ea	80	$232.03 /ea	$3.00 /ea	$3,342.67 /ea	8b			$2.36 /ea	$33.55	$3,376.22 /ea
Regular Catch Basins	installed on street	$1,400.00 /ea	40	$105.01 /ea	$12.00 /ea	$1,664.16 /ea	8a			$5.00 /ea	$71.11	$1,735.27 /ea
	installed off traffic areas	$1,400.00 /ea	80	$98.44 /ea	$3.00 /ea	$1,442.67 /ea	8b			$2.36 /ea	$33.55	$1,476.22 /ea
Corrugated steel catch basins with 12" grate		$550.00 /ea	40	$41.26 /ea	n/a	$586.73 /ea	8b			$2.30 /ea	$32.75	$619.48 /ea
Storm sewers	(typ 450mm)	$480.00 /m	40	$36.00 /m	$0.27 /m	$515.89 /m	n/a			$0.00 /m	$0.00	$515.89 /m
Multiple pipe exfiltration system		$1,000.00 /m	40	$75.01 /m	$0.14 /m	$1,068.77 /m	15b			$0.31 /m	$4.43	$1,073.20 /m
Ditches	(one side of road)	$45.00 /m	20	$4.25 /m	n/a	$60.41 /m	5			$0.29 /m	$4.09	$64.51 /m
Grass swales	(one side of road)	$36.00 /m	20	$3.40 /m	n/a	$48.33 /m	4			$0.30 /m	$4.27	$52.60 /m
Roadside topsoil and grass	(one side of road)	$36.00 /m	20	$3.40 /m	n/a	$48.33 /m	n/a			$0.00 /m	$0.00	$48.33 /m
Culverts	(typ 450mm)	$700.00 /ea	20	$66.08 /ea	$3.80 /ea	$993.78 /ea	7			$5.00 /ea	$71.11	$1,064.87 /ea
Check dams		$300.00 /ea	10	$42.71 /ea	n/a	$607.47 /ea	??			$0.00 /ea	$0.00	$607.47 /ea
Perforated pipes (including granular	no pre-treatment	$175.00 /m	40	$13.13 /m	$0.14 /m	$188.68 /m	15b			$0.31 /m	$4.43	$193.10 /m
material and geotextile)	with pre-treatment	$175.00 /m	40	$13.13 /m	$0.14 /m	$188.68 /m	15d			$0.06 /m	$0.90	$189.58 /m
House sump pumps		$200.00 /ea	10	$28.48 /ea	n/a	$404.98 /ea	n/a			$0.00 /ea	$0.00	$404.98 /ea
Outfall and Erosion control		$10,000.00 /ea	20	$943.91 /ea	n/a	$13,424.57 /ea	10a if at end of curb & gutter			$500.00 /ea	$7,111.00	$7,111.00 /ea
							10b if at end of ditch or swales			$134.50 /ea	$1,912.82	$1,912.82 /ea
							10c if system retains 25mm runoff			$68.74 /ea	$977.57	$977.57 /ea
Dry ponds	40% imperviousness	$20,000.00 /10 ha	40	$150.02 /1 ha $1.50 /m	n/a	$2,133.56 /1 ha $21.34 /m	12	13		$336.28 /1 ha $3.36 /m	$4,782.51	$6,918.07 /1 ha* $69.16 /m
Wet ponds	40% imperviousness	$30,000.00 /10 ha	40	$225.03 /1 ha $2.25 /m	n/a	$3,200.34 /1 ha $32.00 /m	11	13		$396.28 /1 ha $3.96 /m	$5,635.83	$8,836.17 /1 ha* $88.36 /m
Artificial wetlands	40% imperviousness	$35,000.00 /10 ha	40	$262.53 /1 ha $2.63 /m	n/a	$3,733.73 /1 ha $37.34 /m	11	13		$396.28 /1 ha $3.96 /m	$5,635.83	$9,369.56 /1 ha* $93.70 /m
Infiltration Basin	40% imperviousness	$25,000.00 /10 ha	40	$187.52 /1 ha $1.88 /m	n/a	$2,666.95 /1 ha $26.67 /m	12	13	14	$400.75 /1 ha $4.01 /m	$5,699.48	$8,366.43 /1 ha* $83.66 /m
Water quality inlets Oil and grit separators**	40% imperviousness	$5,520.00 /1 ha ($13,800 /ha imp)	40	$414.05 /1 ha $4.14 /m	$4.80 /1 ha ($12/unit/ha imp)	$5,956.89 /1 ha $59.57 /m	9			$500.00 /1 ha $5.00 /m	$7,111.00	$13,067.90 /1 ha $130.68 /m
Infiltration trenches	40% imperviousness	$20,000.00 /1 ha	10	$2,847.55 /1 ha $28.48 /m	n/a	$40,497.87 /1 ha $404.98 /m	16			$277.50 /m'	$3,946.61	$44,444.48 /1 ha
Exfiltration wells	40% imperviousness	$62,500.00 /1 ha	10	$8,898.59 /1 ha $88.99 /m	n/a	$126,555.85 /1 ha $1,265.58 /m	17			$3,100.00 /1 ha	$44,068.22	$170,644.07 /1 ha

Notes:

Conversions from (ha) to (m) are based on the assumption of a typical street ROW of 20 m and 40 m deep lots

*) Total amortized cost does not include land value and potential losses in tax revenues

**) Costing information provided by *Stormceptor*

+) Does not include the cost of the curbs or subdrains

Costs are in 1996 dollars and represent averages. Actual costs may vary between municipalities

Amortized capital cost is at the given discounted rate (7%) over the longevity period

- Annual costs for activities done less than once per year have been determined by a two step calculation
  1. Present value at the discounted rate is determined over the maintenance period
  2. Amortized cost are then calculated over the maintenance period at discount rate of 7%
  3. For activities which are done only once in the lifetime of the device
     the cost is amortized over the entire life = 2X the maintenance period

Table 10.2: Maintenance Activities and Associated Costs

Item	Maintenance Activity			Average Cost per unit	Frequency per year
1	Street Flushing (both sides)			$0.10 /m	2
2	Street sweeping (only for roads with curbs) (both sides)			$0.07 /m	5
3	Shoulder and edge treatment (both sides)			$0.20 /m	2
4	Grass cutting and repairs			$0.30 /m	1
5	Ditch regrading and cleaning (both sides)			$6.00 /m	0.1
6	Swale regrading, sod and topsoil			/m	
7	Culvert thawing and winter drainage ($500 per 100 units)			$5.00 /ea	1
8a	Catch basin cleaning	installed on street		$5.00 /ea	1
8b		installed off street (w/ pre-treatment)		$5.00 /ea	0.5
9	Oil and grit separator cleaning ($250) + disposal ($250) actual cost depends on the number of units being cleaned out at a given time			$500.00 /ea	1
10a	Outfall maintenance	from conventional C&G system		$500.00 /ea	1
10b		from ditch or grass swale system		$500.00 /ea	0.33
10c		if system retains 25mm rainfall		$500.00 /ea	0.2
11	Wet pond maintenance	grass cutting, litter pickup, weed control, re-planting		$390.00 /1 ha drainage area	1
12	Dry pond maintenance	grass cutting, litter pickup, weed control, re-planting		$330.00 /1 ha drainage area	1
13	Sediment removal from end of pipe facilities including disposal	40 % imperviousness (Annual Loading = 0.925m^3/ha)		$323.75 /1 ha	0.05
14	Infiltration basin maintenance	tiling and re-vegitation		$140.00 /1 ha drainage area	0.5
15a	Pervious pipe maintenance	no pre-treatment	flushing	$1.00 /m	0.2
15b			radial washing	$2.00 /m	0.2
15c	Pervious pipe maintenance	with pre-treatment	flushing	$1.00 /m	0.07
15d			radial washing	$2.00 /m	0.07
16	Infiltration trench maintenance (1.5 m deep, control runoff from 25mm runoff @ 40% imp)			$277.50 /1 ha	1
17	Exfiltration wells (assume 3.2 exfiltration wells per hectare for 40% imperviousness)			$3,100.00 /1 ha	1
18	**User Defined Maintenance Activity**				
19	**User Defined Maintenance Activity**				
20	**User Defined Maintenance Activity**				

Notes:
- Conversions from (ha) to (m) are based on the assumption of a typical street ROW of 20 m and 40 m deep lots.
- Costs are in 1996 dollars and represent averages of collected information.
- Actual unit costs may vary between municipalities.
- Frequency of maintenance activities should also be adjusted accordingly.

Cost Comparison Table

System Components		Cost Per Unit		Scenario 1			Scenario 2			Scenario 3			Scenario 4		
				Required	Units	Item Cost	Required	Units	Item Cost	Required	Units	Item Cost	Required	Units	Item Cost
Road Surfaces***	with curbs	$339 59	/m	1000	/m	$339 590 8		/m			/m			/m	
(with curbs, w = 8.5 m)	with ditches or swales (w/o subdrains)	$473 02	/m		/m			/m			/m			/m	
(others, w = 7.5 m + shldr)	with ditches or swales (w/ subdrains)	$377 84	/m		/m		1000	/m	$377,639 22	1000	/m	$377,639 22		/m	
Subdrains 100mm diam		$21 34	/m	2000	/m	$42 671 22	2000	/m	$42 671 22	2000	/m	$42,671 22		/m	
Street Curbs (one side only)		$64 25	/m		/m			/m			/m			/m	
Street Curbs and gutter (one side only)		$84 39	/m	2000	/m	$168 774 64		/m			/m			/m	
Manholes	installed on street	$3 762 15	/ea	10	/ea	$37 621 49		/ea			/ea			/ea	
	installed off traffic areas	$3 376 22	/ea		/ea			/ea			/ea			/ea	
Regular Catch Basins	installed on street	$1 735 27	/ea	32	/ea	$55 528 57		/ea			/ea			/ea	
	installed off traffic areas	$1 476 22	/ea		/ea			/ea			/ea			/ea	
Corrugated steel catch basins with 12" grate		$619 48	/ea		/ea			/ea			/ea			/ea	
Storm sewers (typ 450mm)		$515 89	/m	1000	/m	$515 894 52		/m			/m			/m	
Multiple pipe exfiltration system		$1 073 20	/m	1000	/m	$1 073 198 77		/m			/m			/m	
Ditches (one side of road)		$64 51	/m		/m		2000	/m	$129,010 13		/m			/m	
Grass swales (one side of road)		$52 60	/m		/m			/m		2000	/m	$105,190 09		/m	
Roadside topsoil and grass (one side of road)		$48 33	/m	2000	/m	$96 656 88	2000	/m	$96,656 88	2000	/m	$96 656 88		/m	
Culverts (typ 450mm)		$1 084 87	/ea		/ea		100	/ea	$108,487 33		/ea			/ea	
Check dams		$807 47	/ea		/ea			/ea			/ea			/ea	
Perforated pipes (including granular	no pre treatment	$193 10	/m		/m			/m			/m			/m	
material and geotextile)	with pre treatment	$189 58	/m		/m			/m			/m			/m	
House sump pumps		$404 96	/ea		/ea		100	/ea	$40 497 87	100	/ea	$40 497 87		/ea	
Outfall and Erosion control	Curb and Gutter	$7 111 00	/ea		/ea			/ea			/ea			/ea	
	Ditch and Swale	$1 912 82	/ea		/ea			/ea			/ea			/ea	
	if system retains 25mm runoff	$977 57	/ea		/ea			/ea			/ea			/ea	
Dry ponds	40% imperviousness**	$6 916 07	/1 ha*		/1 ha*		10	/1 ha*	$69 160 73		/1 ha*			/1 ha*	
		$69 16	/m		/m			/m			/m			/m	
Wet ponds	40% imperviousness**	$8 836 17	/1 ha*		/1 ha*			/1 ha*			/1 ha*			/1 ha*	
		$88 36	/m		/m			/m			/m			/m	
Artificial wetlands	40% imperviousness**	$9 369 56	/1 ha*	10	/1 ha*	$93 695 64		/1 ha*			/1 ha*			/1 ha*	
		$93 70	/m		/m			/m			/m			/m	
Infiltration Basin	40% imperviousness**	$8 366 43	/1 ha*		/1 ha*			/1 ha*			/1 ha*			/1 ha*	
		$83 66	/m		/m			/m			/m			/m	
Water quality inlets Oil and grit separators	40% imperviousness**	$13 067 90	/1 ha	10	/1 ha	$130,678 96		/1 ha			/1 ha			/1 ha	
		$130 68	/m		/m			/m			/m			/m	
Infiltration trenches	40% imperviousness**	$44,444 48	/1 ha		/1 ha			/1 ha			/1 ha			/1 ha	
Exfiltration wells	40% imperviousness**	$170 844 07	/1 ha		/1 ha			/1 ha			/1 ha			/1 ha	
TOTAL COST (Present Value)						$2,554,311.51			$862,123.38			$662,655.27			$0.00

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
DRAINAGE SYSTEM OVERALL SCORE (FROM TABLE E)	14.62	13.28	13.45	N/A
COST / OVERALL SCORE	$174,730.24	$64,932.62	$49,282.71	N/A

Notes:

Total costs are based on "average" of collected information Actual costs may vary between municipalities

*) Cost does not include land value and potential losses in tax revenues

**) Cost are approximated linearly for imperviousness ratios other than 40%

All costs are presented as present value of all capital, operation and maintenance activities undertaken over 80 years using a discount rate of 7%