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Integrated stormwater management for land-restricted lakeside villages

By:
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Integrated stormwater management for land-restricted lakeside villages

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Abstract

Many semi-urbanized lakeside villages are facing the problem of surface water quality deterioration owing to uncontrolled discharge of stormwater or the interaction of onsite wastewater disposal systems with the surface water. Traditional stormwater BMPs (Best Management Practices) such as large-scale detention ponds may not be feasible solutions for these villages, due to their small size and limited resources. The current study investigates the potential of lot-level stormwater BMPs for land-restricted lakeside villages. Rear yard ponding, wherein roof runoff is removed by evaporation and infiltration, is being investigated in a typical lakeside village in Portland, Ontario. HEC-HMS is used to estimate the optimum baseline storage of stormwater for the existing drainage basin. The quantitative effectiveness of rear yard ponding can be obtained by comparing the integrated onsite storage provided by all applicable lots in the village to the baseline storage. The movement of phosphorus is also being monitored at a typical lot to investigate the potential of enhanced flushing of subsurface wastewater effluent by ponded stormwater.

NWRI RESEARCH SUMMARY

Plain language title

On-site management of stormwater in semi-urbanized lakeside villages

What is the problem and what do scientists already know about it?

In many semi-urbanized lakeside villages, deteriorating surface water quality results from uncontrolled discharges of stormwater, or the interference of stormwater with subsurface wastewater disposal systems. Traditional community-based solutions to stormwater management by stormwater ponds or similar facilities are not feasible because of low density of development and high associated costs. Thus, it is required to search for on-site solutions to environmentally safe stormwater disposal.

Why did NWRI do this study?

This study is a part of the long-term co-operative research project on stormwater management conducted by NWRI and Queen's University, Kingston, Ontario. This project examines urban stormwater impacts on receiving waters and develops means of impact mitigation by best management practices (BMPs).

What were the results?

Early results indicate that traditional stormwater BMPs are infeasible, because of land availability restrictions. Consequently, remedial measures need to focus on on-lot controls, and backyard ponding in particular. Ongoing investigations examine the risk of stormwater interference with wastewater septic tank drainage fields.

How will these results be used?

The results will be used by the lakeside village in Portland (Centre for Sustainable Watershed, Portland, Ontario) and in other similar developments for addressing stormwater and surface water quality problems.

Who were our main partners in the study?

The main partners were the Department of Civil Engineering, Queen's University, Kingston, Ontario and the Centre for Sustainable Watersheds, Portland, Ontario.

Gestion intégrée des eaux de ruissellement dans les villages possédant peu de terrain situés au bord d'un lac

Ng, J., B.C. Anderson, J. Marsalek, W.E. Watt et S. Rosolen

Résumé

Un grand nombre de villages semi-urbanisé aménagés au bord d'un lac sont confrontés au problème de la dégradation de la qualité des eaux de surface attribuable au rejet incontrôlé des eaux de ruissellement ou à l'interaction des systèmes d'élimination des eaux usées sur place avec les eaux de surface. Or, les pratiques de gestion optimales (PGO) classiques, comme l'aménagement de vastes bassins de retenue, ne sont parfois pas applicables dans ces villages disposant de peu de terrains et de peu de ressources. La présente étude examine le potentiel que présente les PGO faisant appel au stockage des eaux de ruissellement au niveau des parcelles dans ces villages. Le stockage dans la cour arrière des maisons cours, qui permet d'éliminer les eaux de ruissellement des toitures par évaporation et infiltration, fait l'objet d'une évaluation dans un village de bord de lac typique à Portland, en Ontario. On utilise le modèle HEC-HMS pour estimer le stockage de base optimal des eaux de ruissellement pour le bassin hydrographique. On peut déterminer l'efficacité quantitative du stockage dans les cours en comparant le stockage sur place intégré dans toutes les parcelles du village qui s'y prêtent au stockage de base. On suit également les déplacements du phosphore dans une parcelle typique dans le but de déterminer le potentiel d'une meilleure évacuation des eaux usées souterraines par les eaux de ruissellement stockées en bassin.

Sommaire des recherches de l'INRE

Titre en langage clair

Gestion sur place des eaux de ruissellement dans des villages semi-urbanisés aménagés au bord d'un lac.

Quel est le problème et que savent les chercheurs à ce sujet?

Dans un grand nombre de villages semi-urbanisés aménagés au bord d'un lac, le rejet incontrôlé des eaux de ruissellement ou l'interaction des systèmes d'élimination des eaux usées sur place avec les eaux de surface entraînent une dégradation de la qualité des eaux de surface. Les solutions classiques axées sur la communauté, qui consistent à stocker les eaux de ruissellement dans des bassins ou dans des installations similaires, ne sont pas applicables dans ces village à cause de la faible densité du développement et de leurs coûts élevés. Il faut dont trouver d'autres solutions mieux adaptées pour l'élimination sûre des eaux de ruissellement dans ces villages.

Pourquoi l'INRE a-t-il effectué cette étude?

Cette étude s'inscrit dans le cadre d'un projet de recherche en collaboration à long terme sur la gestion des eaux de ruissellement menée par l'INRE et l'Université Queen de Kingston, en Ontario. Ce projet étudie l'impact des eaux de ruissellement urbaines sur les eaux réceptrices, et élabore des méthodes d'atténuation faisant appel à des pratiques de gestion optimales (PGO).

Quels sont les résultats?

D'après les premiers résultats obtenus, il semble que les PGO classiques relatives aux eaux de ruissellement ne peuvent être appliquées à cause du manque d'espace. Par conséquent, les mesures d'atténuation doivent mettre l'action sur les dispositifs aménagés dans les parcelles, et notamment sur le stockage dans les cours des maisons. Les recherches en cours examinent le risque d'une interférence des eaux de ruissellement avec les eaux usées des champs d'épuration de fosses septiques.

Comment ces résultats seront-ils utilisés?

Les résultats seront utilisés par les autorités du village riverain de Portland (Centre for Sustainable Watershed, Portland, Ontario) et d'autres aménagements similaires à régler les problèmes de qualité des eaux de ruissellement et des eaux de surface.

Quels étaient nos principaux partenaires dans cette étude?

Les principaux partenaires sont le département de génie civil de l'Université Queen, de Kingston en Ontario, et le Centre for Sustainable Watersheds, de Portland, en Ontario.

1[st] Water and Environment Specialty Conference of the Canadian Society for Civil Engineering
1[re] Conférence spécialisée sur l'eau et l'environnement de la Société canadienne de génie civil

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INTEGRATED STORMWATER MANAGEMENT FOR LAND-RESTRICTED LAKESIDE VILLAGES

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ABSTRACT: Many semi-urbanized lakeside villages are facing the problem of surface water quality deterioration owing to uncontrolled discharge of stormwater or the interaction of onsite wastewater disposal systems with the surface water. Traditional stormwater BMPs (Best Management Practices) such as large-scale detention ponds may not be feasible solutions for these villages, due to their small size and limited resources. The current study investigates the potential of lot-level stormwater BMPs for land-restricted lakeside villages. Rear yard ponding, wherein roof runoff is removed by evaporation and infiltration, is being investigated in a typical lakeside village in Portland, Ontario. *HEC-HMS* is used to estimate the optimum baseline storage of stormwater for the existing drainage basin. The quantitative effectiveness of rear yard ponding can be obtained by comparing the integrated onsite storage provided by all applicable lots in the village to the baseline storage. The movement of phosphorus is also being monitored at a typical lot to investigate the potential of enhanced flushing of subsurface wastewater effluent by ponded stormwater.

1. INTRODUCTION

A growing concern for many semi-urbanized lakeside villages is deteriorating surface water quality as a result of uncontrolled discharge of stormwater or the interaction of subsurface wastewater disposal systems with surface water. These villages typically lack proper means of stormwater management owing to their small size, resident population and tax-base. In general, a significant portion of annual income for these lakeside villages comes from water-based recreation and tourism, and hence, it is essential for these villages to protect surface water quality to benefit the economy as well as the environment. Traditional communal stormwater BMPs (Best Management Practices), for example, retention and detention ponds, are generally too costly and land-intensive to be applied in these small villages. For that reason, low-impact stormwater BMPs which promote lot-level/decentralized systems (e.g. rainwater garden, rear yard ponding) could be a more affordable and sustainable solution in lakeside villages, provided that the solution(s) is(are) compatible with the traditional onsite water supply and wastewater disposal systems, and maximum groundwater recharge potential. Low-impact stormwater BMPs may not only help to solve the addressed issues, but also to minimize other environmental concerns associated with traditional communal stormwater treatment such as thermal enhancement of the receiving water and loss of groundwater recharge.

In the current research, the feasibility of low-impact stormwater BMPs is being investigated in the village of Portland, Ontario, a typical lakeside village on the Rideau Lake system with a significant tourism base. The village is served by onsite water supply and wastewater disposal systems, and a simple storm sewer network that discharges runoff into Rideau Lake without any treatment. The village is of interest in controlling stormwater discharges owing to the potential of localized eutrophication and possible connection between untreated stormwater loadings and surface water quality deterioration.

An initial elevation survey and site evaluation at Portland has confirmed that traditional communal stormwater BMPs are not suitable due to land restrictions. Preliminary findings indicate that individual lots are significant contributors to the overall stormwater loadings in the village, which further raises the importance of source (e.g. lot-level) control strategies. One suggested lot-level stormwater control is rear yard ponding, where lot runoff from the roof is diverted and retained in a shallow depression in the yard for removal by infiltration and evaporation. The applicability of this onsite stormwater control may be limited by issues such as low lawn/house ratio (an indicator of how much lawn space is available for onsite storage of stormwater) and shallow bedrock or groundwater table. For more details one may refer to *Stormwater Management Design and Planning Manual* prepared by the Ontario Ministry of Environment (2003).

HEC-HMS (USACE, 2000) is used to simulate the village's response to the design storm under existing and pre-development conditions. The optimum baseline storage of stormwater for the existing drainage basin is essentially the excess volume in the existing hydrograph when the existing peak flow is reduced to pre-development peak flow in an attempt to 'mimic' pre-development hydrology in the village. The optimum baseline storage for the main town, which is a scaled parameter of the drainage basin baseline storage, is then compared to the integrated rear yard storage provided by all applicable lots, thereby quantifying the effectiveness of rear yard ponding in a land restricted lakeside village. In addition to the design storm, the models is also run for a storm of higher return-period in order to investigate the hydrologic effects of future climate change on the village and the potential benefits of rear yard ponding for this matter (see Waters, 2001, for details on climate change's impact on rainfall intensity and volume). A field monitoring program is included to investigate the potential of enhanced flushing of onsite wastewater effluent by ponded stormwater, through the detection of phosphorus movement, if any, at a monitoring site under baseline conditions.

2. SITE BACKGROUND

The village of Portland is located on the Rideau Lake system in Leeds and Grenville County, eastern Ontario. The most developed area (main town) is located along the shoreline and consists primarily of residential lots (both seasonal and permanent residency), local businesses and marinas. A subdivision consisting of typical suburban residential lots (high lawn/house ratio) is located on a hill east of the main town. A two-laned Ontario Highway 15 essentially separates the developed area from the undeveloped area in the village. The village is currently served by 6 sets of storm sewer pipes that discharge directly to the Lake without any treatment. The drainage basin which comprises the village of Portland, as can be seen in Figure 1, has an area of 85 ha (0.85 km^2).

3. METHODS

Runoff Simulation

i) Existing Conditions

The following list summarizes the general steps that were taken when developing this model in *HEC-HMS*:

A. Specify design rainfall
B. Divide overall drainage basin into subbasins, which are delineated on a topographic map
C. Identify dominant processes (e.g. storage on surface, in channels, in reservoirs and routing) and then represent drainage basin by a linked network of subbasins, channel routing and reservoir routing elements, if necessary.
D. Select algorithms for each element in the network, and estimate a value for the various parameters.

Design Rainfall Specifications

According to Watt et al. (1989), storm pipes in urban drainage systems in Canada are typically designed for design storms with return periods ranging from 2 to 10 years, and for minor drainage systems (as in the case of Portland), a 5-year storm is often used. The 1-hour storm duration is used in the model as it is described as the most appropriate storm duration for urban areas by these authors. In addition, a 10-year storm is applied to account for future climate change. The rainfall intensity-duration-frequency (I-D-F) curves for the Kingston pumping station in Ontario are applied to the model due to the station's proximity to the study area. The AES Type II 1-hour storm distribution for Southern Ontario can be seen in Watt et al. (1989). Table 1 summarizes the rainfall depths for the 5- and 10-year storms of 1-hour duration.

Table 1. Rainfall Depths for a 1-hour Storm at the Kingston Pumping Station

Return Period	Total Rainfall Depth (mm)
5-year	28.2
10-year	33.0

(Source: Watt et al., 1989)

Drainage Basin/Subbasins Delineations

The overall drainage basin was defined based on topographic and landuse information as provided by an Ontario Base Map (OBM). Subbasins were divided based on: 1) landuse pattern, 2) existing sewer network and 3) surface drainage pattern. Highway 15 generally serves as a division line between 'developed' and 'undeveloped' areas in the existing drainage basin. Areas southeast of Highway 15 are 'moderately-developed' (3 percent imperviousness) or 'undeveloped', while areas northwest of the highway are 'extensively-developed' (the main town) with percent imperviousness ranging from 12 to 44. As seen in Figure 1, subbasins 1, 8 and 10 represent 'moderately-developed' areas; subbasins 2 to 7 represent 'extensively-developed' areas; and subbasin 9 represents wooded, undeveloped area.

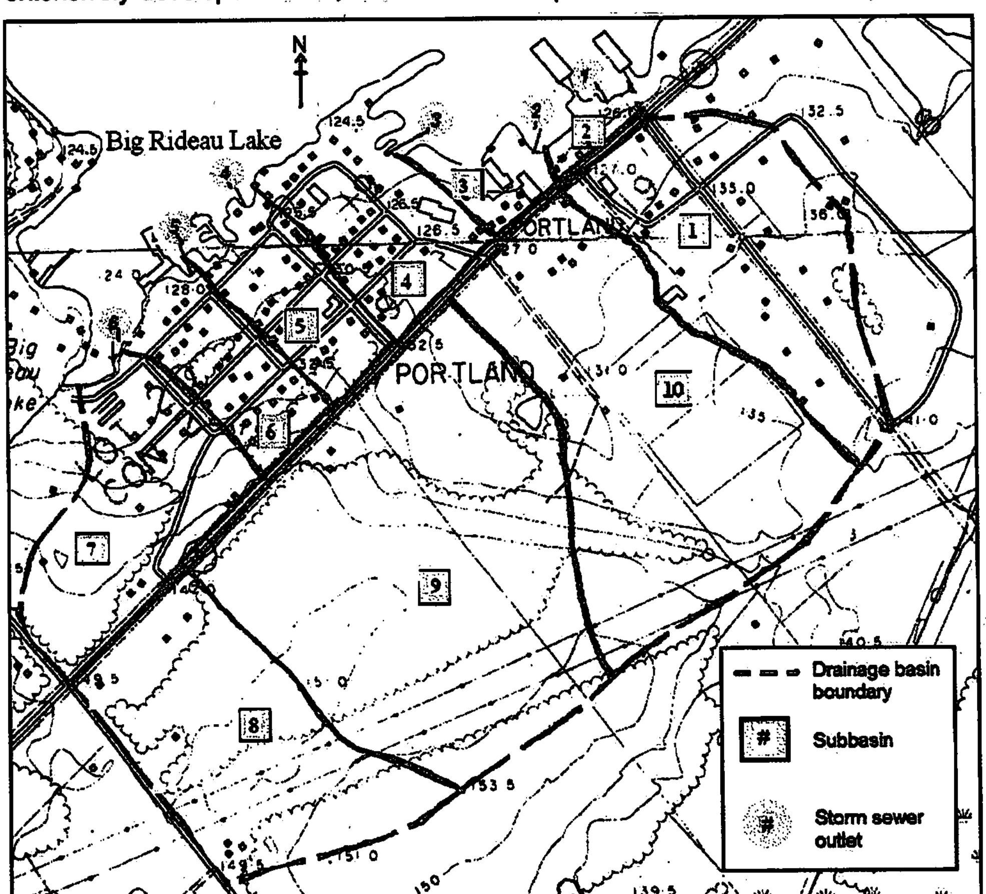


Figure 1. Drainage Basin, Subbasins Delineation and Storm Sewer Outlet Locations

(modified from: Ontario Ministry of Natural Resources, 1991.)

Due to the absence of design drawings, the existing sewer network was reconstructed based on the storm drains' surface elevations, and the main town is generally subdivided according to the presumed storm sewer network and the locations of their outlets (see Figure 1).

Dominant Processes Identification/Model Network Development

According to the air photo and Ontario Base Map, no lakes or channels are present within the drainage basin in investigation. The hydrologic element network in Figure 2a was created based on the surface drainage characteristics. Each of the developed subbasins (all except subbasin 9) is represented by two hydrologic elements: one for impervious surfaces (denoted by I following the subbasin name) and one for pervious surfaces (denoted by P following the subbasin name). Highway 15 is divided into 2 elements (H15_A and H15_B) since a part of it drains to subbasin 2, and the other to subbasin 3. For the same reason, the ditch along Highway 15 is also separated into 2 sections, each of which is modelled as a linear reservoir, as represented by Ditch A and Ditch B in Figure 2a. In essence, subbasins 2 to 7 directly discharge to Outlets 1 to 6, respectively; subbasin 1 discharges to Outlet 1 through a culvert in subbasin 2; H15_A drains to Ditch A that discharges to Outlet 1 through the same culvert in subbasin 2; subbasins 8, 9, 10 and H15_B drain to Ditch B that discharges to Outlet 2 through a culvert in subbasin 3.

Sub-models

The Initial Abstraction (IA) and continuing loss model is applied to the impervious subbasin elements (including H15_A and H15_B), for which IA has a value of 2 mm according to Viessman et al. (1970), with no continuing loss. The US Soil Conservation Survey Curve Number (SCS CN) loss model is applied to the pervious subbasin elements, for which CN is chosen from design charts H2-2 and H2-8 in the *MTC Drainage Manual* (Ministry of Transportation and Communications, 1986) for soil type that is obtained from the *Ontario Soil Survey* (Richards et al., 1949). The SCS unit hydrograph was applied to all subbasin elements, and lag time is approximated as the sum of inlet time and the travel time in sewer, culvert or ditch, where applicable. Inlet time is taken as 5 and 15 minutes for impervious and pervious elements, respectively, and time in sewer/culvert/ditch is obtained by dividing the wetted area by the average flow velocity in Manning's equation, as shown in equation [1].

[1] $V = 1/n \cdot R^{2/3} \cdot S^{1/2}$

where V = average flow velocity in sewer/culver/ditch, m/s
n = Manning's roughness coefficient
R = wetted parameter, m
S = average slope of sewer/culvert/ditch

The storage-outflow relationship is chosen for the two reservoir elements (Ditch A and Ditch B), where the outflows at various storages are calculated offline by the linear reservoir theory as shown in equation [2].

[2] $S = KQ$

where S = storage, m^3
K = storage coefficient, s
$= Q_{max}/S_{max}$
Q = outflow, m^3/s

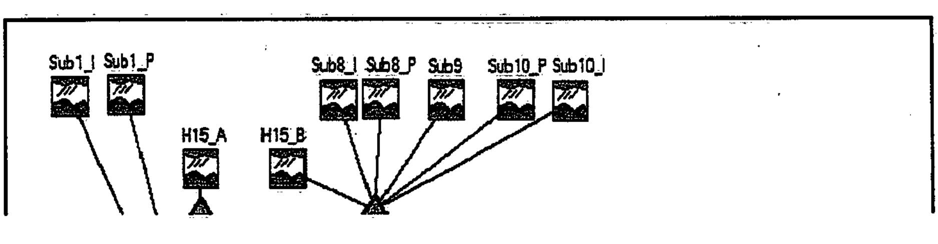
Here, S_{max} is the maximum storage provided by the ditch and Q_{max} is the maximum outflow given by a graphical solution for the culvert discharge equation for projecting inlet type for inlet control as seen in Smith and Oak (1995).

ii) Pre-development Conditions

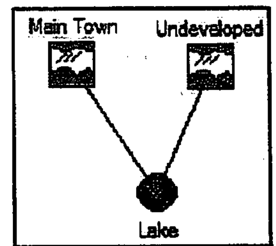
Similar steps as listed in the previous subsection were taken when developing the pre-development model. An air photo and topographic map for the 1920s were used to delineate the subbasins under pre-development conditions, and it was found that the existing main town and part of Highway 15 were already present at the time, but developed to a lesser extent and without the drainage system. The drainage basin essentially is divided into the town and undeveloped area. Figure 2b shows the hydrologic element network in *HEC-HMS* for the pre-developed conditions. The SCS CN loss model and unit hydrograph are applied to both subbasin elements. The lag time in this model is given by the curve number method:

[3] $t_{lag} = (L_w^{0.8} \cdot (1000/CN-9)^{0.7}) / (1900 \cdot S_o^{0.5})$

where t_{lag} = basin lag time, hr
L_w = hydraulic length of watershed, ft
CN = SCS Curve Number, unitless
S_o = average watershed slope, %



a)



b)

Figure 2. Hydrologic Element Network under a) Existing Conditions, b) Pre-developed Conditions.

iii) Existing Conditions with Rear Yard Ponding

Typical onsite storage provided by rear yard ponding for roof runoff is estimated as 0.02 m over typical roof area in the main town (MOE, 2003). Lots located on shallow bedrock and/or groundwater table, or possessing a lower-than-typical lawn/house ratio (as provided by a water management questionnaire that was distributed to the town residents, see **Field Monitoring** section) are considered not feasible for rear yard ponding. However, since it can be very difficult to acquire the depths to bedrock and groundwater table for all lots when identifying the applicability of rear yard ponding, it is reasonable to assume that the elevation of bedrock and groundwater table is consistent throughout the village; yet their relative locations to an artesian well that is present in the village is taken into consideration. The integrated onsite storage provided by all the feasible lots is compared to the baseline storage required by the main town, which is found by scaling the baseline storage required for the existing drainage basin by a factor equivalent to the percentage of main town runoff volume out of the total runoff volume. Onsite stormwater storage can be a proactive solution for future climate change. According to Waters (2001), the 5-year storm will increase to the current 10-year storm, or equivalent to a 17% increase for Southern Ontario. If at least 17% of the roofs are disconnected to the sewer system, overflowing in the existing sewers designed for a current 5-year storm can be avoided in the future. It is also noted that runoff from paved driveways is not significant in this study since 50% of the driveways in the main town are not paved; moreover, it is difficult to divert driveway runoff to a ponding area on lot by gravity since the driveway typically ends at the low point on a property to enhance drainage to storm sewers.

Field Monitoring

A typical residential lot in the main town was chosen as the site for the field monitoring program. The site was selected based on the results of a water management questionnaire, and on design guidelines for rear yard ponding as per MOE (2003). Guideline specifications from this manual along with the site-specific values obtained from site evaluation are provided in Table 2.

In essence, the selected monitoring site possesses a typical lawn/house ratio, typical geophysical settings, and typical answers to the water management questionnaire. However, it must be stressed that it is impossible to locate a "perfect" typical lot due to physical differences including lot sizes, onsite drainage, structural configurations, etc. Hence, the key to the search for a monitoring site lies in the attempt to employ as much baseline information as possible such that the best representative site can be chosen. Table3 summarizes answers to selected questions in the water management questionnaire for the monitoring site along with "representative" answers from other home owners in the village.

Table 2: Comparison between MOE Guideline Specifications and Site-Specific Values for Selection of 'Typical' Lot for Rear Yard Ponding

Design Considerations	Guideline Specifications	Site-Specific Values
Contributing Area (m^2)	< 5000	630
Topography (%)	< 2	< 2
Soil	loam	Farmington loam
Depth to Bedrock (m)	> 1	1.2
Depth to Groundwater Table (m)	> 1	7.5
Storage Volume (mm)	Maximum: 20 mm over roof area	20
(m^3)		1.7
Ponding Depth (m)	< 0.1	0.1
Location	4 m from building foundation	see Figure 3

(Modified from: MOE, 2003)

Table3: Typical and Monitoring Site's Answers to Selected Questions in Water Management Questionnaire

Selected Question in Questionnaire	Typical Answer	(% Answered Questionnaire)	Monitoring Site's Answer
Do you apply any organics or chemicals on your lawn?	No	(65%)	No
What kind of system do you use for wastewater disposal?	Septic system	(92%)	Septic system
What is the age of your septic system?	19 – 20	(15%)	35
What is the pumping frequency of your wastewater system?	2 years	(32%)	2 years
When was the last pumping?	Year 2001	(45%)	Year 2000
Do you have a paved driveway? If yes, where is the runoff discharged to?	No	(54%)	Yes, Storm drain
Where is the roof runoff discharged to?	Lawn	(57%)	Lawn

Six sampling stations were set-up at the monitoring site to detect any changes in levels of phosphorus in the unsaturated zone during storm events and in non-event conditions. This parameter will represent most aqueous contaminants and will help to indicate subsurface flow characteristics at the site. The locations of the sampling stations, as shown in Figure 3, were determined by the boundary of the tile bed and the presumed subsurface flow direction as predicted from a local topographic map. Sampling stations W1, W2 and W3, were placed within the proximity of the tile bed to cover any movement of phosphorus that may be caused by flushing after a storm event. Sampling station W4 was placed to detect any movement of phosphorus from the neighbouring tile field. Sampling stations W5 and W6 were placed up and down gradient of the tile bed. The up-gradient station, W5, is intended to work as a control for comparison purposes since it is expected to experience the least changes in phosphorus within the monitoring site. Four lysimeters at depths of 6" (0.15 m), 12" (0.30 m), 36" (0.91 m) and 42" (1.07 m) were installed at each sampling station in an attempt to develop a complete horizontal and vertical profile of phosphorus distribution at the monitoring site. Weekly samples are being retrieved at present for the analysis of orthophosphate by Flow Injection Analysis (FIA), QuickChem® Method 10-115-01-1-A (Lachat Instruments, 2000) using the QuickChem 8000.

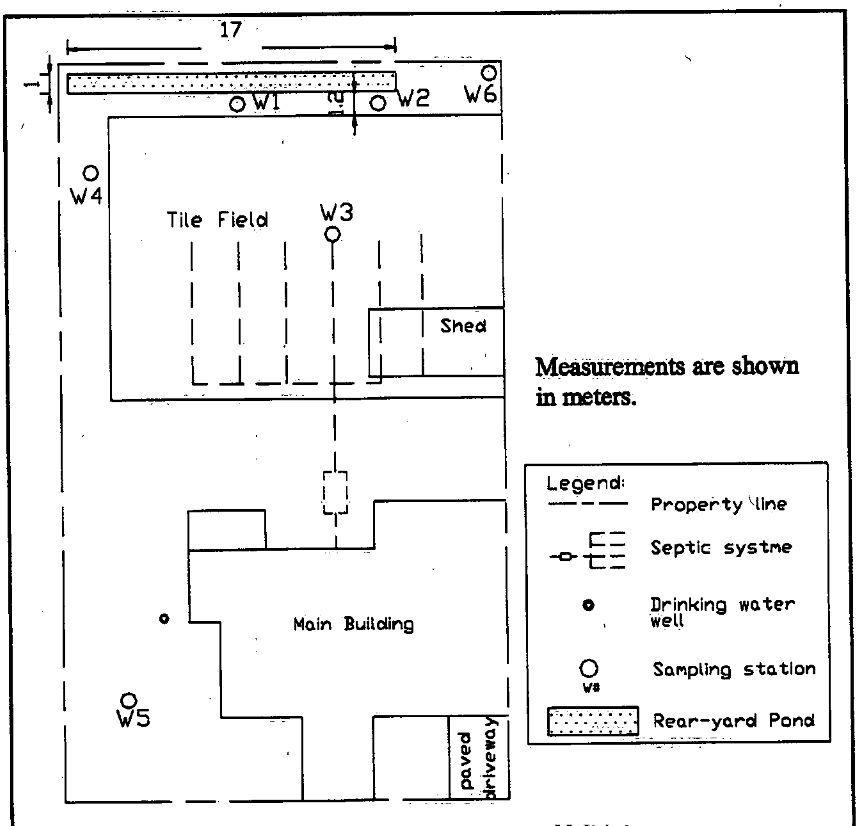


Figure 3. Locations of Sampling Stations and Proposed Rear-yard Pond

4. PRELIMINARY RESULTS

Preliminary findings from the modelling exercise for the 5-year, 1-hour design storm and the 10-year, 1-hour storm for future climate change are presented in this paper. At the time this paper is written, significant findings are not yet seen from the analysis of the field monitoring soil water samples owing to the limited number of samples that have been gathered to date.

The total runoff for a 5-year, 1-hour design storm for the drainage basin under existing conditions was found to be 2530 m^3, and the peak discharge for the pre-development conditions is 0.29 m^3/s. Figure 4 depicts the hydrograph for the existing conditions and the peak flow for the pre-development conditions, where the shaded area in the plot represents the baseline optimum storage of stormwater for treatment for the existing drainage basin. Using numerical integration, the baseline storage for the existing drainage basin was found to be around 1100 m^3 of which 59% or 650 m^3 is the baseline storage required for the main town. After preliminary screening, 11 lots, including the monitoring site, were found to be feasible for rear yard ponding, and the onsite storage provided by these lots adds up to 20 m^3, or 3% of the main town baseline storage. The relatively low value for onsite stormwater capacity suggests that onsite storage of stormwater cannot replace large-scale stormwater BMPs since not all lot-level stormwater contributors are feasible for onsite storage, and the onsite storage capacity cannot alleviate runoff from roads and other paved areas in the main town. However, onsite storage of stormwater may retard or mitigate the transport of lot-level contaminants to surface water body. For the case of future climate change, if the 5-year, 1-hour storm becomes the present 10-year, 1-hour storm, the change in volume for the main town was found to be 300 m^3. This excess runoff volume may be removed from the storm sewer system, which is designed for a present 5-year, 1-hour storm, if prevention of overflowing is desired. It was found that 6% of this excess runoff volume can be removed with the aforementioned onsite stormwater storage capacity.

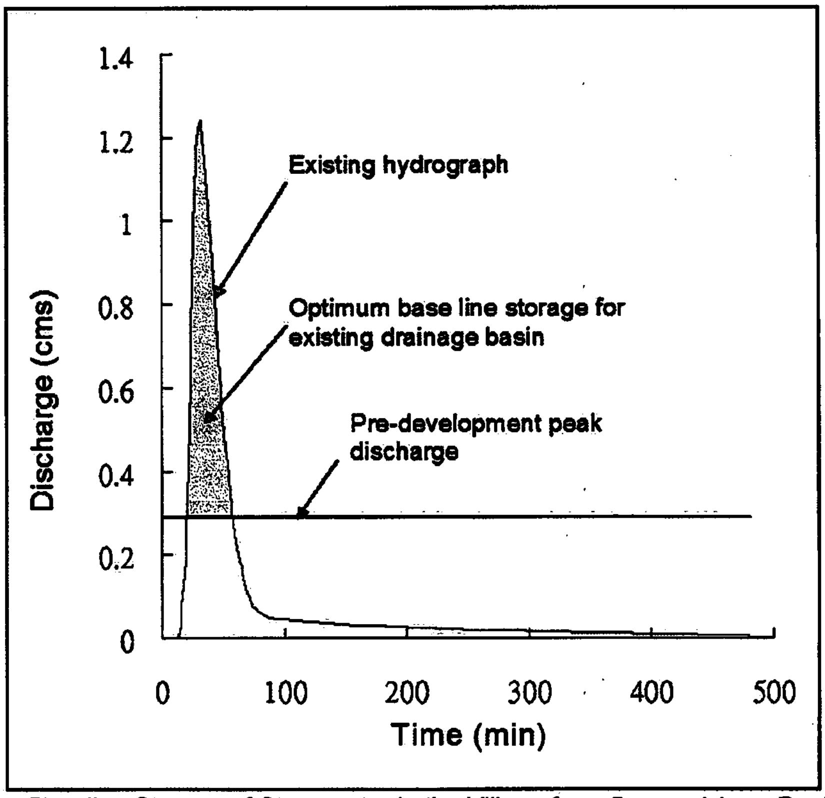


Figure 4. Optimum Baseline Storage of Stormwater in the Village for a 5-year, 1-hour Design Storm

At this stage, final results or conclusions cannot be presented in this paper since the current research is still in progress. The next phase of the study is to present the effectiveness of rear yard ponding in terms of lot runoff volume as opposed to main town runoff volume (which includes roads and other paved areas) as presented in this paper. The lots will be disconnected from the rest of the town to account for runoff volume that is generated from all the lots in the town. For the analysis of future climate change, stormwater storage resulting from disconnecting 17% of roof area will be determined for a more in-depth evaluation of rear yard ponding in the main town of Portland. With regards to field monitoring, a bromide tracer study is under consideration for the detection of potential seepage of septic effluent into the storm sewers, which will help to evaluate the integrity of the existing storm sewer system.

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105 McGill Street
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Centre national de recherche en hydrologie
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