Bear Mountain - Highlands
Final Stormwater Management Plan

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1.0 INTRODUCTION

The preparation of the Bear Mountain Highlands Stormwater Management Plan (BMHSMP) is written largely in light of two previously prepared reports, the *Bear Mountain Langford Stormwater Management Plan* and the *Highlands South Stormwater Management Conceptual Report*. Additionally, other recent reports have been consulted, along with visits to the site.

The BMHSMP establishes the magnitude of control needed and describes a suite of stormwater management practices--also called Best Management Practices (BMPs)—applicable to the site. Through modelling, it determines the volumetric storage requirements and demonstrates that the plan will meet the required criteria.

1.1 Purpose and Problem Definition

The purpose of this Plan is to:

- identify applicable BMPs for the Bear Mountain Highlands development
- introduce the criteria used in selecting BMPs
- evaluate the implementation of these management practices

Stormwater related problems may be thought of as impairments of beneficial uses. Thus, when a view of the ideal set of beneficial uses is known, then a comparison with existing uses will reveal how the potential uses are impaired. Philosophically, this is the way foreword; practically, the implementation of solutions is not that simple, as many of the impairments are intangible.

This plan provides an assessment of the site as a heterogeneous unit. During detailed design the suitability of specific source controls and end-of-pipe solutions will be determined.

1.2 Goals and Objectives

The overall intent of stormwater management for the control of in-stream erosion potential is to at least preserve and hopefully enhance a “stable” and sustainable fluvial system. The watershed’s associated habitat and aesthetic values, as well as education-recreational potential are equally important, along with the need to maintain summer base flows within the watershed.

The objectives of the BMHSMP are:

- preferably infiltrate runoff, or alternatively convey it through the development to a secure outlet with minimal impacts to people, properties and existing wetlands
- contribute to the development of additional water related resources
- balance the needs of economic development and environmental sustainability

In sum, the plan is guided by the principle that the hydrologic cycle is the physical link between ecosystem components, and water within the Bear Mountain Highlands development area is used as an indicator of ecosystem health.

1.3 Beneficial Water Uses

Typical future water uses within the watershed are identified below. The BMHSMP identifies these as beneficial uses of water within the watershed which need to be protected during development, as shown in Table 1.

Table 1: Bear Mountain Highlands Beneficial Water Uses

Flood control impoundment of high flows for delayed release	Dams, reservoirs & channel protection
Water based recreation	Hiking, picnicking, boating Nature enjoyment activities (e.g. bird watching) Aesthetic enjoyment
Fish and wildlife habitat	Aquatic and riparian habitats Protection of community structure Protection of rare and endangered species
Water Quality Management	Protection of minimum flows for water quality preservation Low flow augmentation from reservoirs

2.0 SITE CHARACTERIZATION

The site has a total drainage area of about 230 hectares and is located in the District of Highlands with a contiguous boundary with the Langford development of the same name, as shown in Figure 1. Site topography covers a change in relief of 325 m in the west to about 90 m in the east, with the low lying area covering some 35% of the entire parcel. The catchments flow into the Millstream River system; the natural drainage patterns are illustrated on Figure 2.

The site has been characterized and environmentally sensitive areas inventoried in a parallel report [2]. The proposed development consists of an 18 hole golf course, with residential and commercial areas covering a small percentage of area adjacent to Langford. The remainder of the site, according to the developer's concept plan, will consist of forest and open space within the golf course, natural greenways, parks, trails and riparian buffer zones.

2.1 Catchments

The site was earlier divided into catchments, as shown in Table 2 and illustrated in Figure 2. At this point, a phasing plan for the residential and commercial development occurring in catchments 201, 401 and 501 of the site has not yet been determined.

Table 2: Catchment Size and Topography

Subcatchment	Hydraulic Length	Elevation range	Slope	Area
I.D.	m	m	m/m	ha
101	560	10	0.018	42.3
201	935	125	0.133	44.0
301	450	45	0.100	40.6
401	675	20	0.030	77.7
501	675	43	0.064	24.9

2.2 Soils

The site terrain has been described as mainly controlled by meta-volcanic bedrock (Wark Gneiss) with minor occurrences of limestone at depth [6]. Soils on the site have been classified by the BC Ministry of the Environment as Sprucebark (Appendix B). More detailed descriptions are provided under the Canadian Soil Classification System (Agriculture Canada), identifying the following soil types: Arrowsmith, Metchosin, Mexicana, Qualicum and Rumsley. Further information on this classification can be obtained from the District of Highlands Municipal Office.

2.3 Streams

The longitudinal profile of the streams on site follow a typical flow regime: subsurface flow at highest elevations, to ephemeral and intermittent flow at lower elevations, and perennial flow at locations discharging into the Millstream systems.

In order to understand their geomorphic features, streams are often categorized according to where they are located within the drainage network. As defined by Strahler [3], a small creek with no upstream tributaries would be assigned an order of one. All the streams falling within the Bear Mountain Highlands development are first or at most second order streams. These small stream order numbers represent minimal geomorphic diversity and the smallest dimensions for a watercourse within the watershed. They are summarized in Table 3 and reference the figure in Appendix C.

Table 3: Stream Order

Channel ID (Enkon)	1	2	3	4	5	6	7	8	9	10	11	12
Strahler order	2	1	1	1	1	1	1	1	1	1	1	1

The stream beds visited were found to have slopes of approximately 2 – 5 % gradients, although there are others which are much steeper than this.

A stable stream channel has an innate ability to absorb a certain amount of change in the sediment-flow regime before the threshold of adjustment is reached. This tolerance is reduced in streams designed as in “transition” or “in adjustment” according to geomorphic assessment techniques. One stream (#4) was assessed with this method and found to be in a stable condition. Due to the lack of evidence of erosion and absence of traditional urban development, the others are anticipated to be in a similar state. See Appendix B.

Channels in each catchment have been inventoried by a combination of field survey and aerial photo interpretation by Enkon and Focus.

None of the channels on site have been mapped with a 200-year flood line delineation through the FDRP program.

Table 4: Natural Channels Before Development (August 2002)

Catchments		Channels		Channel Density
ID	Area	Length	Area	per catchment
-	ha	m	m^2	%
101	42.3	274	959	0.23
201	44.0	179	627	0.14
301	40.6	262	917	0.23
401	77.0	2767	9685	1.26
501	24.9	20	70	0.03

Table 4 shows the current drainage density within each catchment. This information is useful as a base line for future reference. However, the developer’s concept plan shows that the only road construction would be Hannington Road, and likely narrow cart paths. If this is the case, then the drainage of wetland areas by ditches would not occur.

After a 6 – 8 week long dry period (mid-August 2002), most steams on site were dry, although streams #1 and #4, and perhaps others, had isolated pools which appear to result from either a perched water table or artesian conditions, or both. This was confirmed during the author's site visit, and also during the groundwater exploration program, where a free flowing well rose some 3 m when drilled.

The Ministry of Water Lands and Air Protection do no issue licenses for abstraction of groundwater although they do for surface water abstraction. Table 5 illustrates a list of licensees having water rights on Millstream.

Table 5: Millstream Water Licenses

Lic. No	**Purpose**	**Qty.**	**Licensee**	**Priority Date**
C014943	Land Improve	40 ac-ft	Mcminn Robert, Victoria	19410402
C017097	Domestic	1000 gal/d	Langford Poultry Farm, Victoria	19460103
C018495	Land Improve	0	York Fred, Victoria	19480218
C018495	Land Improve	0	York Fred, Victoria	19480218
C018495	Land Improve	0	York Fred, Victoria	19480218
C024311	Domestic	1000 gal/d	Joy Kerry, Victoria	19580327
C024312	Land Improve	0	Joy Kerry, Victoria	19580327
F016740	Domestic	1000 gal/d	Bishop William, Langford	19470618
F018235	Land Improve	0	Bjola Leslie, Colwood	19580107

2.4 Wetlands

Fens are peat-accumulating meadow-like wetlands that form at low points in the landscape or near slopes where ground water intercepts the soil surface. Although possibly fed by groundwater, the channel sites visited would not classify as fens because of the absence of grasses and sedges. Some of the wetlands are fed primarily by groundwater, while others result from inadequate subsurface drainage and depressions that have no outlet.

These areas would not necessarily be drained simply as a result of the construction activities anticipated for the proposed golf course, as they may be localized hydraulically or depend on aquifer recharge. See Appendix A for some additional comments.

Recent studies have indicated that wetlands do not contribute to seasonal flow regulation [1].

3.0 STORMWATER HYDROLOGY

3.1 Major & Minor Systems

The fundamental aspect of stormwater planning is consideration of the whole hydrologic system, including the interrelationship of the “major” and “minor” drainage systems. The differences between the two systems have been described as “the differences between drainage and flood control, or between conveyance and damage prevention systems” [4]. A comparison between the two systems is shown in Table 6.

Table 6: Potential Benefits of Designing for Major and Minor Drainage Systems

Minor Flows	Major Flows
Reduced street maintenance	Damage and liability reduction
Reduced traffic delays	Land value enhancement
Improved conveyance	Protection of life
Improved aesthetics	Improved aesthetics
Alleviation of health hazards	

This report recognizes these two separate systems. For pre and post development conditions, the minor system conveys frequent runoff events while the major system conveys infrequent events that exceed the capacity of the minor system. The division between the two is as much a function of the watershed hydrologic processes as it is a function of municipal standards dictating the dimensions for common drainage elements, like curb heights, catchbasins, road slopes, lot grading, sizing storm sewer and ditches, etc.

For pre development conditions at Bear Mountain, the minor system is defined as the stream or low flow portion of the watercourse.

For post development, the minor system also includes lot grades, ditches, backyard swales, roof leaders, foundation drains, gutters, catchbasins, and storm sewers.

The major system at Bear Mountain for pre development comprises the floodplain of the natural streams, the valleys, and existing ponds. For post development, swales, artificial channels, roadways, stream road crossings, and constructed ponds are added. For large rainfall events, the minor system overflows into the major system.

3.2 Return Periods

Return periods are a statistical concept used to specify an event which may occur, on average, once every “return period” number of years. For example, a 200-year storm is one which may occur, on average, once every 200 years. However, this is not to imply that the event will occur only once every 200 years. It may not occur at all or it may occur twice or three times during that period, but it is not that likely.

Additionally, a rainfall event occurring once, on average, every 200 years, will not likely generate runoff which would occur, on average, every 200 years. Watershed variables, like antecedent moisture conditions, also influence the amount of runoff generated. In statistical terms, then, the 200 year rainfall and the 200 year runoff are independent events.

Return periods are calculated using the equation below.

$$T = (NYRS + 1 - 2A) / (M - A)$$
T = return period in years
M = rank of event
A = parameter to account for the unknown nature of the underlying frequency distribution (A = 0 for Weibull distribution, A=0.4 recommended in SWMM [5])

For the Bear Mountain Highlands development, drainage systems must minimize the risk to life and property for the 10- through 200-year return period rainfall events.

Customarily, bylaws require the minor drainage system to be designed for the runoff from the post development 10-year rainfall, and the major system be designed for the additional runoff from the 200-year rainfall event.

4.0 IMPACTS OF DEVELOPMENT

The Bear Mountain Highlands Development will impact both positively and negatively on the watershed. In a negative sense, increased impervious surfaces means increased peak flows and a shorter time to peak. In hydrologic terms, some of the developed ground surface is no longer subject to the regenerative processes which it was when in a natural state. Although these impacts cannot be eliminated, they can be significantly reduced. The estimated increase in impervious surfaces is shown in Table 6a.

In a positive sense, there would be much more subsurface storage area made available due to the sand – peat mixture used on the golf course greens for drainage.

Table 6a Additional Post Development Imperviousness

Catchment	Additional Impervious	
	ha	%
101	0	0
201	1.21	3%
301	0	0
401	4.71	6%
501	1.22	5%

Some impervious areas can be designed such that they discharge close to where the runoff is generated. For example, a common management practice for roof leaders is to disconnect them from storm drains and have the runoff infiltrate. Foundation weeping tiles also are often similarly connected, and if enough site grade is available then they too can be discharged so they are not hydraulically connected to the storm drain system.

Techniques of this nature comprise the art and science of modern hydrology--the focus of intense professional activity for the past 50 years.

Section 5.0 describes the range of BMPs potentially available for use on Bear Mountain and some sketches are in Appendix E.

4.1 Water Uses for Urban Conditions

Although the major emphasis of this plan is on flow quantities, the desired use of water for the urban conditions is important in understanding which BMPs to use. Generally, it is desirable to infiltrate as much runoff as possible in order to contribute to base flow and to recharge the groundwater.

But in areas where contaminants are added by human activity, it may be more desirable to treat runoff through sedimentation before encouraging infiltration, especially if groundwater is used for human consumption. This may be the case for some land uses on the Bear Mountain Development.

4.2 Golf Course Water Requirement Needs

Catchments within the golf course are 101, 201, 301, 401 and 501. The estimated irrigation requirements for the remaining catchments will be satisfied by a combination of stormwater runoff and on-site wells. Irrigation water needs and flood control will both determine pond storage.

Table 7 shows the historic water requirements for golf courses in the Victoria area. This information is an indicator of the range of water consumption likely to be expected on the proposed golf course in the Highlands.

Table 7: Greater Victoria Historic Golf Course Water Consumption (Imperial Gallons)

	Golf Course	Year					Notes from golf course staff
		1998	1999	2000	2001	2002	
1	Olympic View	32,916,600	26,250,600	24,695,200	18,699,100	26,263,800	
2	Colwood			19,991,268	19,058,904	22,792,884	333,920 Igal mid-summer nightly usage
3	Uplands	20,507,136	21,861,840	16,788,720	14,461,200	19,272,240	230,000 Igal per night peak season irrigation period typically late April - late September
	Annual Mean	26,711,868	24,056,220	20,491,729	17,406,401	22,776,308	
	5-Year Mean	22,288,505 (101,189 m^3)					

The interim companion report by Thurber Engineering [6a] estimates that the combined rated yield of wells W405, W407 and W408 is potentially 32.1 L/s (610,890 Igal / d). The maximum nightly usage from nearby similarly sized golf courses is reported in Table 7 as 333,920 imperial gallons per day.

5.0 STORMWATER MANAGEMENT PRACTICES [7]

Management practices fall into two separate categories: structural practices and non-structural practices.

5.1 Structural Management Practices

Stormwater Management Practices (SWMP) are based on location of application. In this section, the practices discussed are all structural, in that a physical structure results. The siting and sizing of SWMPs depends on the types which are proposed. The recommended strategy provided here is an integrated treatment train approach to water management that is premised on providing control in three locations: a) at the lot level, b) during conveyance, c) at the end-of-pipe. This combination of controls is mixed in an optimum manner to meet the multiple criteria for water balance, water quality, erosion control and water quantity.

5.1.1 Lot Level and Conveyance Controls

Both lot level and conveyance controls rely primarily on infiltration and filtering as their mechanism of contaminant removal. They pre-treat the water and reduce runoff volumes and peak flows, thus reducing the size and cost of downstream infrastructure.

The main purpose of lot level and conveyance controls is to mitigate changes in the water balance which take place when development occurs. The hierarchy of benefits achieved by these types of control is:

- Groundwater Recharge (emphasis on stream recharge, not deep aquifer recharge)
- Erosion Control
- Peak Shaving for storms with less than a 10-year return period

As the names imply, these controls are applied at the individual lot level and form part of the conveyance system. They typically serve multiple lots with small drainage areas (less than 2 hectares), so they have moderate applicability to the Bear Mountain Highlands Development. Most lot level controls can be implemented if the soil percolation rate is at least 15 mm/hr or if there is positive drainage from the site.

The available lot and conveyance controls can be divided into two categories according to their primary function: 1) peak flow reduction, 2) infiltration.

Peak Flow Source Controls

Peak flow source controls are used to reduce water quantity concerns or to reduce infrastructure costs. These controls include the following:

- Rooftop Storage - restrict discharge rate from roof drains to provide rooftop detention

- Parking Lot Storage – use catch-basin restrictors or orifices in the storm sewer to detain stormwater on parking lots

- Superpipe Storage - oversize storm sewers to create pipe storage

- Rear Yard Storage – implement restrictors in rear yard catch-basins to create rear yard storage

- Lot Grading – if a site is naturally flat, use 2 – 5% slope within 2 – 4 metres of building and a flatter slope (<2%) for the remaining lot area

Infiltration Based Source Controls

Infiltration-based source controls function to mitigate the impacts that development normally has on water balance and water quality. Through reduction in the surface runoff volume, they also contribute to erosion protection and flood control. Their use can result in cost savings for end-of-pipe facilities, although they often require innovative subdivision design and cooperation from the developer and home-owner for successful implementation. Infiltration based methods are not recommended in areas where there is a high potential for groundwater contamination or dry weather spills. Thus, they are not recommended for commercial parking lots unless there is some form of pretreatment upstream, since there is a high potential for dry weather spills and chlorides to enter the groundwater system.

Infiltration based source controls include the following:

- reduced grading to allow greater ponding of stormwater and natural infiltration

- directing roof leaders to rear yard ponding areas, soakaway pits, or to cisterns

- sump pumping foundation drains to rear yard ponding areas

- infiltration trenches

- grassed swales

- pervious pipe systems

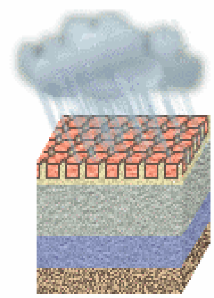
- filter strips

- stream and valley corridor buffer strips

- redirecting roof leaders and foundation drains to distant surface ponding areas

5.1.2. Conveyance Controls

Porous Pavement [8]


Porous pavement

This is an asphalt or concrete based paving material that allows stormwater to quickly infiltrate the surface pavement layer to enter a high-void aggregate sub-base layer. The captured runoff is stored in this reservoir until it either infiltrates into the underlying soil, or is routed through a perforated underdrain system to a conventional stormwater conveyance. Porous pavements have a higher capital cost than more conventional BMPs.

Porous pavement is used in the road shoulder to provide a transition between the traveled surface and the grassed swale, in the centre of cul-de-sacs or in parking lanes. A local example of its application is the Victoria Technology Park.

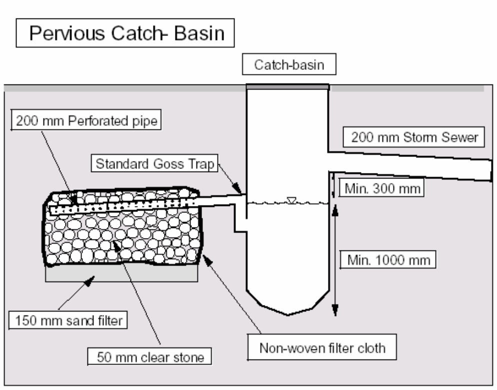
Pervious Pipes

Pervious pipes operate as infiltration sinks during periods of high water, and as exfiltration sources during periods of low water.

The benefits provided by using pervious pipes with respect to water quality, erosion, and storage are difficult to quantify since the exfiltration is dependent on pipe slope, number of perforations, size of perforations and depth of flow.

Pervious pipes may be applicable on Bear Mountain in areas where there is adequate site drainage, such as in locations where percolation rates are greater than 5 min/inch. When operating as infiltration sinks, they convey water to their point of discharge, if one exists.

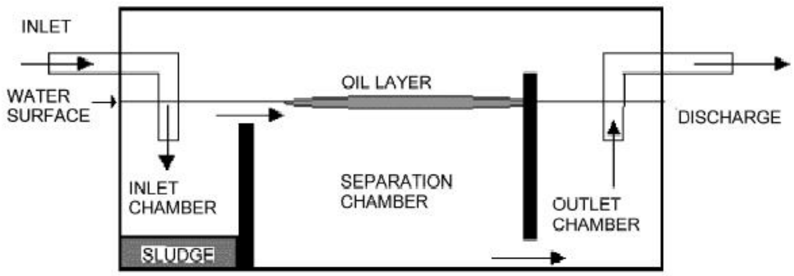
Pervious Catch Basins



The benefit with respect to water quality, quantity, and erosion control resulting from the installation of pervious catch basins can be estimated using the same methodology as that derived for soakaway pits. A typical pervious catchbasin is shown to the left [7].

Water first enters the chamber sump and contaminants settle out. When inflows exceed the capacity of the sump, it overflows into the buried rock pit that is essentially a 'bottomless pit', where it infiltrates into the ground. The second chamber is designed to handle a two year storm, but when this is exceeded, it drains to a storm sewer. These units are intended to infiltrate road drainage which has high levels of suspended sediment.

Oil and Grit Separator



Oil and grit separators are typically two- or three-chamber structures designed to remove sediment, oil, grease and large particulates, with outflow routed to the storm system. Another type uses coalescing plates to increase surface area for enhanced settling. As they are intended for removal of hydrocarbons, they are used near fuel dispensing facilities.

Enhanced Grass Swales

Grassed swales have historically been associated with rural drainage and have been constructed primarily for stormwater conveyance. However, they are now being promoted to filter and detain stormwater runoff. Swale drainage can be a useful technique in areas of low grade, provided the conveyance channel is not too long.

Enhanced grass swales have a permanent check dam to hold back water during small events. The check dam acts as a weir during larger events and can be modelled as a reservoir. The rating curve for the reservoir can be determined using the weir equation and the stage storage relationship upstream of the check dam. Given the small storage volume contained in one swale, and the likelihood for numerous swale areas, the storage volume from several swales should be lumped together in this assessment.

5.1.3 End of Pipe Controls

End-of-pipe stormwater management facilities receive stormwater from a conveyance system and discharge to the receiving waters. As the "last line of defense", they control the remaining impacts of urbanization after source controls have been applied. End-of-pipe controls are efficient for pollutant removal and flow control, but they do little to maintain the pre-development hydrology and water balance.

Wet Ponds

Wet ponds have a permanent pool of water but are less land-intensive than constructed wetland systems. In addition, they usually provide sufficient storage to ensure that post development peak flows are controlled to pre-development levels for storms ranging from a 10-year through 200-year return period. Their good performance is generally attributed to the following factors:

- performance does not depend on soil characteristics
- the permanent pool provides extended settling, prevents re-suspension and minimises outlet blockage
- biological removal of pollutants

Wet ponds can be designed with extensive landscaping and associated recreational amenities to become a development centre piece, contributing to the character of the community and enhancing its aesthetic quality.

Artificial Wetlands

The artificial wetland is a preferred end-of-pipe SWM facility for water quality enhancement. It is suitable for providing the storage needed for erosion control purposes, but is limited in flood control ability because of the restriction on active storage depth. The benefits of constructed wetlands are the same as wet ponds, but include enhanced nutrient removal.

Dry Ponds

Dry ponds have no permanent pool of water. While they can be used for erosion and flood control, the removal of stormwater contaminants in these facilities is purely a function of the drawdown time in the pond. Orifice size, which determines drawdown time, limits the duration of detention period.

Extended Detention Areas

Extended detention occurs in the upper storage volume of a pond or wetland which is subject to periodic wetting from storm events. Due to the fluctuating soil moisture content of the area, the growing conditions require close attention to ensure that the proposed plants become established.

Infiltration Basins

Infiltration basins are above-ground pond systems constructed in highly pervious soils. They are designed to allow water to infiltrate into the basin and flows either recharge the groundwater system or are collected underground for discharge to a downstream outlet.

Sand Filters

Filters are generally intended for drainage areas less than 5 ha and have no practical application for erosion or quantity control. In some applications they discharge to the storm sewer system but generally they discharge to the ground. Direct discharge to a watercourse is possible where there is sufficient topographic relief. They are effective in removing pollutants but often require pre-treatment to resist clogging.

5.2 Non-structural Stormwater Management Practices

The activities described below can be controlled through municipal bylaws and legislation. They are outside the authority of the residents at the site, but the Golf Course Board can implement some of these practices without specific government sanction.

However, successful watershed planning requires prior establishment of jurisdictions, institutions, agencies, regulations, technical expertise, authority, and implementation frameworks. When these work together a plan can be implemented successfully.

Land Use and Comprehensive Site Planning

Widely viewed as the most cost-effective control for stormwater quantity and quality, this SWMP involves preventing impacts from occurring, rather than retrofitting additional controls and conducting restoration projects downstream. Existing or potential water quality problems are identified and goals and measures are defined for preventing, reducing or reversing water quality degradation. These goals and measures are incorporated into the planning objectives.

Landscaping and Vegetative Practices

Vegetation increases surface roughness, helping to control both the quantity and quality of stormwater runoff. Not typically used as stand-alone measures, vegetative practices are effective means of pre-treatment to reduce the size, cost, operation and maintenance of other BMPs. Climatically appropriate landscaping and vegetative practices also enhance the aesthetic quality of a development.

Herbicide and Fertilizer Management

Stormwater runoff quality may be improved by reducing pesticide and herbicide volumes. Management issues include: applying the chemicals at the proper time, applying only the types and amounts necessary, and considering the environmental conditions and hazards at the site. Other control options include optimizing low maintenance vegetation, and establishment of an Integrated Pest Management (IPM) program. An outline of an IPM is shown below.

- Identify problem pests and understand their life cycle
- Establish tolerance thresholds for pests
- Monitor to detect and prevent pest problems
- Modify the maintenance program to promote healthy plants and discourage pests
- If pests exceed the tolerance thresholds use cultural, physical, mechanical or biological controls first and chemical controls last.
- Evaluate and record the effectiveness of the control, and modify maintenance practices to support lawn or landscape recovery and prevent recurrence

Litter and Debris Controls

Curb accumulations (normally where the highest concentration of roadway 'dust & dirt' can be found) can be controlled by street sweeping. Reduction of litter and debris accumulations can be attained by source controls. Curb elimination can reduce roadway accumulations by allowing sediment and finer materials to be scattered by wind (atmospheric and vehicular generated) and rainfall runoff across vegetated berms.

Illicit Discharge Controls

Storm sewer systems are often used as an inexpensive or convenient alternative to proper disposal of wastewater and fluids. Illicit discharges typically occur as illicit connections to storm sewers or illicit dumping at storm drains. Controls for the former may include: close inspection during sewer construction, routine outfall inspection, interior pipe inspection and interior building inspection. Illicit dumping controls may include: storm drain labelling, personnel training regarding proper disposal techniques, increase personnel and public awareness, encourage the reporting of dumping incidents and/or investigate reported complaints. These controls can be included in a municipal bylaw similar to the one prepared by the CRD, which has been adapted by some municipalities for local use.

Chemical Storage

Certain materials should be protected from exposure to rainfall and runoff to avoid leaching of contaminants and discharge to surface waters. Vehicle maintenance and storage areas, fuelling areas and gasoline stations, parking areas, weigh stations, food service facilities, as well as road surfaces can contribute petroleum and other contaminants to runoff. Of particular concern for transportation and highway facilities are deicing chemicals, fuels, oils, solvents, cleaning solutions, paints and pesticides.

SWMP Maintenance

Removal of sediment, debris, and nuisance vegetation are among the most common problems requiring maintenance. Maintenance of BMP facilities also minimize flooding caused by blocked or constricted conveyance/storage systems.

At the detailed design stage, drawings for stormwater management facilities will be submitted for approval as part of the overall subdivision design package. This would include grading plans, drainage plans, detailed plans and profiles of storm and sanitary sewers, water mains, other utilities, road profiles, etc. The present document does not include any of these drawings as they are not directly relevant to it. A maintenance plan will be provided for each facility at the end of the design stage.

Table 8: Criteria for Selection of BMPs for Bear Mountain Highlands

BMP	Area	Groundwater	Bedrock	Soil	Topo.
Wet pond	> 5ha	-	-	-	-
Infiltration basin	< 5ha	> 1m below bottom	> 1m below bottom	loam, > 15mm/hr	-
Infiltration trench	< 2ha	> 1m below bottom	> 1m below bottom		-
Filter strip	< 2ha	> 0.5m below bottom	-	-	-
Sand filter	< 5ha	> 0.5m below bottom	-	-	-
Oil/grit separator	< 2ha	-	-	-	-
Grassed swale	-	-	-	-	< 5%
Perforated pipes	-	> 1m below bottom	> 1m below bottom	loam, > 15mm/hr	-

The BMPs which are likely applicable to the Bear Mountain Highlands site are listed in Table 8. Their suitability will be confirmed after geotechnical considerations are concluded.

6.0 HYDROLOGIC COMPUTER MODELLING

The computer model used in the determination of runoff volumes and peak flows is the USEPA Stormwater Management Model, SWMM, described as “the most comprehensive urban runoff model” [8]. SWMM allows continuous or event based simulation for a variety of catchments, conveyance, storage, treatment and receiving water systems.

The generation of runoff from rainfall is done in SWMM by solving the continuity equation with Manning’s equation to generate runoff volumes and the catchment hydrograph.

Continuous simulation is generally preferred over event-based simulation, as it takes into consideration antecedent moisture conditions. The infiltration rate and the runoff generated is largely a function of antecedent moisture conditions. Given enough spatial and temporal input data, SWMM provides a very realistic picture of watershed rainfall-runoff processes.

Modelling of the physical process occurring within the watershed allowed evaluation of different detention pond scenarios.

As the site is ungauged, stream flow and precipitation measurements were not available for model calibration and validation. However, rainfall and runoff data collection is recommended for this site. Event based simulation dominated the modelling process.

6.1 Water Quality Modelling

Certain land use activities create “hot spots” where stormwater runoff collects pollutants that should be treated through sedimentation in a pond facility. Modelling of runoff from these land use areas will be undertaken during the detailed design stage for each phase, where the proposed pond structural components will be optimized for sediment removal efficiency.

Potential land uses on Bear Mountain Highlands which fall into this category are listed below.

- vehicle storage areas (bus, truck, etc.)
- outdoor liquid container storage
- outdoor loading/unloading facilities
- public works storage areas
- facilities that generate or store hazardous materials
- commercial container nursery

6.2 Model Scenarios

The District of Highlands will require that the post development flows not exceed the predevelopment flows for all rainfall events up to the 200-year storm. Consequently, the 24 hour, 10-year and 200-year precipitation events were modelled. Additionally, actual hourly precipitation data was collected for the period covering August 1964 to August 1999. This period data was analyzed and the event occurring over the period of 18 – 21 January 1967 was used as input to the model.

6.3 Model Parameters

The average slope was determined by selecting between 5 – 8 points at the edge of each catchment, then calculating the path length of each point to the catchment outlet, dividing the path lengths by the change in elevation, and taking an area-weighted average of the slopes.

Infiltration was modelled using the Green-Ampt formulation, the preferred method in the absence of calibration data. The formulation is physically-based, and input values can be related to soil type. Infiltration parameters were estimated by identifying the soils in the Bear Mountain site from published data [10] and then finding the hydraulic conductivity and capillary suction for each soil type. The parameter values used are listed in Table 9.

Table 9: Soil Parameters

Soil description (Sprucebark, SJ)	Approx. depth from surface	Suction	Hydraulic conductivity	Initial moisture deficit
	(m)	(mm)	(mm/hr)	(-)
Cobbly loamy sand	0 – 1.0	102	120	0.34

Manning’s ‘n’ values were selected from the literature [3] based on average type of ground cover.

Table 10: Manning’s “n”

Scenario	Ground Cover	"n"
Pervious	Dense shrubbery & forest litter	0.4
Impervious	Concrete or asphalt	0.012

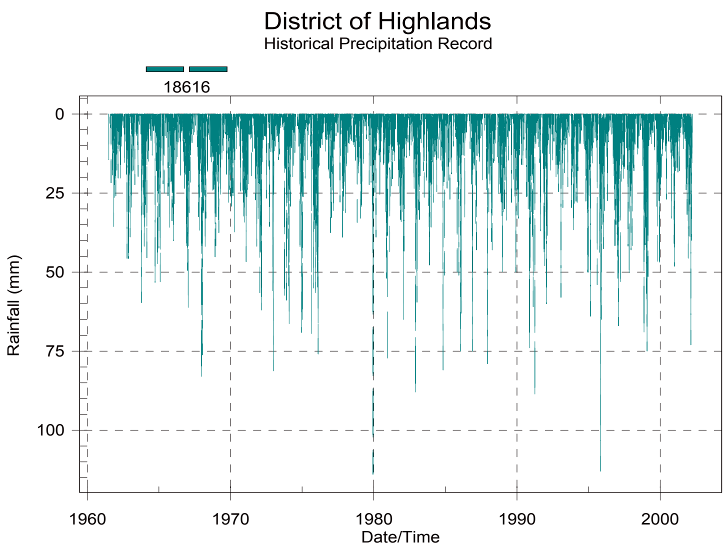
6.4 Precipitation

Historical and synthetic (i.e., derived) rainfall have been used in this study. The historical storm was found by inspection of a 40-year daily precipitation record (1 July 1960 – 30 March 2002) for District of Highlands (station 1018616).

Hourly data was not available so the analysis results are limited. However, the storm of 10 – 21 December 1979 was used because it had the largest rainfall depth occur on 13 December.

Winter storms most useful for design are usually greater than 10 hours, with gradually increasing rain intensity that often peaks late in the storm.

A comparison of the historic storm with the 10-year 24-hour design storm generated from the District of Highlands IDF curve (Gonzales) shows that the 10-year storm peak intensity is much higher, indicating that the design storm method is very conservative.

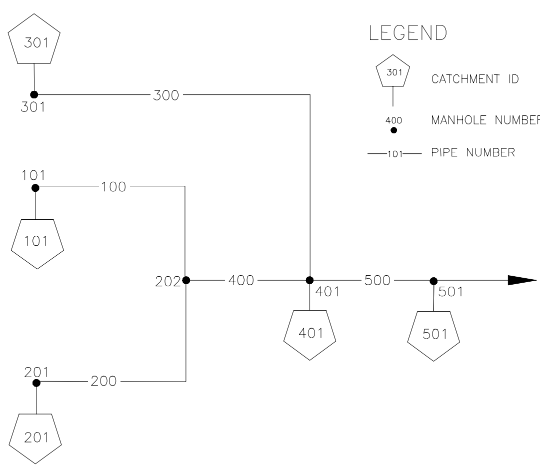


Synthetic design storms are hypothetical, but useful because the hyetograph shape can be formulated, as opposed to using a constant precipitation over the same duration. Either cyclonic or convective storm shapes are used in making the hyetograph. Cyclonic storms usually have the highest intensities near the middle of the event, whereas convective storms usually have it near the beginning. A cyclonic storm shape was chosen because it appeared to better represent the local conditions.

The storm duration chosen for the modelling was of 24-hour duration.

6.5 Model Results

The catchment schematic used to formulate the computer model is shown below.



Modelled runoff results for each catchment are summarised in Tables 11a-c, as well as in the hydrograph plots. The plots show the pre and post development uncontrolled peak flows and the attenuated (controlled) flows resulting from end-of-pipe controls. Note that in each case the controlled post development flow is less than or equal to the predevelopment flow.

Due to the absence of recorded stream flow data for the site, calibration was not possible.

Table 11a: Comparison of Pre and Post Development Peak Flows

Catchment	Predevelopment	Controlled Post Development	Uncontrolled Post Development
	200-year design storm peak flows		
101	0.46 m3/s	0.45 m3/s	0.61 m3/s
201	1.31 m3/s	1.29 m3/s	1.40 m3/s
301	0.77 m3/s	0.76 m3/s	0.85 m3/s
401	0.75 m3/s	0.75 m3/s	1.06 m3/s
501	0.67 m3/s	0.63 m3/s	0.72 m3/s
	10-year design storm peak flows		
101	0.07 m3/s	0.06 m3/s	0.20 m3/s
201	0.29 m3/s	0.29 m3/s	0.35 m3/s
301	0.15 m3/s	0.14 m3/s	0.23 m3/s
401	0.12 m3/s	0.11 m3/s	0.35 m3/s
501	0.14 m3/s	0.12 m3/s	0.18 m3/s
	10 – 21 December 1979 peak flows		
101	0.02 m3/s	0.02 m3/s	0.02 m3/s
201	0.06 m3/s	0.05 m3/s	0.10 m3/s
301	0.04 m3/s	0.04 m3/s	0.04 m3/s
401	0.04 m3/s	0.04 m3/s	0.15 m3/s
501	0.03 m3/s	0.03 m3/s	0.07 m3/s

Table 11a shows the predevelopment peak flows, the post development (uncontrolled) peak flows and the controlled peak flows for the design storms and the historic storm. These figures show that the uncontrolled peak flows can be reduced to predevelopment rates. Table 11a also shows that the post development peak runoff from the historic storm is much less than that occurring from the 10-year design storm.

Peak flows were reduced by simulating the effects of stormwater detention. Detention can be accomplished in many ways, other than the traditional method of constructing detention ponds. Additional methods for the golf course include increased subsurface storage capacity from sand – peat soil fill on the greens, tees and fairways. (See App. B) For residential areas, this could be done through bylaws mandating the above described lot level conveyance controls.

Table 11b: Comparison of Pre and Post Development Runoff Volumes

Catchment	Predevelopment	Uncontrolled Post Development	Excess runoff
	200-year design storm runoff volume		
101	7,180 m3	10,400 m3	3,220 m3
201	10,500 m3	13,700 m3	2,200 m3
301	8,650 m3	11,700 m3	3,050 m3
401	12,400 m3	18,500 m3	6,100 m3
501	5,820 m3	7,630 m3	810 m3
	10-year design storm runoff volume		
101	595 m3	2,740 m3	2,145 m3
201	1,660 m3	3,863 m3	2,203 m3
301	1,030 m3	3,080 m3	2,050 m3
401	961 m3	4,910 m3	3,949 m3
501	863 m3	2,110 m3	1,257 m3
	Historical storm (10 – 21 Dec. 1979) runoff volume		
101	161 m3	161 m3	0 m3
201	539 m3	4,510 m3	3,971 m3
301	300 m3	300 m3	0 m3
401	258 m3	14,300 m3	14,042 m3
501	273 m3	4,030 m3	3,757 m3

Table 11b show the corresponding runoff volumes generated for each catchment for pre and post development flows. Obviously, the uncontrolled post development volumes are greater than the predevelopment volumes as a result of increased impervious surface areas.

The excess runoff is the difference between the predevelopment and the uncontrolled post development runoff volumes. It represents the volume of runoff that would be infiltrated using source controls and/or detained in a pond.

The minor system is designed to handle the 10-year runoff volume. The difference between the 10-year and 200-year runoff volumes will be handled by the major system when the minor system is at capacity during the 200-year storm event. The volume of water storage provided as a result of the sand – peat fill on the golf course greens (15,778 m^3) is over triple that required (4,226 m^3), as shown in Table 11c. The additional subsurface volume of runoff storage available occurring as a result of the shot rock fills used for road construction and lot pad development have not been included in this calculation. See Appendices A and B.

Table 11c Post Development Excess Runoff Volumes to Control

Catch.	10-year storm	200 year storm	200 minus 10-year storm
	Minor sys storage vol	Runoff volume	Major sys. volume
101	2,145 m3	3,220 m3	1,075 m3
201	2,203 m3	2,200 m3	0 m3
301	2,050 m3	3,050 m3	1,000 m3
401	3.949 m3	6,100 m3	2,151 m3
501	1,257 m3	810 m3	0 m3
	Total storage required		4,226 m3
Storage available from sand on golf course (see App. A)			15,778 m3

7.0 CONCLUSIONS AND RECOMMENDATIONS

This study was undertaken to evaluate the impact of increased stormwater runoff from the development of an 18-hole golf course and residential development on Bear Mountain in the District of Highlands.

Runoff volumes have been determined for each catchment. Although the SWMM simulated a wet pond to reduce post development peak flows to pre development rates, the implementation of a combination of this type of treatment and increased subsurface storage could be used to attain this control. The modelling confirmed the magnitude of control required.

A quick calculation shows that there is enough golf course storage being provided on the greens, tees and fairways to reduce the post development runoff rates to the pre development levels for the 10- and 200-year design storms.

When compared to the historical rainfall record for the District of Highlands for the period covering 1961 to 2003, the design storm approach significantly exaggerates the precipitation depths.

Based on the information gathered and assessed to date, the following recommendations are provided:

1) Set up stream flow monitoring and rainfall collection stations to gather base line surface water data for comparisons with the site in its developed condition.
2) Install level recording equipment in the pumping & observation wells to monitor groundwater fluctuations.
3) Monitor changes in geomorphic stream features in areas where post development impacts could occur.
4) Prepare a water balance to include stormwater and groundwater source volumes, stockage areas and irrigation consumption.
5) Prepare a detailed design report for the permanent and temporary facilities to accompany subdivision drawings submission

8.0 REFERENCES

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