Best Management Practices Guide
For Stormwater

Prepared for

Greater Vancouver Sewerage and Drainage District
4330 Kingsway
Burnaby, B.C.

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Prepared by:

Allan Gibb, Harlan Kelly
DAYTON & KNIGHT LTD.
P.O. Box 91247 (612 Clyde Avenue)
West Vancouver, B.C., V7V 3N9

Thomas Schueler
CENTRE FOR WATERSHED PROTECTION
8391 Main Street
Ellicott City, MD  21043

Richard Horner
230 NW 55th Street
Seattle, WA  98107

Joseph Simmler, John Knutson
ECONOMIC & ENGINEERING SERVICES INC.
12011 Bel-Red Road, #201
Bellevue, WA  98009
PROLOGUE

The Greater Vancouver Sewerage and Drainage District (GVS&DD) and its member municipalities are committed to the principle of managing liquid wastes in a manner which protects the receiving environment using cost-effective approaches. This commitment is detailed in the 1996 Liquid Waste Management Plan (LWMP) submission for the GVS&DD area and is the basis for development of the Stage 2 LWMP. The LWMP process is mandated by the provincial government and is designed to facilitate an integrated and local approach to making liquid waste management decisions. Within the GVS&DD area, effective management of urban stormwater runoff is a key component of the LWMP.

As the responsibilities for stormwater management rest primarily with municipalities, the stormwater management component of the LWMP is intended to help municipalities address stormwater management in a regional context while recognizing the uniqueness of each municipality, their needs, priorities and objectives. To help develop the stormwater management component, the Stormwater Management Technical Advisory Task Group (SWTG), which is comprised of municipal, GVS&DD, senior government, and independent members, was established in May, 1997.

This report examines options for stormwater Best Management Practices (BMPs) in the context of local economic, geologic, and climatic conditions. The SWTG has chosen to present stormwater BMP options in the form of a high-level guide, addressing three levels of stormwater BMPs: operations and maintenance; non-structural; and structural, plus a separate appendix, outlining sediment control BMPs.

For more information on this or any other Liquid Waste Management Plan programs, please contact:

GVRD
Policy and Planning Department
Regional Utility Planning
4330 Kingsway
Burnaby, B.C., V5H 4G8
Phone: (604) 436-6800
Fax: (604) 436-6970
ACKNOWLEDGEMENTS AND REPORT REVIEWERS

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Igor Zahynacz, P.Eng. City of Port Coquitlam
Tony Barber, P.Eng. City of North Vancouver
Eric Emery, P.Eng. City of Surrey
Hugh Fraser, P.Eng. Corporation of Delta
Bill Jones City of Richmond
Greg Scott, P.Eng. City of White Rock
Steven Lan, P.Eng. Township of Langley
Mike Iviney, A.Sc.T. City of Coquitlam
Steve Mctaggart, P.Eng. City of Vancouver
Bernie Serné, A.Sc.T. District of Maple Ridge
Barry Chilibeck, P.Eng. Department of Fisheries and Oceans Canada
Chris Jenkins, P.Eng. Ministry of Environment, Lands and Parks, Victoria
Jian Guo, P.Eng. Ministry of Environment, Lands and Parks, Surrey
Marielou Verge, M.R.M. Environment Canada
Bob Gunn, Dipl. Tech. Fish, Wildlife & Rec. Program, BCIT
Ted Van der Gulik, P.Eng. Ministry of Agriculture and Food
Stan Woods, P.Eng. Greater Vancouver Regional District
SYNOPSIS BY STORMWATER MANAGEMENT TECHNICAL ADVISORY TASK GROUP

This synopsis addresses how this stormwater Best Management Practices (BMP) guide was developed, how it is intended to be used, and the next steps in the Liquid Waste Management Plan (LWMP) process. A summary of the BMP guide is contained in the Summary and Report Overview that follows.

Senior governments are putting significant pressure on local governments to take more proactive roles in stormwater management and environmental protection. Recent legislative initiatives provide local governments with new options and opportunities for protecting the environment and managing stormwater runoff. Given the unique geography, topography, needs, and resources of each municipality, this guide is intended to assist in the pre-screening and selection of stormwater BMPs, and reduce the uncertainty surrounding the costs and effectiveness of different BMP technologies, particularly those adapted from outside the region.
SUMMARY AND REPORT OVERVIEW

The purpose of this document is to provide member municipalities of the Greater Vancouver Sewerage and Drainage District (GVS&DD) with a toolbox consisting of a series of stormwater best management practice (BMP) options that are applicable within the GVS&DD area. This document is not intended to recommend or prescribe any specific BMP options, but rather to summarize the costs, benefits and applicability of each BMP discussed, so that each individual municipality can select BMPs that suit its own unique needs.

This document is designed for use as a planning tool; it is not intended for use as a design manual. General design requirements and constraints are included where appropriate for the various BMP options, along with schematic drawings for illustrative purposes. Detailed design information can be found in the manuals referenced in this document.

The BMP options contained in this document have been classified into three broad categories, namely Non-Structural BMPs, Structural BMPs, and Operational and Maintenance BMPs. Erosion and sediment control BMPs for construction sites are contained in Appendix H under separate cover. Regulatory options for stormwater management within the GVS&DD were developed previously (D&K et al., 1998).

To assist municipalities in determining which BMPs can be expected to meet municipal-specific goals and priorities as well as site-specific constraints and criteria, a screening and selection procedure using tabular matrices is described in Section 2. The GVS&DD and its member municipalities can use the six-step procedure in Section 2 to help develop detailed stormwater management plans, and/or to address specific aspects of existing stormwater management systems.

Section 3 contains detailed discussion of the Non-Structural BMPs selected for this manual. General descriptions, implementation requirements, performance capabilities, limitations, costs, and benefits are included.

Structural BMPs are discussed in Section 4, including a description of each BMP, potential applications, design considerations and schematic drawings, pre-treatment and post-treatment requirements, documented performance in removing contaminants, limitations, implementation requirements, operation and maintenance requirements, and costs versus benefits.

Section 5 contains detailed discussion of the Operational and Maintenance BMPs selected for this manual. General descriptions, implementation requirements, schematic drawings, performance capabilities, limitations, costs, and benefits are included.
Non-Structural and Operational and Maintenance BMPs are often funded by various agency departments, making cost tracking and estimation difficult. Cost estimates for Non-Structural and Operational and Maintenance BMPs were estimated from values reported in the literature, contacts with jurisdictions in the states of Washington and Oregon, local information, and the experience of the project team.

Various agencies responsible for Operational and Maintenance and stormwater program activities in the states of Oregon and Washington were contacted. The agencies were asked to provide detailed cost information regarding Non-Structural and Operational and Maintenance BMPs. A primary source of information was the Unified Sewerage Agency (USA) of Washington County, Oregon. USA is responsible for regulating, managing, and maintaining surface water, sewage, and stormwater systems for over 155,000 homes and businesses in the urban area west of Portland, Oregon. Approximately 20% of USA’s efforts are devoted to managing stormwater and surface waters for quality and quantity concerns. USA currently maintains about 200 stormwater BMPs, including a mixture of quantity control detention ponds, water quality ponds, swales, stormwater filters, and constructed wetlands. The agency imposes an average monthly stormwater fee of Cdn $6.00 (US $4.00) on the service population in addition to system connection charges.

USA provided annual operating budgets (1999) for some of the BMPs detailed in this study. The costs are presented on a per capita basis (program unit cost/population) and a unit service area basis (program unit cost/services area). In some cases, the USA budget include both sanitary and stormwater activities. In these instances, the assumption of a 20% stormwater and 80% sanitary allocation of costs was made. The values from USA include all operation and maintenance or program costs except for office space. Educational BMP costs are funded equally from sanitary and stormwater funds. Typical USA costs include salaries and benefits, materials, supplies, rental equipment, office supplies, administrative costs, and miscellaneous expenses.

An overview of Non-Structural BMP costs and benefits is included at the end of Section 3, to assist in determining relative advantages and disadvantages of each BMP in light of watershed goals and objectives. For comparative purposes, an urban municipality 10,000 hectares in area with a population of 150,000 was assumed. The costs of each Non-Structural BMP when applied to this municipality using the costing data contained in Section 3 are summarized in Table 3-1 at the end of Section 3-1. The degree to which each BMP meets the overall watershed goals is included in Table 3-1.

Some Structural BMPs have been extensively used at full scale, and general equations have been developed for capital and O&M costs (e.g., Brown and Schueler, 1997). Others are relatively new, and little cost data are available. A recent report by the Centre for Watershed Protection in the state of Maryland reports costing estimates and equations for BMPs based on an extensive...
review of the available information in the U.S. to date (CWP, 1998). The costs and equations in
the CWP report were adjusted for inflation and normalized to the “twenty cities average”
Engineering News Record construction cost index to adjust for regional biases, based on a
methodology followed by the American Public Works Association (APWA, 1992). The CWP
report includes a cost adjustment factor to adapt the twenty cities average costs to each of the
U.S. Environmental Protection Agency’s nine rainfall regions.

For the purposes of this study, the CWP twenty cities average cost equations were adjusted to the
Seattle area (rainfall region adjustment factor = 1.04). In cases where cost equations were not
developed in the CWP study for BMPs included in this manual, estimated costs were based on an
extensive review of the literature, on the experience of the study team, and on contacts with
suppliers and stormwater professionals in Washington State and Oregon. Sources are referenced
in the text for all cost estimates. Costs in U.S. dollars were multiplied by a factor of 1.5 to
convert to Canadian dollars.

An overview comparison of Structural BMP costs and benefits is included at the end of Section
4, to assist in determining the relative advantages and disadvantages of each BMP in light of the
watershed goals and objectives. For comparative purposes, three example sites were developed,
a 15 ha residential area, a 2 ha municipal office complex, and a 0.5 ha municipal repair and
maintenance yard. Appropriate BMPs for each type of development were selected according to
the design criteria and limitations described in Section 4. Capital and O&M costs for the BMPs
considered applicable to the residential area, the office complex, and the repair yard are
summarized in Tables 4-1, 4-2, and 4-3, at the end of Section 4. The degree to which each
example BMP meets the overall watershed objectives described in Section 2 is included in
Tables 4-1 through 4-3.

An overview of Operational and Maintenance BMP costs and benefits is included at the end of
Section 5. For comparative purposes, an urban municipality 10,000 hectares in area with a
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1.0 INTRODUCTION

1.1 Background and Objectives

The purpose of this document is to provide member municipalities of the Greater Vancouver Sewerage and Drainage District (GVS&DD) with a toolbox consisting of a series of stormwater best management practice (BMP) options that are applicable within the GVS&DD area. This document is not intended to recommend or prescribe any specific BMP options, but rather to summarize the costs and benefits of each BMP discussed, so that each individual municipality can select BMPs that suit its own unique needs. To assist municipalities in determining which BMPs can be expected to meet municipal-specific goals and priorities as well as site-specific constraints and criteria, a screening and selection procedure using tabular matrices is included, along with illustrative examples. The GVS&DD and its member municipalities can use this document for the development of detailed stormwater management plans, and/or to address specific aspects of existing stormwater management systems.

This document is designed for use as a planning tool; it is not intended for use as a design manual. General design requirements and constraints are included where appropriate for the various BMP options, along with schematic drawings for illustrative purposes. Detailed design information can be found in the manuals referenced in this document.

The BMP options contained in this document have been classified into three broad categories, namely Non-Structural BMPs, Structural BMPs and Operational and Maintenance BMPs. Erosion and sediment control BMPs for construction sites are contained in Appendix H under separate cover. Regulatory options for stormwater management within the GVS&DD were developed previously (D&K et al., 1998).

1.2 Stormwater Management in the Municipal Context

In general within the GVS&DD, stormwater systems are designed to accept only uncontaminated runoff, and there are restrictions on stormwater discharges to sanitary sewer systems (see Appendix F). A significant portion of stormwater runoff originates on private property (runoff from buildings and driveways), and is often collected into ditches or pipes before being discharged downstream into the municipal stormwater system. Municipalities usually operate the larger and downstream portions of stormwater management and conveyance systems. Municipally operated systems, which may include man-made facilities such as swales, ditches, and pipes, usually discharge the stormwater into a naturally existing stream or watercourse.

The development of urban infrastructure (roads, parking lots, housing, stormwater drainage systems) and human activities (vehicle use, lawn care, etc.) changes the characteristics (quantity and quality) of stormwater runoff. These changes may impact the receiving environment by
causing such things as flooding and erosion, habitat damage, reduced species diversity, elevated contaminant concentrations, and degraded water quality.

Ideally, stormwater is managed on a watershed basis within the broad framework of land management and ecosystem planning. Some of the available stormwater management and watershed protection tools are as follows:

- education, awareness, and stewardship programs for the watershed community;
- planning of watershed goals and objectives;
- environmental inventory, monitoring, and impact assessment studies;
- protection of sensitive areas, trees, and riparian buffers;
- land use planning to focus development in less sensitive areas;
- erosion and sediment control, particularly during construction; and
- stormwater best management practices (source control, structural, treatment, etc.).

Municipalities are responsible for many aspects of planning, operating, and maintaining stormwater management systems, and they have significant influence over land development and management of stormwater on private property. However, the entire watershed community (senior and local governments, developers, industry, farmers, public, etc.) must work together for good stormwater management and environmental protection to be achieved. This report has been prepared for the municipal audience, and it focuses on specific aspects of stormwater management over which municipalities have jurisdiction or significant influence. As such, this report is only one step towards better stormwater and environmental management in the municipal context.

1.3 Conduct of Study

This study was undertaken by a team of consultants in conjunction with the GVS&DD and the Stormwater Management Task Group (SMTG). The terms of reference for the study are included in Appendix A.

The consulting team initially obtained and reviewed information on stormwater best management practices within the GVS&DD and elsewhere. Attention was focussed on the Puget Sound area of Washington State, since this area is relatively advanced in stormwater management, and climatic and geological conditions are similar to those in the GVS&DD. The information was used to prepare a comprehensive, preliminary list of BMPs to be considered for inclusion in the draft report. Draft procedures for screening and selecting appropriate BMPs for specific local situations were developed in conjunction with the preliminary list.

The preliminary list and draft BMP selection procedures were then reviewed and discussed at a workshop that included key members of the consulting team, representatives of the GVS&DD, members of the SMTG, and interested others. The primary purpose of the workshop was to
revise and refine the preliminary list to focus on proven BMPs that were judged to be potentially successful under local conditions. The key findings of the workshop are summarized in Appendix B.

The BMPs contained in the revised list were carried forward for more detailed evaluation, including design requirements, performance limitations, implementation requirements, costs, and benefits. A draft report was then prepared by the consulting team. Key members of the consulting team and the GVS&DD reviewed and discussed the format and content of the draft report with the SMTG at a half-day workshop. The GVS&DD prepared a summary of relevant comments based on the workshop feedback and on subsequent review of the draft report by members of the SMTG. The final report was then prepared and submitted to the GVS&DD.
2.0 INSTRUCTIONS FOR THE USE OF THIS DOCUMENT

This section contains a six-step procedure for use in selecting stormwater BMPs. It is important to emphasize that there are no generic solutions for stormwater management. Each situation has unique aspects that must be addressed, if a successful long-term stormwater management plan is to be developed. The selection procedure described in this section is designed to assist municipalities in developing a combination of BMPs that are realistically achievable, and will meet their own specific needs, as well as those of regulatory agencies and other stakeholders.

Most stormwater BMPs are designed to accomplish specific goals. Therefore, before attempting to select BMPs, a clear definition of goals and of the priorities associated with those goals must be developed. The goals and priorities for a specific situation in turn depend on a range of factors that include geographical, ecological, regulatory, economic, and social-political issues. These issues must be considered at the outset, if a realistic set of goals and priorities is to be developed for use in selecting appropriate BMPs.

To ensure that all of the important issues for a study area are considered in developing the goals and priorities, a watershed inventory should be assembled. The inventory is required to determine the current state of the study area and its aquatic resources, and to assess the probable long-term stormwater impacts on those resources in light of the community land use plan. In addition, stormwater management measures must be compatible with regulatory requirements. The watershed inventory provides the information necessary to ensure that regulatory requirements and decisions regarding the location and level of BMP application are reflected in the goals and priorities developed for BMP selection. For the purposes of this discussion, four levels of BMP application can be identified as follows:

(a) **anti-degradation** – avoid deterioration of a resource;  
(b) **enhancement** – improve a degraded resource to some degree;  
(c) **restoration** - return a degraded resource to a state similar to what likely existed before extensive, permanent human occupancy; and  
(d) **preservation** - retain a resource in its current state.

Some combination of the above levels of application may be appropriate, depending on the specific situation. It must be recognized that development of a pristine watershed or area will result in some degradation of aquatic resources, regardless of what BMPs are used. Anti-degradation may be taken as a minimum level of application to stem resource losses. The degree to which enhancement is possible is a function of the watershed condition. Full restoration is a virtual impossibility when the watershed has been changed much, because its hydrology and chemistry no longer support the habitat that nourished all biota once present. Furthermore, with substantial change from the original state, conditions generally cannot be cost-effectively manipulated using Structural BMPs to recreate that support system. Therefore, implementing a preservation level of application requires the use of Non-Structural BMPs that prevent
substantial watershed change in the first place; in this case, the importance of planning cannot be over emphasized. Aquatic resources in an altered (non-pristine) watershed can feasibly be enhanced to some degree short of achieving full restoration through the application of Structural, long-term Non-Structural, and Operational and Maintenance BMPs in the watershed, as well as appropriate stream habitat improvements.

The use of the word “watershed” implies that analysis and planning is conducted on a large scale encompassing a major river basin. However, it is recognized that, in many cases, planning is carried out for designated study areas on a much smaller scale. The BMP selection procedures described in this document may be applied to large-scale planning for entire river basins, or to smaller sub-watershed areas within those basins.

Each municipality in consultation with resource management agencies must make decisions regarding the proposed level of BMP application to preserve or enhance specific aquatic resources. All important aquatic resources should be considered, be they located in relatively pristine (undeveloped) watersheds or in heavily urbanized areas. Setting priorities at the outset will help municipalities to focus their limited financial and technical resources where they will be the most effective. Priorities will vary, depending on the needs and visions of individual municipalities.

An early draft of this manual (October, 1998) was designed to integrate the BMP selection procedure with the September 1998 draft of a watershed classification system (entitled Proposed Watershed Classification System for Stormwater Management in the GVS&DD Area) that was being developed by others. The draft watershed classification system that was incorporated into the October 1998 BMP Guide was subsequently found to be inconsistent with the current legislation and policies of Fisheries and Oceans Canada and the BC Ministry of Environment, Lands and Parks, and the BMP selection procedure required revision. This (revised) BMP guide incorporates a selection procedure that is consistent with existing legislation and policies; the text from the October 1998 draft is included in Appendix G for information only.

The BMP selection procedure is outlined on Figure 2-1. As shown, Step 1 is to conduct the watershed inventory, followed by development of the watershed goals and priorities in Step 2. Steps 3 through 5 contain an iterative procedure to develop and refine a list of BMPs that address the goals and that are appropriate for the specific attributes of the study area. Step 6 is to evaluate the BMP implementation requirements, costs, and benefits, and select BMPs that best address the goals and priorities, while remaining sustainable in the long term. Each of the six steps in the selection procedure is described in more detail below.
Figure 2-1: BMP SELECTION PROCESS
2.1 Step 1: Watershed or Study Area Inventory

The primary aims of the watershed inventory are to evaluate existing conditions, identify aquatic resource activities/uses within the watershed or designated study area (water supply, aquatic and wildlife habitat, fisheries, agriculture, recreation, tourism, aesthetics, etc.), and assess threats to those resources caused by storm runoff. The inventory should include assembly of existing data (soils, land use, resource and receiving water use, surface and subsurface drainage systems, water and sediment quality, hydrology, hydrogeology, etc.), analysis of the need for new studies, and identification of interested and affected parties (stakeholders). General guidance on compiling a watershed inventory is available elsewhere (e.g., MOELP, 1992).

The recently published GVS&DD guide for assessing watershed health (GVS&DD, 1999) can be used as a tool to help determine the current state of a watershed. The guide can also be used to evaluate the impact of the community land use plan on future watershed health, and to assess the potential beneficial effects of BMPs that affect land use planning (e.g., restrictions on impervious area and protection of riparian areas).

The GVS&DD classification of watershed health is based on two factors, the percentage of the watershed area covered by impervious surfaces, and the percentage of a 30-meter wide riparian strip on both stream banks in forested land cover. Based on this system, watersheds are classified into four categories, ranging from excellent (low impervious area, extensive intact riparian buffers) to poor (high impervious area, minimal riparian buffers). For guidance on assembling watershed impervious cover and riparian forest cover data and classifying watershed health, refer to GVS&DD (1999).

Regulatory requirements should be included in the watershed inventory, since they play an important role in setting goals and priorities. In some parts of British Columbia, projects that involve work in or about streams and emergency works in watercourses depend in part on a stream classification system. The classification system endorsed by the Federal Department of Fisheries and Oceans (DFO) and the BC Ministry of Environment, Lands and Parks (MOELP) contains four classes based upon fish use that apply to every watercourse, including streams, lakes, and ditches as follows (see GVS&DD, 1999 and MOELP, 1998 for more detail):

a) Class A – inhabited by salmonids and/or rare or endangered species year-round, or potentially inhabited year-round with access enhancement;

b) Class A(O) – inhabited or potentially inhabited with access improvement by salmonids only during the overwintering period, with non-salmonid species often present year-round;

c) Class B – no documented or reasonable potential for fish presence but functions as a significant source of food and nutrient to downstream fish; and

d) Class C – no documented or reasonable potential for fish presence and has insignificant food and nutrient value to downstream fish.
Classification of open watercourses, ditches, ponds, lakes, etc. according to the above system will assist municipalities in identifying important fisheries resources, and it may be a requirement of regulatory agencies for project approval in any case.

Once the watershed inventory has been assembled, Step 2 can be undertaken. It is likely that the need for further study will be identified during Step 1. In some cases, it may be decided that this additional information is essential before Step 2 can be undertaken. In many cases, however, it will be possible to proceed with Steps 2 through 6, with the understanding that additional future information may affect some aspects of the stormwater management plan.
2.2 Step 2: Develop Goals, Objectives, and Priorities

2.2.1 General Description

Step 2 is to develop a list of general goals and specific objectives for each watershed or study area, and to set priorities for those goals based on the information assembled in Step 1.

Each municipality will have different policies and visions for the future, depending on the existing and planned level of development, physical and climatic characteristics, existing and potential aquatic resources, and social and political situation. Before attempting to select BMPs, each municipality should identify realistic overall goals for stormwater management within a particular watershed that reflect the proposed level of BMP application (anti-degradation, enhancement, restoration, preservation). This may be an iterative procedure; for example, a municipality may begin with goals that include a relatively high level of BMP application (e.g., restoration), and then discover during Steps 3 through 6 that this level of application is practically or economically infeasible. In that case, the goals may have to be modified to reflect a lower level of BMP application (e.g., enhancement or preservation), or additional financial/technical resources may have to be identified.

The municipality should set priorities for the goals and objectives relative to the prospects for achieving them in the context of the existing condition of the watershed and the importance of success from the aquatic resource protection and renewal standpoint. The priorities should be separated into high, medium, and low categories. Other stakeholders (e.g., DFO, MOELP, citizens groups, businesses, etc.) may have additional or different goals and priorities for a particular watershed; the needs of these other stakeholders should be taken into account in developing the goals and priorities. The Habitat Protection Branch of MOELP, Lower Mainland Region, expects that stormwater BMPs will meet essential fish and/or wildlife habitat and ecosystem health protection or improvement requirements.

Figure 2-2 shows a suggested list of general watershed goals and specific objectives that serve each of those goals. Many of the goals and objectives are interrelated, and they should be regarded as components of an integral whole. For example, the objective Minimize Streambank Erosion is listed under the goal Protect Life and Property (Figure 2-2). However, this objective also serves the goals Protect Fish Habitat (Turbidity and Sedimentation), Protect Water Quality (Sediment), and Community Support and Acceptance (Fish and Wildlife Habitat, Aesthetics, Public Safety). The selection procedure is designed to assist municipalities in designing a cost-effective stormwater management plan, by identifying BMPs that serve multiple goals and objectives.

Sections 2.2.2 through 2.2.5 contain brief descriptions of the goals and objectives shown on Figure 2-2.
Step 2: Develop Watershed Goals, Objectives and Priorities

FIGURE 2-2: SUMMARY OF CANDIDATE GOALS AND OBJECTIVES

- Community Support and Acceptance
- Parks and green space
- Fish and wildlife habitat
- Aesthetics
- Public safety

- Protect Water Quality
- Sediment and phosphorus
- Nitrogen and phosphorus
- Heavy metals
- Oil and grease
- Harmful organisms

- Protect Fish Habitat
- Water temperature
- Turbidity and sedimentation
- Dissolved oxygen
- Stream structure
- Groundwater recharge
- Water level fluctuations
- Vegetation / food supply
- Water quality

- Protect Life and Property
- Control flooding frequency
- Minimize streambank erosion
- Prevent drainage obstructions
- Worker / public safety hazards

List of Priority Goals and Objectives
2.2.2 Protect Life and Property

Protection of Life and Property, and the specific objectives under that goal, should be a high priority in all stormwater management programs. However, actions taken to meet this goal and its objectives must be consistent with other goals and their objectives, which are a function of resource anti-degradation, enhancement, restoration, or preservation. For example, armoring a stream bank might be acceptable in a stream reach that does not constitute fish habitat (e.g., designated Class C under the DFO/MOELP system), but it would generally be both unnecessary and inconsistent with fish habitat protection in a stream reach that does or potentially could constitute fish habitat (e.g., designated Class A). In the second case, protection of life and property should be achieved by keeping human habitation away from potential flooding, and by preserving the natural soil and vegetation system, measures that also protect habitat.

For the purpose of evaluating BMPs, four separate objectives serving the goal of Protect Life and Property were identified (Figure 2-2). These individual objectives, which are briefly discussed below, may have higher or lower priorities in different municipalities, depending on the nature of the watershed and the drainage infrastructure, as well as present and future land use.

Control Flooding Frequency – Development generally increases the risk of flooding downstream, due to greater runoff volumes and flow rates caused by the increase in impervious area that accompanies development. Control of peak runoff flow rates can be used to prevent or mitigate major flooding events that might result in extreme damage to property and significant risk to life. Major flooding events normally occur during large, infrequent storms when major drainage flow paths such as roads and streams are overwhelmed. Control of peak runoff flow rates can also be used to prevent minor flooding that might result in localized damage to property, but would not normally result in extreme damage to property or significant risk to life. Minor flooding events normally occur during smaller, more frequent storms that overwhelm the minor drainage infrastructure such as community storm sewers and ditches. Methods of reducing peak runoff flow rates include temporarily detaining collected runoff water in storage structures with subsequent release at controlled rates, minimizing the impervious area associated with development, and promoting infiltration of precipitation into the soil. Infiltration reduces the volume of runoff as well as the peak flow rate, while detention reduces only the peak flow rate.

Minimize Streambank Erosion – Development often results in increased stream bank erosion, due to the greater frequency and duration of highly erosive bankfull flows caused by increased runoff volumes. Erosion in watercourses increases the risk of landslides and slumping of banks, with consequent risk to life, loss of property, and damage to buildings and infrastructure. Substantial habitat loss also accompanies erosion of stream beds and banks. In addition, deposition of eroded materials downstream obstructs drainage paths
and damages fish habitat. Streambank erosion can be controlled by reducing the frequency and/or duration of bankfull flows through similar measures to those described above for controlling peak runoff rates, and by stabilizing streambanks with vegetation or non-erodible material.

Prevent Sedimentation and other Drainage Obstructions – Deposition of eroded materials and dumping of fill materials, trash and debris in or near watercourses may result in obstruction of drainage paths (watercourses and piping systems). Obstruction of drainage paths reduces the flow capacity, with a consequent increase in the risk of flooding, due to overtopping of streambanks and inundation of piping systems. Obstructions in watercourses also increase the flow velocity, which contributes to streambank and streambed erosion. Methods of preventing drainage obstructions include control of erosion and sedimentation, and prevention of unauthorized dumping.

Worker/Public Safety Liabilities – Some drainage works such as open ponds and storage structures may have associated safety risks for municipal maintenance workers and members of the public. These risks can be minimized by careful design and operation of facilities. Safety issues are further discussed in Section 2.2.5.

2.2.3 Protect Fish Habitat

Protection of fish habitat is a high priority goal in most watersheds, particularly those that have been identified as significant fish habitat areas. On the other hand, restoration or enhancement of fish habitat may not be a realistic goal in heavily developed urban watersheds that have few if any surface streams. For example, enhancing or restoring fish habitat might be regarded as a higher priority in a Class A watercourse than in a Class B or C watercourse, because the potential for resource gain is greater in the less impacted watershed. Similarly, habitat preservation would be considered more important than restoration or enhancement in a Class A or B watercourse, because the certainty of success is greater when acting to keep what exists than when manipulating the environment in an attempt to regain what is lost.

As shown on Figure 2-2, eight specific objectives serving the goal Protect Fish Habitat were identified; brief descriptions of these objectives are given below.

Water Temperature – Removal of streamside natural vegetative cover generally results in solar warming of unshaded watercourses and ponds. This in turn may result in a significant rise in water temperature. Many important species of fish such as salmon and trout require cold water to survive. Solar warming of water can be minimized by promoting shading vegetation in strategic locations.

Turbidity and Sedimentation – Discharges of urban surface runoff often contain suspended solids or other contaminants that increase the turbidity of the water in receiving streams. Since salmon and trout feed by sight, an increase in turbidity often has
a negative impact on fisheries resources. Settling of suspended solids may also clog spawning gravels and block spawning paths. Turbidity and sedimentation in stormwater discharges can be minimized by controlling erosion, by settling or filtering suspended solids in structural treatment facilities, by source control, and by removal of settled sediments from stormwater conveyance systems.

*Dissolved Oxygen* – Urban surface runoff often contains degradable organic material such as plant litter and animal droppings that exerts an oxygen demand when it is bacterially decomposed in receiving waters. This results in a reduction in the dissolved oxygen concentration in streams and ponds, which may stress or kill fish. Source control can be used to minimize the oxygen demand of stormwater discharges. Removal of oxygen demanding material from stormwater discharges by treatment is discussed in Section 2.2.4.

*Stream Structure* – The structure of streams is sometimes altered by straightening and armouring of banks to increase the flow capacity, by removing natural organic debris, by erosion and sedimentation, or by dumping of materials near or in streams. These activities generally have a negative impact on fisheries, by changing the stream pool structure and by damaging or eliminating spawning beds and fish habitat. Stream structure can be preserved by maintaining natural, open watercourses, and by prevention of erosion and sedimentation.

*Groundwater Recharge* – The most significant impact of urban development on the hydrology of streams is the decrease in pervious area caused by the construction of impervious surfaces (roads, buildings, etc.) This results in an increase in the amount of surface runoff, with a resulting decrease in the amount of precipitation infiltrating into the ground. This in turn results in decreased groundwater recharge and lower dry season base flows in streams. Low base flows during the dry season can damage or eliminate spawning beds and fish habitat. This can be mitigated by promoting groundwater recharge. Groundwater recharge may also be an objective where residents rely on wells for water supply. Groundwater recharge can be maintained by promoting infiltration of stormwater through minimizing impervious surface and by structural infiltration facilities. Contaminated stormwater routed to infiltration facilities should be treated before being allowed to percolate to the groundwater.

*Water Level Fluctuations* – The increase in runoff flow rates resulting from development often lead to greater water level fluctuations in receiving streams, lakes, and ponds during runoff events. Over the long term, increased water level fluctuations may reduce or eliminate native species (both plant and animal) in and near the stream, with a consequent negative impact on fish habitat and food supply. Water level fluctuations can be minimized by promoting infiltration of stormwater, and by temporarily detaining peak runoff flows in structural facilities.
Vegetation/Food Supply – The most obvious impacts of urban development on fish food supply are the removal of natural vegetated cover in the watershed, and the increase in impervious surface resulting from construction. Removal of natural streamside vegetation generally reduces or eliminates the insect population that many species of fish rely upon for food. Conservation or replacement of the native vegetative cover can help to maintain the natural food supply for fish.

Water Quality – Urban surface runoff is known to carry a variety of materials that have potential negative impacts on water quality, including sediment, excess nutrients, metals and trace elements, organic contaminants, floatable materials such as plastics, oxygen-demanding materials, oil and grease, and harmful bacteria and viruses. Most of these materials also have a negative impact on the survival of fish, either through toxicity or degradation of habitat. Water quality is discussed in more detail in Section 2.2.4.

2.2.4 Water Quality

The relative importance of water quality in stormwater management programs depends in part on the nature and use of the water bodies that receive urban runoff. Within the GVS&DD, the priorities associated with the goal Protect Water Quality are likely to be related to fish habitat, drinking water supplies, and protection of recreational/aesthetic values. Water quality may also be an issue in low-lying agricultural areas where irrigation water is taken from drainage ditches. As shown on Figure 2-2, seven specific water quality objectives serving the goal Protect Water Quality were identified; these objectives are described below. Source control BMPs for controlling stormwater contaminants should be emphasized, since treatment methods tend to be expensive, and the long-term effectiveness of treatment systems has yet to be established.

Sediment – Sources of sediments and solid particles in the urban environment include soil erosion, vegetation, human and animal waste, corrosion and wear of vehicles, weathering of structures and pavements, sanding and de-icing of roadways, and atmospheric deposition. Sediment and suspended solids carried by urban runoff may have a negative impact on fish habitat, as described in Section 2.2.3. In addition, many of the contaminants found in urban runoff such as metals and harmful organic compounds tend to associate with solid particles. This may result in an accumulation of potentially toxic contaminants in areas where solids tend to settle (e.g., near stormwater outfalls), with a consequent negative effect on the local aquatic community. Coarse suspended solids can often be removed from urban runoff by gravity settling. Some form of filtering may be required to remove finer solids that do not settle well.

Nitrogen and Phosphorus – Sources of nitrogen and phosphorus in urban runoff include decaying organic matter originating from plant and animal wastes, fertilizers, and atmospheric deposition. Both nitrogen and phosphorus are important plant nutrients, which may stimulate the growth of algae and other nuisance aquatic vegetation in surface waters (eutrophication). Phosphorus is normally of primary importance in fresh waters,
while nitrogen is more important in the marine environment. In addition, ammonia nitrogen and nitrite nitrogen are toxic to fish, while nitrate nitrogen is a health concern in drinking water. Nitrogen and phosphorus are often present in both soluble and particulate forms in urban runoff. Soluble forms, which cannot be removed by settling or filtering, are normally removed through biological uptake by plants and/or bacteria.

**Metals and Trace Elements** – Metals and trace elements found in urban runoff include lead, zinc, copper, cadmium, mercury, iron, nickel, and arsenic. Sources of metals in urban runoff include corrosion and wear of vehicles, wearing of road surfaces, fluid leaks from vehicles, vehicle exhaust, industrial emissions, paints and preservatives, pesticides, soil erosion, and illicit dumping. Arsenic is often used as an anti-caking agent in road salts. Many toxic metals and trace elements tend to accumulate in the food chain, and they may also be harmful to the quality of water used for water supply, aquatic habitat, and recreation. Some metals such as lead tend to associate with particulates, and so can be removed by settling or filtering. Other metals, including copper, zinc, and cadmium, may have a significant soluble fraction in urban runoff. Soluble metals are difficult to remove, although some revert to solid forms under certain conditions.

**Oil and Grease, Organic Contaminants** – Harmful organic compounds found in urban runoff include oil and grease (including hydrocarbons), plasticizers, polychlorinated biphenyls (PCBs), pesticides and anti-sapstain chemicals. Some of these are toxic, some are carcinogenic, and some tend to accumulate in biological tissue. Organic compounds may consequently be detrimental to the quality of water used for water supply, aquatic habitat, and recreation. The primary source of oil and grease and harmful organic contaminants in urban runoff is associated with the operation of motor vehicles (fluid leaks and spills, illicit dumping of used oils, tire wear, combustion byproducts). Sources of other harmful organic contaminants include pesticides, plastic products, asphalt, wood preservatives, paints and stains, and industrial emissions. High concentrations of oil and grease can sometimes be removed from stormwater by floatation. Some hydrocarbons tend to associate with particulates, and can be removed through settling or filtering. Some organic contaminants (e.g., certain pesticides) are mainly in soluble form, and are difficult to remove.

**Oxygen Demand** – Degradable organic matter present in urban runoff exerts an oxygen demand as it undergoes bacterial decomposition in receiving waters. The resulting low levels of dissolved oxygen in streams and ponds may have a negative impact on aquatic life forms, aesthetics and recreational values. Sources of oxygen-demanding substances in urban runoff include bird and animal droppings, plant debris, and putrescible garbage. Illicit connections between sanitary sewers and storm drains allow untreated sewage to enter the storm drainage system, greatly increasing the oxygen demand in the storm drainage water. Oxygen demand is normally present in urban runoff in both particulate and soluble forms. Particulate forms of oxygen-demanding materials can be removed through settling or filtering. Soluble forms normally require biological oxidation by bacteria.
**Bacteria and Viruses** – The presence of indicator bacteria such as fecal coliforms in receiving waters is generally taken as evidence that disease-causing bacteria and viruses may also be present. Sources of indicator bacteria in stormwater discharges include contamination from domestic sewage and animal droppings. Fecal contamination generally has a negative impact on the quality of water used for water supply, recreation, and aquatic habitat, due to health concerns. Fecal contamination can be removed from runoff to some extent by filtering or settling out solid particles, and by natural die off in biological treatment systems.

**Floatable Materials** – Floatable materials picked up by urban runoff include plastic products, cans and bottles, cigarette filters, and woody debris. These materials degrade the aesthetic nature of receiving waters, and some may become entangled with or be ingested by aquatic life and wildlife. Floatable materials can be removed from runoff by screening and filtering in mechanical or biological treatment systems.

2.2.5 **Community Acceptance and Support**

Community acceptance and support for BMPs can be an important aspect of stormwater management programs. Some BMPs have a high potential positive impact on community values, while the public may view others as potential liabilities. Some BMPs, particularly those associated with land use planning, lend themselves to community enhancement. Other BMPs, particularly structural facilities, require careful design to avoid public concerns regarding safety and aesthetics. Four specific objectives were identified for enhancement of community acceptance and support (Figure 2-2).

Each Community Acceptance and Support objective is briefly discussed below. The objectives can be further divided into social and ecological categories. Within the social category are Parks and Greenspace, Aesthetics, and Public Safety objectives. The Fish and Wildlife Habitat objective comprises the ecological category. This breakdown recognizes that an aquatic system can have substantial beneficial uses for the human community, even if its biological resources are limited, and that management efforts to protect and enhance those beneficial uses should have appropriate priority. Where ecological objectives are being pursued, community acceptance and support is essential for success, and it must accordingly be assigned rightful priority.

**Parks and Greenspace** – Public recreational opportunities may be provided through the creation of parks and greenspace and/or preservation of natural areas. Many BMPs can be integrated with parks and greenspace, particularly if this is addressed at the planning level. Retrofitting of BMPs to enhance existing parks and greenspace is also possible.

**Fish and Wildlife Habitat** – The creation and preservation of fish and wildlife habitat is a natural consequence of some BMPs. The resulting enhancement of recreational fisheries,
aesthetic value, and educational opportunities will generally be viewed in a positive light by most members of the public.

*Aesthetics* – The aesthetic value of BMPs, be it positive or negative, can be an important issue in community acceptance of stormwater management strategies. Land use planning and design standards have a significant impact on the aesthetic value of developments. Structural stormwater management facilities may have positive or negative aesthetic value, depending on design and maintenance. Public concerns over potential insect nuisance may have a bearing on community support for structural facilities that contain standing water.

*Public Safety* – Public safety, particularly for small children, is an important issue in gaining community acceptance for BMPs. A common safety concern is the potential for small children to fall into open stormwater detention structures, particularly those that contain standing water. Another concern associated with small children is the location of wooded areas next to playgrounds and schoolyards. These issues can usually be addressed by careful design and maintenance.
2.3  Step 3: Develop List of Candidate BMPs Using Initial Screening Matrices

Step 3 is to develop and refine a list of candidate BMPs that potentially meet the goals, objectives, and priorities identified in Step 2. Initial screening matrices for matching candidate BMPs with overall watershed goals and specific objectives are contained in Tables 2-1 through 2-4. The BMPs in Tables 2-1 through 2-4 are grouped according to the three main categories of Non-Structural BMPs, Structural BMPs and Operation and Maintenance BMPs. The BMPs that have high or moderate positive impacts on the high priority goals and objectives identified in Step 2 should be selected first using these matrices. The BMPs that have high or moderate positive impacts on medium priority goals and objectives should be selected second. If desired, BMPs for low priority goals and objectives can also be selected (third). Within each category of priority, the individual BMPs that address the largest number of goals and objectives should located at the top of the list. This initial selection procedure forms the list of candidate BMPs in order of priority (List #1), to be refined during Step 4.

Table 2-1 contains the initial screening matrix for BMPs that are suitable for meeting the general goal Protect Life and Property. As shown, Structural and Non-Structural BMPs meet the largest number of specific objectives associated with this goal. However, Operational and Maintenance BMPs, particularly those associated with maintaining structural BMPs and preventing obstruction of drainage paths, can also help to meet this goal (Table 2-1).

Tables 2-2 and 2-3 contain initial screening matrices for BMPs that are suitable for the goals Protect Fish Habitat and Protect Water Quality, respectively. As shown, BMPs from all three categories help to meet both of these goals. Table 2-4 contains an initial screening matrix for determining Community Acceptance and Support for BMPs. Non-Structural BMPs generally meet the largest number of objectives for community acceptance. Several Structural BMPs have a potential negative impact on Community Acceptance and Support, mainly due to safety and aesthetics concerns. However, this can normally be overcome by careful design and proper operation and maintenance.

A summary of BMP design objectives is included in Table 2-5, to assist in focusing selection of candidate BMPs.
### Table 2-1: Initial BMP Screening Matrix for Protection of Life and Property

<table>
<thead>
<tr>
<th>Type of BMP</th>
<th>Best Management Practice</th>
<th>Control Flooding Frequency</th>
<th>Minimize Streambank Erosion</th>
<th>Prevent Sedimentation &amp; Obstructions</th>
<th>Worker/Public Safety Liabilities</th>
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</thead>
<tbody>
<tr>
<td>Non-Structural</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffer Zones/Preservation of Natural Areas &amp; Drainage Systems</td>
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<td>3</td>
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</tr>
<tr>
<td>Impervious Area Reduction/Restriction/Disconnection</td>
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<td>Construction Design/Review/Inspection/Enforcement</td>
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<td>2</td>
<td>3</td>
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<tr>
<td>Consultant and Contractor Education</td>
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</tr>
<tr>
<td>Education and Training of Municipal Employees</td>
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<td>2</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Commercial/Industrial Education</td>
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<td></td>
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<tr>
<td>Coalescing Plate Separator</td>
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<td>Water Quality Inlet</td>
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<td>Manhole Sediment Trap, Trapped Catch Basin</td>
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<td>Conventional Dry Detention Pond &amp; Dry Vault</td>
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<td>Extended Detention Dry Pond &amp; Vault</td>
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<td>2</td>
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<td>Engineered Wetlands</td>
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<td>Roof Downspout System</td>
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<td>Porous Pavement, Concrete Grid &amp; Modular Pavers</td>
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<td>Operation and Maintenance</td>
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<td>Detection/Removal/Prevention of Illicit Connections</td>
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<tr>
<td>Catch Basin Cleaning</td>
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<td>Roadway and Bridge Maintenance</td>
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</table>

- **1** High Positive Impact
- **2** Moderate Positive Impact
- **3** Little or Unknown Impact
- **X** Special Design and Management Required to Avoid Potential Negative Impact

**Note:** The table includes a rating system for each BMP, indicating its impact on different aspects of stormwater management. The ratings range from 1 (High Positive Impact) to 3 (Little or Unknown Impact), with 0 indicating a special design and management requirement to avoid potential negative impact.
### Table 2-2: Initial BMP Screening Matrix for Protection of Fish Habitat

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- High Positive Impact: **
- Moderate Positive Impact: *
- Little or Unknown Impact: 
- Special Design and Management Required to Avoid Potential Negative Impact: X

* Always select these BMPs for further consideration when the goal is protection of fish habitat.
### Table 2-3: Initial BMP Screening Matrix for Protection of Water Quality

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- ☀ High Positive Impact
- ☀ Moderate Positive Impact
- ☀ Little or Unknown Impact

X Special Design and Management Required to Avoid Potential Negative Impact
### Table 2-4: Initial BMP Screening Matrix for Community Support and Acceptance

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<th>Aesthetics</th>
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<td><strong>Operational and Maintenance</strong></td>
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<td>Maintenance of Structural BMPs</td>
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<tr>
<td>Detection/Removal/Prevention of Illicit Connections</td>
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<tr>
<td>Spill and Complaint Reporting and Response</td>
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<td>Maintenance of Runoff Conveyance Systems and Hillslopes</td>
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</table>

- **High Positive Impact**
- **Moderate Positive Impact**
- **Little or Unknown Impact**
- **Special Design and Management Required to Avoid Potential Negative Impact**
#### Table 2-5: Define and Select Stormwater Design Objectives for BMPs

<table>
<thead>
<tr>
<th>Watershed Objective</th>
<th>Stormwater Design Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect Life and Property</td>
<td><strong>O&amp;M:</strong> Emphasize BMPs to prevent obstruction of drainage system and ensure proper maintenance of Structural BMPs.</td>
</tr>
<tr>
<td></td>
<td><strong>STRUCTURAL:</strong> Select design storm to provide stormwater detention to meet predevelopment peak discharge targets for flood protection.</td>
</tr>
<tr>
<td></td>
<td>Select extended detention design event and method, determine channel protection volume and select detention BMP options to employ for streambank erosion protection (see Section 4).</td>
</tr>
<tr>
<td></td>
<td><strong>NON-STRUCTURAL:</strong> Conduct floodplain analyses, establish protected areas, impervious area restrictions and site design standards. Emphasize education and training.</td>
</tr>
<tr>
<td>Protect Fish Habitat</td>
<td><strong>O&amp;M:</strong> Emphasize BMPs to prevent spills and illegal pollutant discharge and to maintain Structural BMPs.</td>
</tr>
<tr>
<td></td>
<td><strong>STRUCTURAL:</strong> Select BMPs that protect or enhance fish and wildlife habitat.</td>
</tr>
<tr>
<td></td>
<td><strong>NON-STRUCTURAL:</strong> Consider buffers, natural area conservation and drainage practices. Look for opportunities for impervious cover reduction.</td>
</tr>
<tr>
<td>Protect Water Quality</td>
<td><strong>O&amp;M:</strong> Emphasize construction practices, maintenance of structural BMPs, removal of illicit connections and complaint response. Consider street and catch basin cleaning practices.</td>
</tr>
<tr>
<td></td>
<td><strong>STRUCTURAL:</strong> Select BMPs that can provide removal of the pollutant(s) of greatest concern. Decide the method and volume for water quality design (see Section 4).</td>
</tr>
<tr>
<td></td>
<td>Prevent infiltration of untreated stormwater. Promote infiltration of rooftop runoff, open channels, filter strips, and bioretention areas to increase recharge. Consider incentives to reward innovative site designs to promote recharge.</td>
</tr>
<tr>
<td></td>
<td><strong>NON-STRUCTURAL:</strong> Determine key stormwater discharge points and target key sectors for pollution prevention training and education.</td>
</tr>
<tr>
<td>Community Support and</td>
<td><strong>O&amp;M, STRUCTURAL, NON-STRUCTURAL:</strong> Emphasize approaches that enhance aesthetic value and protect fish and wildlife habitat.</td>
</tr>
<tr>
<td>Acceptance</td>
<td></td>
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</tbody>
</table>
2.4 Step 4: Screen Candidate BMPs According to Level of Development and Land Use Activity

Opportunities for the successful application of specific stormwater BMPs depend to some extent on the existing level of development and on the land use activity within the municipality. Step 4 is to eliminate candidate BMPs from List #1 that are not applicable to the level of development and/or the land use activity in specific areas of interest within the watershed.

The municipalities within the GVS&DD vary widely in the existing level of development. Some areas are already extensively or fully developed. Some fully developed areas may be expected to remain essentially as-is for the foreseeable future, and some may be expected to undergo redevelopment in the near or more distant future. Similarly, some areas that are currently undeveloped may be expected to remain essentially as-is (e.g., agricultural areas), or extensive new (greenfield) development may be planned for other undeveloped areas.

Another factor that affects the successful application of specific BMPs is the land use activity. Some BMPs are potentially effective for all types of land use activity (residential, commercial, industrial, and agricultural), while others are mainly designed for a specific land use such as industrial activities.

During Step 4, the land area within the watershed under study should be classified according to the level of development and land use activity. Suggested categories for level of development and land use activity are shown in the screening matrices contained in Table 2-6 (Non-Structural BMPs), Table 2-7 (Structural BMPs), and Table 2-8 (Operational and Maintenance BMPs). The matrices contained in Tables 2-6 through 2-8 can be used in conjunction with the list of candidate BMPs developed in Step 3 (List #1), to eliminate BMPs that are not applicable to each distinct level of development and/or land use activity within the watershed. A candidate BMP should be checked against both the Level of Development and Land Use Activity categories and eliminated if unsuitable on either count.

Step 4 will result in a second list (List #2) of BMPs that can potentially be applied to each distinct level of development and land use activity within the municipality (e.g., new residential development, existing residential development, etc.).
### Table 2-6: Selection of Non-Structural BMPs According to Level of Development and Land Use Activity

<table>
<thead>
<tr>
<th>Non-Structural Best Management Practice</th>
<th>Level of Development</th>
<th>Land Use Activity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Developed</td>
<td>New (Greenfield) Development</td>
</tr>
<tr>
<td>Buffer Zones, Preservation of Natural Areas and Drainage Systems</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Impervious Area Reduction/Restriction/Disconnection</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Construction Design/Review/Inspection Enforcement</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Consultant and Contractor Education</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Employee Training</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Commercial/Industrial Education</td>
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<td>✓</td>
</tr>
<tr>
<td>Public Education and Participation</td>
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</tr>
</tbody>
</table>

- ✓ - BMP Suitable
- X – BMP Not Suitable
Table 2-7: Selection of Structural BMPs According to Level of Development and Land Use Activity

<table>
<thead>
<tr>
<th>Structural Best Management Practice</th>
<th>Developed</th>
<th>New (Greenfield) Development</th>
<th>Redeveloping</th>
<th>Residential</th>
<th>Municipal Office Complexes, Commercial</th>
<th>Municipal Repair &amp; Maintenance Yards, Industrial</th>
<th>Parks and Greenspace, Agricultural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coalescing Plate Separator</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>Water Quality Inlet</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Manhole Sediment Trap, Trapped Catch Basin</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dry Vault and Wet Vault</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dry Pond</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Wet Pond</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Engineered Wetlands</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>●</td>
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<td>✓</td>
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<tr>
<td>Vegetated Swale/Grassed Channel</td>
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<td>✓</td>
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<td>✓</td>
<td>●</td>
<td>✓</td>
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<tr>
<td>Off-line Infiltration Basin</td>
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<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Roof Downspout System</td>
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<td>✗</td>
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<tr>
<td>Bioretention, Dry Swale with Underdrains</td>
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<tr>
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</tr>
<tr>
<td>Catch Basin Filter</td>
<td>✓</td>
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<td>●</td>
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<tr>
<td>Multi-Chambered Treatment Train</td>
<td>✓</td>
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<td>✓</td>
<td>●</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓ - BMP Suitable
✗ – BMP Not Suitable
### Table 2-8: Selection of Operational and Maintenance BMPs According to Level of Development and Land Use Activity

<table>
<thead>
<tr>
<th>Operational and Maintenance Best Management Practice</th>
<th>Level of Development</th>
<th>Land Use Activity</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Redeveloping</td>
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<tr>
<td>Maintenance of Structural BMPs</td>
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<td>Detection/Removal/Prevention of Illicit Connections</td>
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<td>Spill and Complaint Reporting and Response</td>
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<tr>
<td>Street Cleaning</td>
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<td>Maintenance of Runoff Conveyance Systems and Hillslopes</td>
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<td>Roadway and Bridge Maintenance</td>
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</table>

✓ - BMP Suitable  
X - BMP Not Suitable
2.5 Step 5: Screen Structural BMPs According to Site-Specific Constraints

The BMPs contained within the two main categories of Non-Structural BMPs and Operational and Maintenance BMPs are generally not constrained by site-specific characteristics such as topography, climate, geology, etc. The use of Structural BMPs, on the other hand, is often constrained by site-specific characteristics, and suitable BMPs of this type must therefore be considered on a site-specific basis.

Site-specific factors that may constrain the use of Structural BMPs include topographic, climatic, and geological characteristics. In locations where structural BMPs are being considered, a list of site-specific constraints should therefore be developed. Suggested site-specific characteristics for BMP selection are contained in the screening matrix shown in Table 2-9. The matrix in Table 2-9 should be used to eliminate Structural BMPs from List #2 that are not suitable at designated locations in light of site-specific constraints. A separate list of potentially suitable Structural BMPs (List #3) should be developed for each distinct site or group of sites with common characteristics. More detail on site-specific constraints for Structural BMPs is contained in Section 4 of this report.
### Table 2-9: Site-Specific Constraints for Structural BMPs

<table>
<thead>
<tr>
<th>Structural Best Management Practice</th>
<th>Catchment Area Served</th>
<th>Climate, Precipitation</th>
<th>Soil Type</th>
<th>Site Slope</th>
<th>Water Availability</th>
<th>Depth to Water Table</th>
<th>Depth to Impermeable Layer</th>
<th>Proximity to Bldgs &amp; Wells</th>
<th>Space Requirement</th>
<th>Available Hyd. Head</th>
<th>Sediment Load &amp; Floatables</th>
<th>Public Access &amp; Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coalescing Plate Separator</td>
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- **1** - Generally not a constraint
- **2** - may be overcome with careful design
- **3** - severe constraint

Greater Vancouver Sewerage & Drainage District

*Liquid Waste Management Plan-Stormwater Management*
2.6 Step 6: Evaluate Implementation Requirements, Weigh Costs vs. Benefits

Lists #2 and #3 may contain several BMPs that are potentially suitable for each distinct level of development, land use activity, and site-specific constraint within the study area. Final selection of BMPs should be done in light of the relative priorities of the selected goals and objectives, the number of goals and objectives served by each BMP, estimated costs, implementation requirements, municipal resources, and expected benefits to be derived from implementing each BMP.

Specific dollar costs and details on the implementation requirements, benefits, and performance limitations for each BMP are discussed in Sections 3 through 5 of this report. The relative benefits of each BMP can be compared using Tables 2-1 through 2-4 in this section.

The costs and implementation requirements should be compared to the municipal resources available, so that only BMPs that are realistically achievable and sustainable over the long term are selected. In particular, no BMP should be selected and installed unless it will be inspected and maintained as necessary to keep it functioning as intended.
3.0 NON-STRUCTURAL BMPs

This section contains detailed discussion of the Non-Structural BMPs selected for this manual. General descriptions, implementation requirements, applications, planning and design criteria, limitations, costs and benefits are included.

Stormwater management programs normally include a significant structural component. Structural stormwater BMPs (discussed in Section 4) are designed to compensate for the adverse impacts of development (i.e., increased flooding and erosion/sedimentation, damage to fish and wildlife habitat, contamination of water resources, reduced groundwater recharge). Non-Structural stormwater BMPs, on the other hand, are designed to prevent adverse impacts from happening in the first place. Over the long term, it is reasonable to expect that preventing stormwater management problems will be more effective and less expensive than correcting problems after they become apparent.

In the Non-Structural BMP approach, stormwater management is considered a core issue in development and redevelopment planning, instead of attempting to design stormwater management systems to fit existing development plans. Non-Structural BMPs can be divided into two broad categories. One is planning, design and construction of developments and redevelopments to minimize or eliminate adverse impacts. The other involves education and training to promote awareness of the potential problems associated with storm runoff, and of source control approaches that can help to solve those problems.

For the purposes of this analysis, the category of planning, design, and construction to minimize adverse impacts was divided into three Non-Structural BMPs. The first is preservation and protection of key natural drainage and habitat features by prevention of development in these areas. The second is minimization of the amount of impervious surface created by development, and elimination of direct connections between impervious surfaces and the drainage conveyance system. The third is regulation of construction methods and practices to prevent environmental damage and encroachment on protected areas. The category of education and training was divided into two Non-Structural BMPs. The first includes municipal employees, consultants, contractors, and commercial/industrial enterprises, and the second is the general public.

Non-Structural activities are often funded by various agency departments, making cost tracking and estimation difficult. Cost estimates for Non-Structural BMPs were estimated from values reported in the literature, contacts with jurisdictions in the states of Washington and Oregon, local information, and the experience of the project team.

Various agencies responsible for stormwater program activities in the states of Oregon and Washington were contacted. The agencies were asked to provide detailed cost information regarding Non-Structural BMPs. A primary source of information was the Unified Sewerage Agency (USA) of Washington County, Oregon. USA is responsible for regulating, managing, and maintaining surface water, sewage, and stormwater for over 155,000 homes and businesses.
in the urban area west of Portland, Oregon. Approximately 20% of USA’s efforts are devoted to managing stormwater and surface waters for quality and quantity concerns. The agency imposes an average monthly stormwater fee of Cdn $6.00 on the service population in addition to system connection charges.

USA provided annual operating budgets (1999) for the Non-Structural program BMPs detailed in this study. The costs are presented on a per capita basis (program unit cost/population) and a unit service area basis (program unit cost/services area). In some cases, the USA budget included both sanitary and stormwater activities. In these instances, the assumption of a 20% stormwater and 80% sanitary allocation of costs was made. The values from USA include all program costs except for office space. Educational BMP costs are funded equally from sanitary and stormwater funds. Typical USA costs include salaries and benefits, materials, supplies, rental equipment, office supplies, administrative costs, and miscellaneous expenses.
3.1 BMP NS1: Buffer Zones/Preservation Of Key Drainage And Habitat Features

3.1.1 Description

Natural site features such as riparian corridors, streams, lakes, wetlands, surface depressions, soils, and vegetation are integral to the hydrologic cycle. These features help to store, infiltrate, evaporate, and cleanse storm runoff. Removal or modification of these features in conjunction with the increased impervious area associated with development causes adverse downstream impacts that include increased runoff flow rates and volumes, contamination of receiving waters, destruction of habitat, and reduced groundwater recharge. Preservation of key natural drainage and habitat features through careful planning can minimize the adverse impacts of development. This BMP is supported by BMP NS2, (Reduction/Disconnection of Impervious Area), BMP NS3 (Construction Design/Review/Inspection/Enforcement), and BMPs NS4 and NS5 (Education and Training).

Protection of key natural features can be achieved through cluster developments that maximize open (undeveloped) space and minimize the required length of roadway and other infrastructure. Clustering concentrates development on smaller lots into compact areas, and leaves relatively large areas undeveloped, in contrast to conventional grid developments that cover the entire site with larger lots.

3.1.2 Applications

- applies to peak flow control, stream bank erosion protection, obstruction of drainage paths, water quality enhancement, groundwater recharge, and community enhancement
- suitable for new developments and redeveloping areas but has limited opportunities for use in areas of existing development
- suitable for all types of land use
- cluster development not practical in ultra urban areas

3.1.3 Planning and Design Criteria


  Site Planning

- develop a site map that identifies the following features and avoid altering or constructing in these areas wherever possible (adapted from Horner et al., 1994):
- perennial streams and other natural drainage paths, wetlands, floodplains, natural depressions/storage areas.
- riparian corridors and other habitat areas
- aquifer recharge and discharge areas
- critical natural areas such as steep slopes, high water table, bedrock/impervious layers, and other limitations

• delineate protected areas before development planning begins and verify delineation in the field – mark these areas on all plans and maps and post signs in the field, ensure contractors are familiar with the limits of disturbance
• consider the socioeconomic values of the surrounding community
• integrate the stormwater plan into the overall site design
• design and place structures to correspond to site features such as slopes, depressions, etc.
• consider reducing the lot size and position lots to benefit from the open space that results from clustering (views of natural areas and other positive site features)
• maximize and link zones of open space
• avoid fragmentation of open space and restrict the use of impervious cover for open space (hard courts, bike paths, etc. – see BMP NS2)
• consider the space requirements for Structural BMPs, particularly ponds, swales and filter strips, etc. (see Section 4)
• perform annual inspections to detect encroachment

Development Plan Review

• employ a unified and streamlined development review process
• develop simple and practical performance criteria
• be responsive to the needs of the development community for fair and timely review and common sense requirements

Stream Buffers and Natural Areas

• establish appropriate buffer zones to protect riparian corridors and natural drainage paths, maintain and protect dense vegetation in these areas, and retain vegetated buffers in their natural state wherever possible
• recommended sizes for stream buffers and leave strips in British Columbia are described elsewhere (DFO/MOELP, 1993)
• minimize number and width of stream crossings and cross at direct rather than oblique angles – do not create fish barriers at crossings
• consider averaging of buffer widths and lot sizes to increase flexibility
• maximize undisturbed area for total site through clustering if possible
• maximize undisturbed area within individual lots and link undisturbed areas to those on adjacent lots where possible
• preserve native site vegetation and plant communities
• maximize opportunities for reforestation/revegetation of existing cleared areas

**Natural Drainage Features**

• design runoff management systems to incorporate natural drainage features and follow existing topography and drainage paths wherever possible
• maximize depression storage on individual lots and on slopes by placing berms parallel to contours
• maximize time of concentration by lengthening flow paths and routing flow over vegetated surfaces (e.g., filter strips and swales)
• spread runoff from urban surfaces evenly over buffers using curb cuts or other methods, avoid channelized flow across buffers
• classify site soils by type and permeability rating
• minimize construction and disturbance in areas of permeable soils and use these areas for stormwater management wherever possible
• focus development on areas with the least permeable soils where possible
• implement top soil conservation bylaws to protect native soils (see D&K et al, 1998 for guidance)

### 3.1.4 Limitations

• stream buffers and other protected areas are subject to disturbance and encroachment
• establishing buffer zones to protect riparian corridors and natural features may reduce the developable area
• stream buffers are limited in their ability to remove contaminants and must often be supplemented with Structural BMPs (Schueler, 1995).
• restrictions on land use required to mitigate stormwater problems may not be politically feasible
• requires supporting bylaws and regulations (see D&K et al., 1998 for guidance)
• zoning bylaws may have to be amended
• zoning bylaws may not be effective unless reinforced by a comprehensive planning process
• cluster development is often not the first choice of developers – conventional grid development may be seen as having the greatest potential return on investment

### 3.1.5 Program Development Costs and Implementation Requirements

**Costs for an Integrated Program that Includes BMPs NS1, NS2, and NS3**

• requires development of site design standards and procedures for review and approval of development applications, including development of planning...
3.1.6 Ongoing Program Operation Requirements and Costs

Costs for an Integrated Program that Includes BMPs NS1, NS2, and NS3

- requires ongoing review/approval of development plans and applications, review and approval of development applications and construction plans, bylaw enforcement
- $1,040/km$² per year or $0.90 per capita per year, not including office space (USA, 1998)

3.1.7 Benefits Vs Costs

Integrated Development Planning and Design, Reduction/Disconnection of Impervious Area, Regulation of Construction Practices (BMPs NS 1, NS 2, and NS 3)

- the costs of conducting, planning, design, and construction of developments for a municipality 10,000 ha in size with a population of 150,000 would be in the range $75,000 to $150,000 for program development, with ongoing program costs of $100,000 to $135,000 – this is relatively inexpensive compared to large-scale implementation of Structural BMPs (see Section 4), and it is likely to be more effective over the long term.
- preventing problems is more cost effective than attempting to correct them
- Structural BMPs are limited in their ability to correct problems
- see Section 3.6 at the end of this Section for an overview cost benefit summary
Cluster Development

- benefits associated with clustering include architectural diversity, provision of community recreation areas, preservation of rural landscape character, increased sense of community, and more affordable housing, as well as protection of key site features and reduced impervious area (Wells, 1994b)
- cluster development helps to preserve native soils and vegetation
- cluster development reduces the required size of Structural BMPs
- cluster development reduces the impact of construction and the costs of on-site erosion and sediment controls.
- cluster development sites can result in savings of $6,500 per development unit in infrastructure costs over conventional single family developments (DDNREC, 1997)
- cluster development can reduce the capital cost of development by 10% to 33%, mainly due to a reduction in the length of infrastructure required and a reduction in clearing and grading (Schueler, 1997a).
- estimated cost savings for reduced length of roadway (pavement, curb and gutter, storm sewer) are $740/linear metre of roadway (Schueler, 1997a)
- a national survey in the U.S. of 39 cluster development programs indicated that 67% of the cluster development properties appreciated at an equal or greater rate than conventional subdivisions, and 18% appreciated at a lower rate (Wells, 1994b)

Stream Buffers

- preservation of stream buffers can be used for runoff treatment through overland flow
- forested shoreline and stream buffers on flat soils are effective in removing sediment, contaminants, and bacteria from runoff
- stream buffers provide a critical right of way for the 100-year runoff
- stream buffers help to prevent erosion, enhance fish and wildlife habitat, recreational opportunities, and enhance aesthetic values
- stream buffers 30 m in width protect up to 5% of the watershed area from development
- stream buffers distance surface waters from direct urban runoff and allow space for Structural BMPs
- stream buffers provide a foundation for connected greenways
- stream buffers help to prevent warming of streams
- homes situated near restored streams have been shown to be 3% to 13% higher than homes located next to unrestored streams (Schueler, 1997a)
Preservation of Key Drainage and Habitat Features

- preservation of natural drainage features reduces the need for Structural BMPs
- natural drainage systems are relatively free of capital and O&M costs compared to structural systems
- preservation of natural areas, native soils and vegetation helps to increase time of concentration and promote infiltration
- the presence of forest cover can reduce storm runoff volumes by 17% (Schueler, 1997b)
- each ha of coastal wetland can contribute $3,000 to $34,000 to the local economy through recreation, fishing and flood protection (Schueler, 1997a)
- savings in annual mowing costs can be $1,000 to $2,400 per ha when open lands are managed as natural buffers rather than turf (Schueler, 1997a)
- greenway parks increase the values of adjacent homes by up to 33% (Schueler, 1997a)
- locating houses next to greenbelt buffers has been found to increase the property value by 32% (Schueler, 1997a)
- conserving forests on residential and commercial sites can enhance property values by an average of 6% to 15% (Schueler, 1997b)
- homes and businesses that retain trees can save 20% to 25% in heating and cooling bills compared to homes where trees are cleared (Schueler, 1997a)
3.2 BMP NS2: Reduction/Disconnection Of Impervious Area

3.2.1 Description

Reductions in impervious area can be undertaken by reducing the overall size of the developed area, and/or by reducing the amount of impervious surface created within the developed area. Disconnection of impervious surfaces can be undertaken by directing runoff from roofs and paved surfaces over vegetated surfaces before it reaches the drainage conveyance system. This BMP supports BMP NS1 by helping to preserve natural areas, drainage features, and groundwater recharge.

Reductions in impervious area can be achieved through cluster developments that maximize open (undeveloped) space and minimize the required length of roadway and other infrastructure. Clustering concentrates development on smaller lots into compact areas, and leaves relatively large areas undeveloped, in contrast to conventional grid developments that cover the entire site with larger lots and result in more overall impervious area (roads, sidewalks, etc.).

3.2.2 Applications

• applies to peak flow control, stream bank erosion protection, obstruction of drainage paths, water quality enhancement, groundwater recharge, and community enhancement
• suitable for new developments and redeveloping areas but has limited opportunities for use in areas of existing development
• suitable for all types of land use
• cluster development not practical in ultra urban areas

3.2.3 Planning and Design Criteria

• see Schueler (1997c), Horner et al. (1994), Olympia (1995) and PGC (1997) for detailed guidance

General Planning and Policies

• integrate impervious surface reduction into policies and regulations (see D&K et al., 1998 for guidance in developing bylaws and regulations)
• establish growth management policies that encourage infill of urban areas and reduce urban sprawl
• provide a public transportation system and other alternative modes of transportation that reduce the need for streets and parking, and that encourage underground and under-building parking and multi-storied parking structures
• examine potential for shared parking and develop flexible parking regulations that limit the amount of impervious surface, while still providing for parking needs
• limit land clearing on development sites, especially those with sensitive features
• prevent compaction of native soils (see D&K et al., 1998 for top soil conservation bylaws)
• encourage measures such as covenants and easements that protect existing vegetation and undisturbed areas
• encourage cluster development
• encourage the use of taller structures that reduce the size of building footprints
• develop and distribute printed materials that complement policies (see BMPs NS4 and NS5)
• develop and provide training and technical assistance to the development and business community (see BMP NS4)
• results of a 2 year study in Olympia, WA indicate that a 10% to 20% reduction in total impervious area associated with new development is a reasonable goal (Wells, 1994a)

Reduction of Impervious Area

• consider clustering of building lots and density bonuses
• consider reducing the number of building units
• consider modifying the type of unit (e.g., from single family to townhouse)
• reduce road widths to the minimum required
• minimize driveway widths and lengths
• consider reducing required setbacks for buildings from lot lines to minimize driveway length
• reduce parking ratios and parking stall sizes
• minimize the number of cul-de-sacs
• design cul-de-sacs and turnarounds to minimize imperviousness and reduce size to the minimum that will accommodate emergency vehicles
• design sidewalks for single-side movement
• use porous surfaces where possible (see Structural BMPs S13 and S14)
• use swales and open ditches rather than curb and gutter systems
• limit soil compaction on development sites, restore infiltration capacity wherever possible
Disconnection of Impervious Area

- consider the use of roof downspout systems and other infiltration techniques (see Structural BMPs S11 through S15)
- gently slope sidewalks, alleys, etc. away from streets and other impervious surfaces towards vegetated strips or gravel catchments

3.2.4 Limitations

- requires supporting bylaws and regulations (see D&K et al., 1998 for guidance)
- zoning bylaws may have to be amended
- zoning bylaws may not be effective unless reinforced by a comprehensive planning process
- cluster development is often not the first choice of developers – conventional grid development may be seen as having the greatest potential return on investment

3.2.5 Program Development Costs and Implementation Requirements

- see Section 3.1.5

3.2.6 Ongoing Program Operation Requirements and Costs

- see Section 3.1.6

3.2.7 Benefits Vs Costs

Integrated Development Planning and Design, Reduction/Disconnection of Impervious Area, Regulation of Construction Practices (BMPs NS 1, NS 2, and NS 3)

- see Section 3.1.7
- see Section 3.6 at the end of this section for an overview cost benefit summary

Cluster Development

- see Section 3.1.7
- cluster development can reduce site and watershed imperviousness by 10% to 50% depending on the original lot size and the road network (Wells, 1994b) – this reduces peak runoff flow rates, runoff volumes, and stormwater contaminant loads, while promoting groundwater recharge – the consequence is a reduced need for Structural BMPs
- cluster development typically keeps 40% to 80% of the total site area in permanent community open (potentially pervious) space
Reduction of Impervious Area

- reduced amount of impervious surface reduces runoff peak flows, promotes infiltration and contaminant removal
- construction costs and O&M costs are reduced for narrower roads, smaller parking spaces, reduced length of curb and gutter, fewer sidewalks, etc.
- narrower roadways can save $125 to $250 per linear metre (Schueler, 1997a)
- elimination of sidewalks can save $50 per linear metre (Schueler, 1997a)
- reduced impervious area reduces the need for Structural BMPs

Disconnection of Impervious Area

- disconnection of runoff from roofs and other impervious areas increases the time of concentration and promotes infiltration
- elimination of curbs and gutters can result in savings of $75 per linear metre of roadway (DDNREC, 1997).
3.3 BMP NS3: Construction Design/Review/Inspection/Enforcement

3.3.1 Description

For the purposes of this manual, this BMP includes design of construction plans, plan review, inspection and enforcement. Specific structural and other BMPs aimed at on-site control of erosion and sedimentation at construction sites are described in Appendix H under separate cover.

Construction design, review, inspection and enforcement is essential to ensure that the benefits of BMP NS1 (Buffer Zones/Preservation of Key Drainage and Habitat Features) and BMP NS2 (Reduction/Disconnection of Impervious Area) are realized. In addition, proper construction techniques and scheduling can help to protect downstream areas and resources from flooding, sedimentation, and contamination.

3.3.2 Applications

- applies to peak flow control, stream bank erosion protection, obstruction of drainage paths, water quality enhancement, groundwater recharge, and community enhancement
- suitable for new developments and redeveloping areas
- suitable for all types of land use

3.3.3 Planning and Design Criteria

- see Horner et al. (1994), Olympia (1995) and PGC (1997) for detailed guidance

Construction Design

- require a stormwater management plan including BMPs for source control and removal of contaminants from site runoff - see Appendix F for discussion of GVRD source control bylaw and WSDOE (1992) and CDM et al. (1993) for detailed guidance regarding on-site source controls for construction sites
- construct and stabilize runoff management systems at the beginning of site disturbance and construction activities
- minimize disturbed areas and stripping of vegetation and soils, particularly on steep slopes, and stabilize denuded soils as soon as possible
- implement on-site erosion and sedimentation control BMPs (see Appendix H)
- consider additional stormwater requirements for projects constructed during the rainy season
BMP NS3: Construction Design/Review/Inspection/Enforcement

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- ensure proper storage of all hazardous materials and design spill prevention and control plan, ensure secondary containment in vehicle fueling, washing and maintenance areas
- require proper precautions and practices for paving operations
- proper containment and disposal of concrete wash water
- roughen and/or terrace slopes to prevent erosion
- implement employee education and training (see BMP NS4)

Construction Review

- employ a unified and streamlined construction plan review process
- develop simple and practical performance criteria
- be responsive to the needs of the development community for fair and timely review and common sense requirements
- review stormwater reference materials before conducting site inspections

Construction Inspection/Enforcement

- inspect construction site regularly to determine compliance with requirements (e.g., after installation of Structural BMPs, after clearing and grubbing, during placement of fill material, upon completion of rough and final grading, upon completion of trenching and form work and prior to pouring of concrete, at various points in the building process, after installation of insulation and drywall)
- bring maps delineating protected areas on site visits, inspect and maintain signs marking protected areas in the field
- maintain accurate records of all violations and of all verbal and written warnings, stop work orders, etc.
- ensure regular collection and removal of trash and waste materials
- require covered trash receptacles and covered stockpiles
- require stabilized site entrances with provisions to prevent tracking of mud and debris off site
- ensure proper storage and maintenance of equipment in designated areas

3.3.4 Limitations

- regulation of construction practices requires supporting bylaws and enforcement to be effective (e.g., see D&K et al., 1998).
- zoning bylaws may not be effective unless reinforced by a comprehensive planning process
- developers and contractors may resist comprehensive requirements for construction methods and practices
3.3.5 Program Development Costs and Implementation Requirements

- see Section 3.1.5

3.3.6 Ongoing Program Operation Requirements and Costs

- see Section 3.1.6

3.2.7 Benefits Vs Costs

*Integrated Development Planning and Design, Reduction/Disconnection of Impervious Area, Regulation of Construction Practices (BMPs NS 1, NS 2, and NS 3)*

- see Section 3.1.7
- see Section 3.6 at the end of this section for an overview cost benefit summary

*Construction Design, Review, Inspection and Enforcement*

- this component is essential to realize the benefits of site design standards and prevent encroachment on and damage to protected areas
- proper stormwater management and containment of wastes and debris on construction sites prevents sedimentation and obstruction of drainage paths downstream, protects habitat and water quality, and protects downstream sites from aesthetic nuisances
- erosion and sediment control hold soil on-site and reduce regrading costs
- protection of native soils from disturbance and compaction helps to preserve natural site drainage
- careful phasing of construction can lead to overall economies, phasing and site stabilization can reduce the need for sediment removal facilities
- cost of on-site erosion and sediment controls can average $3,000 to $5,700 per cleared hectare per year, depending on the duration of construction and the site conditions (Schueler, 1997a)
3.4 BMP NS4: Education And Training Of Municipal Employees, Consultants, Contractors, Commercial/Industrial Enterprises

3.4.1 Description

Education and training is more a method of implementing BMPs than a BMP in itself. Development site planning and design, regulation of construction practices, source control, and maintenance activities all depend heavily on education and training. Education and training is essential if the benefits of BMPs NS1 through NS3 are to be achieved. Developers, consultants, and contractors will be much more likely to support the use of Non-Structural BMPs if they understand the legal, financial, and environmental consequences of poor development practices, as well as the benefits that can be realized through the implementation of these BMPs. Education and training is also an essential element of source control programs (see Appendix F for a discussion of the GVRD source control bylaw).

Depending on the objectives, education and training may be directed at municipal employees, design consultants and construction contractors, industrial and commercial enterprises, or the general public (see BMP NS5 for public education). All of these audiences should be included in a comprehensive stormwater management program. Municipalities should begin with education and training of their own staff. The credibility of programs aimed at consultants, contractors, and private enterprise will be enhanced if municipal staff lead by example.

3.4.2 Applications

- can be used to enhance and support Structural, Non-Structural, and Operational and Maintenance BMPs aimed at flood control, stream bank erosion protection, protection/enhancement of water quality and habitat, recreational and aesthetic values
- suitable for all types of land use and all levels of development
- suitable for the following audiences (adapted from CDM et al., 1993):
  - technical (internal) - municipal staff
  - technical (external) – other government agencies and neighboring municipalities
  - business – industrial and commercial, trade associations
  - construction – developers and contractors
  - consultants
  - groups of individuals defined by a specific pollutant that they discharge (e.g., used motor oil, pesticides)

3.4.3 Performance
the benefits of education and training for stormwater management are difficult to quantify (a comprehensive 5 year stormwater education program currently underway in California will include surveys to measure program effectiveness, but this information is not yet available – Rogers et al., 1997)

a large percentage of the population can be reached through a single, integrated multi-faceted campaign that focuses on a desire to “do the right thing” to enhance neighborhoods and preserve the environment for the future – a much smaller percentage is harder to reach, is more likely to pollute, and is not motivated by a desire to do the right thing (Rogers et al. 1997)

3.4.4 General Criteria

- see Rogers et al. (1997) and CDM et al. (1993) for detailed guidance

**Common Elements for all Education and Training Programs (BMPs NS4 and NS5)**

- pattern programs after established and successful programs in other jurisdictions, e.g., Alameda Countywide Clean Water Program, CA, the City and County of San Francisco, CA, the Santa Clara Valley Nonpoint Source Pollution Control Program, CA, the City of Palo Alto CA, the Municipality of Metropolitan Seattle WA, and the Unified Sewerage Agency of Washington County OR (WEF, 1998)
- invest early in watershed education and outreach
- clearly delineate responsibility for championing watershed protection
- an education and training program should provide a municipality with a strategy for educating its employees, contractors, consultants, commercial/industrial enterprises, and the public about the economic and environmental importance of stormwater management, how activities within the watershed relate to watershed health, and how modifying behavior can contribute to the solution
- promote a clear identification and understanding of specific activities and procedures that have the potential to affect stormwater either directly or indirectly and promote ownership of the problems
- create an awareness and identification of the local watershed
- identify responsible parties where possible
- identify solutions (BMPs) that can address specific problems
- aim education and training at changing behavior that adversely affects stormwater
- stencil storm drains with messages to prevent illicit or improper dumping – these programs can often be coordinated with youth groups or civic associations (Horner et al., 1994)
- integrate stormwater training and education into existing education programs where possible (e.g., water conservation, solid waste, recycling, etc.)
- integrate audience feedback into training and BMP implementation
integrate the education and training program with source control programs

Municipal Employees, Consultants, Contractors, Commercial/Industrial Enterprises

key activities include the following (adapted from CDM et al., 1993):
- program planning and tracking – surveys and database to assess priorities and needs and to monitor progress, consider the use of professional survey firm to ensure scientifically sound results
- program identity – message, logo, tag line to promote a consistent image and connect with other issues and programs
- business programs – workshops, publications, focus on priority businesses, use positive incentive-based approach rather than traditional command and control approach
- consultant and construction programs – workshops, educational materials, certification program

list activities that have the potential to contaminate stormwater and identify appropriate source control and Operational and Maintenance BMPs using this and other manuals (e.g., CDM et al., and WSDOE, 1992)

use new employee orientation packets, in-house newsletters, staff meetings, bulletin boards, e-mail, paycheque stuffers as well as seminars and workshops

integrate stormwater management education and training into other training programs

for non-stormwater discharges to drains see Table 4-1 in Appendix E for quick reference to train employees in proper and consistent methods for disposal

see WSDOE (1992) and CDM et al. (1993) for specific information on requirements for municipal and industrial/commercial activities including those listed below
- vehicle and equipment fueling, steam cleaning and washing, repair and maintenance – train employees in proper fueling and cleanup procedures, spill containment and cleanup etc.
- outdoor storage and loading/unloading of materials – use a written operations plan that describes procedures for loading and unloading, have emergency spill procedures and properly trained personnel in place, identify and correct potential problems such as loose fittings, poor welding, and improperly fitted gaskets on liquid storage tanks
- cover outdoor storage areas where possible
- pesticide and fertilizer use – use properly trained personnel, use integrated pest management, use native vegetation, minimize use of chemical fertilizers, consider alternate products
- building repair and maintenance – sweep paved surfaces, contain and properly dispose of waste products
- perform polluting activities during dry weather if possible
- use less toxic alternative products where possible
3.4.5 Limitations

- limited by municipal financial and staff resources
- changing patterns of behavior is not easy - repeated exposure to messages from a variety of sources may be necessary to modify behavior
- audience may not be receptive

3.4.6 Program Requirements and Costs

- $5 million for a comprehensive 5 year program aimed at a population of 10 million that includes the public, businesses, and public agency employees (Rogers et al., 1997)
- commercial/industrial education $34/yr/1,000 population (GVRD, 1998)
- training seminars for employees, consultants and contractors $7,500 for 2 day workshop incl. materials (adapted from Schueler, 1998c)
- stakeholder involvement program $25,000/yr (Schueler, 1998c)
- storm drain signs and stencils including water quality monitoring, training seminars, supervision, newsletter and assuming volunteer labour $65,000 (Ferguson et al., 1997)
- water interpretive staff specialist $120,000/yr, materials to support interpretive specialist program $20,000/yr (Schueler, 1998c)
- pollution prevention survey $7,500 for 2 person crew incl. vehicle (Schueler, 1998c)
- educational videos $1,500 per minute (Schueler, 1998c)

3.4.7 Benefits Vs Costs

- significant economies can be realized by developing a coordinated regional program rather than developing individual programs for each municipality
- although the benefits of education on stormwater management are difficult to quantify, this BMP is widely regarded as essential to support development site planning, design and construction, source control programs, Structural BMPs, and Operational and Maintenance BMPs
- see Section 3.6 for overview cost benefit summary
3.5  BMP NS5: Public Education

3.5.1  Description

Public understanding and support is an essential component of stormwater management programs. People will be much more likely to comply with source control programs and other stormwater management measures if they understand the legal, financial, and environmental consequences of poor management practices, and the benefits that can be achieved through complying with regulations and recommended practices.

Municipalities should set an example for the members of the general public by beginning with education and training of their own staff. The credibility of programs aimed at the public will be enhanced if municipal staff lead by example.

3.5.2  Applications

- can be used to enhance and support Structural, Non-Structural, and Operational and Maintenance BMPs aimed at flood control, stream bank erosion protection, protection/enhancement of water quality and habitat, recreational and aesthetic values
- suitable for all types of land use and all levels of development
- suitable for the following audiences (adapted from CDM et al., 1993):
  - political – elected officials, department heads, agencies, commissions
  - general public - residential
  - environmental groups
  - community groups
  - schools and youth groups
  - media – print and electronic

3.5.3  Performance

- see Section 3.4.3.

3.5.4  General Criteria

- see Rogers et al. (1997) and CDM et al. (1993) for detailed guidance

*Common Elements for all Education and Training Programs (BMPs NS4 and NS5)*

- see Section 3.4.4
General Public

- publicize the economic and environmental benefits of watershed protection
- key activities include the following (adapted from CDM et al., 1993):
  - program planning and tracking – surveys and database to assess priorities and needs and to monitor progress, consider the use of professional survey firm to ensure scientifically sound results
  - program identity – message, logo, tag line to promote a consistent image and connect with other issues and programs
  - collateral material – newsletter, fact sheets, brochures, posters at regular intervals to publicize program
  - coordinating committees – integrate with other environmental education efforts and at schools and other municipal departments
  - media campaign – press releases, advertising, public service announcements, radio, television, newspapers to repeat messages from a variety of sources – cultivate media support by educating media on the purpose of the program
  - residential programs – storm drain stenciling, home toxic materials checklist/alternatives, specific neighborhood projects
  - presentations – environmental booth, speakers bureau, special events
  - consumer programs – point of purchase displays, printed grocery bags to convey program messages
  - school education – facility tours, contests, curriculum
- implement program as a coordinated campaign in which each message is related to the last
- sustain program over the long term to reach the maximum possible audience and reinforce messages before moving on to the next phase
- include small businesses in the public program since their awareness and technical background is probably similar to that of the public
- use a multimedia approach to reach audiences
- translate messages into appropriate languages (depending on the community) to avoid misinterpretation, account for cultural differences as well as translation
- involve focus or advisory groups in developing the program to increase effectiveness and promote ownership of problems
- use everyday language and avoid technical terms, jargon, and acronyms
- support all statements with current technical backup to avoid spreading erroneous information
- break up complicated subjects into smaller, simple concepts – avoid “information overloads”
- focus on the quality rather than the quantity of messages
- designate “econeighborhoods” and secure residents’ commitments to follow good housekeeping practices
- use education displays, pamphlets, booklets and utility stuffers to publicize messages
• consult a qualified public education specialist for assistance

3.5.5 Limitations

• see Section 3.4.5.

3.5.6 Program Requirements and Costs

• $5 million for a comprehensive 5 year program aimed at a population of 10 million that includes the public, businesses, and public agency employees (Rogers et al., 1997)
• public education $60/yr/1,000 population (GVRD, 1998)
• public education and participation programs $1,560/yr/km² drainage area or $1.26/capita/yr (USA, 1998)
• publicity and communications strategy $27,000/yr (Schueler, 1998c)
• stakeholder involvement program $25,000/yr (Schueler, 1998c)
• support cleanup activities in creeks $300,000/yr (Schueler, 1998c)
• storm drain signs and stencils including water quality monitoring, training seminars, supervision, newsletter and assuming volunteer labour $65,000 (Ferguson et al., 1997)
• water interpretive staff specialist $120,000/yr, materials to support interpretive specialist program $20,000/yr (Schueler, 1998c)
• public attitude survey $2,000 to $2,500 per 1,000 households (Schueler, 1998c)
• pollution prevention survey $7,500 for 2 person crew incl. vehicle (Schueler, 1998c)
• educational videos $1,500 per minute (Schueler, 1998c)
• training of classroom teachers $5,000/yr, equipment for classroom training $60,000 per year for handouts, displays, etc. (Schueler, 1998c)
• supplies for volunteers $25,000/yr (Schueler, 1998c)
• flyers $0.15 to $0.40 each (Schueler, 1998c)

3.5.7 Benefits Vs Costs

• see Section 3.4.7
• see Section 3.6 for overview cost benefit summary
3.6 Overview Cost Benefit Comparison of Non-Structural BMPs

This section contains an overview of Non-Structural BMP costs and benefits, to assist in determining relative advantages and disadvantages of each BMP in light of watershed goals and objectives. For comparative purposes, an urban municipality 10,000 hectares in area with a population of 150,000 was assumed. The costs of each Non-Structural BMP when applied to this municipality using the costing data contained in Sections 3.1 through 3.5 are summarized in Table 3-1. The degree to which each BMP meets the overall watershed goals is included in Table 3-1.
Table 3-1: Non-Structural BMP Cost Benefit Overview for a 10,000 ha Municipality with a Population of 150,000

<table>
<thead>
<tr>
<th>BMP</th>
<th>Program Cost¹</th>
<th>Potential Benefits</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop Program for Review of Development Planning, Design and Construction</td>
<td>$75,000 to $150,000</td>
<td>³ ³ ³ ³</td>
<td>develop design manuals and review process</td>
</tr>
<tr>
<td>Ongoing Program Costs for Review of Development Planning, Design and Construction</td>
<td>$100,000 to $135,000 per year</td>
<td>³ ³ ³ ³</td>
<td>review, approval and inspection of site designs and construction methods and practices</td>
</tr>
<tr>
<td>Develop Basin Drainage Plans and Environmental Studies</td>
<td>$50,000 per year²</td>
<td>³ ³ ³ ³</td>
<td>ongoing program for drainage planning and environmental review</td>
</tr>
<tr>
<td>Develop and Review Bylaws</td>
<td>$50,000</td>
<td>³ ³ ³ ²</td>
<td>essential to support other BMPs</td>
</tr>
<tr>
<td>Comprehensive Education and Outreach Program</td>
<td>$150,000 to $200,000 per year</td>
<td>² ² ³ ²</td>
<td>includes municipal staff, industrial/commercial businesses and general public - economies of scale can be realized through cooperative efforts</td>
</tr>
</tbody>
</table>

¹ see individual sections in this chapter for cost equations and sources

² assuming a study area of about 500 ha/yr on average

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Greater Vancouver Sewerage & Drainage District

Liquid Waste Management Plan-Stormwater Management
4.0 STRUCTURAL BMPS

Structural BMPs are discussed in detail in this section, including a description of each BMP, potential applications, design considerations and schematic drawings, pre-treatment and post-treatment requirements, documented performance in removing contaminants, limitations, implementation requirements, operation and maintenance requirements, and costs versus benefits. Section 4.1 contains a summary of design sizing standards for Structural BMPs. Sections 4.2 through 4.20 contain the detailed descriptions of the Structural BMPs selected for this manual. An overview cost benefit comparison of Structural BMPs is included in Section 4.21.

4.1 Design Sizing Standards and Costing Criteria for Structural BMPs

Structural BMPs can be designed to accomplish flood control, stream bank erosion control, water quality improvement, groundwater recharge, or some combination of these objectives. The water volume that a BMP facility is designed to handle depends on the limiting design objective. The design volume for each type of facility also depends on the nature of the catchment, the pattern of precipitation, and the level of protection required. As described below, structural facilities designed for flood control and streambank protection normally have the largest design volumes, followed by facilities designed for contaminant removal and groundwater recharge.

4.1.1 Flood Control Volume

Development (and sometimes re-development) generally causes increased runoff flow rates and volumes, due the addition of impervious surface and related land cover conversion. This can lead to an increase in the frequency of flooding downstream, caused by overtopping of streambanks during runoff events. The approach for flood control is normally to restrict the post-development peak runoff flow rate to that of the pre-development peak runoff flow rate for selected design storms. Flood control is typically undertaken by routing collected runoff through on-line conventional detention facilities; the collected water is released from these facilities at a slower rate than it enters, with the excess water being temporarily stored in a pond or vault. Detention storage affects only the timing and the magnitude of the peak runoff flow rate; it does not affect the volume of runoff.

In British Columbia, the 10-year or 5-year storm event is often used for design purposes in developing detention storage for on-site flood control in subdivisions, while the 100 year event may be used for designing regional conveyance systems and facilities. The duration of the design storm is normally that which produces the highest peak runoff flow rate. King County in Washington State specifies in their stormwater management manual that the post-development peak discharge rates must meet the pre-development discharge rates for both the 2-year and 10-year events, in basins with little habitat value or where
downstream channels are not sensitive to erosion. This is intended to prevent increases in peak flows for all storms in the return frequency range 2-year to 10-year. Where residential or commercial buildings or roadways may be flooded by the 100 year event, additional on-site controls or off-site improvements are required (KC, 1998). In the state of Maryland, the design storm for flood control is the 10-year event for most regions of the state, and the 2-year event for the Eastern Shore. The 100-year event is used in Maryland to protect development within the 100-year floodplain (CWP, et al., 1997).

4.1.2 Streambank Erosion Protection Volume

Conventional detention practices are only partially successful in preventing stream bank erosion, since they do not necessarily reduce the frequency and duration of the highly erosive bankfull flow condition. Bankfull flow may result from smaller, more frequent storms that do not pose a significant flood risk, as well as from larger events. Extended detention facilities and/or infiltration of precipitation to ground are normally required to control the frequency and duration of bankfull flows. Extended detention facilities employ lower release rates than conventional detention facilities; this may require a larger storage volume for extended detention compared to conventional detention, depending on the design storm selected for each. While extended detention can be used to control the duration of bankfull flow, it does not reduce the runoff volume. Reduction of runoff volume requires that infiltration techniques be employed.

Similar to the flood control volume, the streambank erosion protection volume is normally developed by comparing the existing or pre-development condition hydrograph to the post-development hydrograph. In the State of Maryland, the recommended design stream channel protection volume is 24 hour detention of the runoff from the 24-hour, 1-year event, which is typically a 60-75 mm rainfall event in that area (CWP et al., 1997). Ontario specifies 24-hour detention of the runoff from the 25 mm storm for erosion control (OMEE, 1994). King County in Washington State requires that the duration of peak flows be maintained at pre-development levels for all flows from 50% of the 2-year peak flow up to the full 50-year peak flow for streams with erosion-prone channels and/or important aquatic habitat. The King County standard is designed to maintain existing (pre-developed) erosion rates, by maintaining the aggregate time that flows exceed an erosion-causing threshold (KC, 1998). The Washington State Department of Ecology requires that streambank erosion control be undertaken by limiting the peak rate of runoff from individual development sites to 50% of the existing condition 2-year, 24-hour storm, while maintaining the existing condition peak runoff rate for the 10-year and 100-year, 24-hour design storms (WSDOE, 1992).

4.1.3 Water Quality Treatment Volume

Where water quality is concerned, it is normally not cost effective to design treatment facilities to handle large, infrequent storms. The majority of the total annual rainfall volume is typically delivered by smaller, more frequent storms. The current approach in
most jurisdictions is to design treatment facilities to handle the runoff from the smaller storms that account for the majority of the total runoff volume, and to bypass the larger events. This approach is judged to provide adequate water quality control, while avoiding the need for unreasonably large, expensive facilities.

The Washington State Department of Ecology recommends that water quality improvement BMPs in the Puget Sound area be designed to treat the runoff volume resulting from the 24-hour, 6-month event (this event produces about 30 mm of rainfall in the Seattle area). The rationale is that storms of this size or smaller account for over 90% of the annual precipitation in the Puget Sound area, and it is not economical to attempt to treat the runoff resulting from larger, infrequent storms (WSDOE, 1992). A similar approach is used in the state of Maryland, where the design water quality volume is based on the storage needed to capture and treat 90% of the average annual runoff volume, which equates to a design precipitation event of about 25 mm in that area (CWP, 1997). King County in Washington State specifies a water quality treatment volume of 95% of the total runoff volume (KC, 1998). Since isopluvial maps do not normally provide values for less than the 2-year storm, the 6-month storm must be extrapolated; this was done for a number of locations around the Puget Sound Basin, and it was found that a good rule of thumb method for estimating the 6-month, 24-hour design value was to take 0.64 times the 2-year, 24-hour storm (WSDOE, 1992). An alternative approach for estimating the design water quality volume (called the Maximized Water Quality Capture Volume) is described in WEF (1998).

The general design objective for treatment BMPs in the King County manual is 80% removal of total suspended solids; this only applies to runoff from pollution-generating impervious surfaces, which are specified to include roads, parking area and driveways but do not include roofs or runoff from vegetated areas (KC, 1998).

Unlike the flood control volume and the streambank erosion protection volume where the objective is to match selected post-development conditions to pre-development conditions, only the fully developed condition is normally modeled for the water quality storm.

### 4.1.4 Groundwater Recharge Requirements

Groundwater recharge in stormwater management is undertaken to reduce runoff volumes, and/or to prevent or mitigate a reduction in dry season flows in watercourses. Similar to peak flow control for flood prevention, the objective of groundwater recharge requirements is to maintain the post-development recharge rate at that of the pre-development recharge rate. The pre-development groundwater recharge rate depends on ground slope, soil type, vegetative cover, precipitation, and evapo-transpiration. Groundwater recharge objectives are site-specific, and generalizations are therefore difficult.
Few stormwater design manuals contain specific procedures for estimating groundwater recharge requirements. Ontario specifies that no runoff from a 5 mm storm should occur for any development (excluding roads) as a minimum level of control for baseflow maintenance (OMEE, 1994). The manual for the state of Maryland (CWP et al., 1997) contains a procedure for calculating the design recharge volume based on the Hydrologic Soil Group, the percent impervious cover, and the drainage area; this procedure is included in Appendix C.

4.1.5 Design Storm Events for Detention Storage

With the exception of the King County manual, the design standards discussed above for flood control and erosion control are based on single-event models. It has been found that single-event models overestimate peak flows for undeveloped conditions, with the result that detention facility release rates are overestimated, and storage requirements are underestimated. In addition, single-event models cannot represent the sequential storm characteristics of the GVS&DD climate. The single-event model normally includes the assumption that detention facilities are empty when the storm begins. It has been found (notably in the Puget Sound area) that detention facilities designed using the single-event model may be overwhelmed during a series of sequential storms, due to both undersized storage and to incomplete draining of facilities between storms. Experience in the Puget Sound area has shown that detention facilities designed using the single-event model do not meet performance goals (e.g., KC, 1998 and WSDOE, 1992).

Continuous modeling is recommended for the climatic conditions typical of the GVS&DD climate (KC, 1998). Efforts to develop more accurate models for simulating the performance runoff detention facilities are ongoing. The Washington State Department of Ecology recommends using a 50% safety factor for commercial detention storage and a 20% safety factor for residential detention storage, if conventional single event modeling is used; this standard is based on the 1989 version of the King County manual. The 1998 King County manual allows single-event modeling only for sizing conveyance systems; continuous modeling is required for evaluating storage features (KC, 1998). More detailed discussions of the relative merits of different hydrologic models under climatic conditions typical of the GVS&DD can be found elsewhere (e.g., WSDOE, 1992 and KC, 1998).

4.1.6 Costing Criteria

Some stormwater BMPs have been extensively used at full scale, and general equations have been developed for capital and O&M costs (e.g., Brown and Schueler, 1997). Others are relatively new, and little cost data are available. A recent report by the Centre for Watershed Protection in the state of Maryland reports costing estimates and equations for BMPs based on an extensive review of the available information in the U.S. to date (CWP, 1998). The costs and equations in the CWP report were adjusted for inflation and normalized to the “twenty cities average” Engineering News Record construction cost.
index to adjust for regional biases, based on a methodology followed by the American Public Works Association (APWA, 1992). The CWP report includes a cost adjustment factor to adapt the twenty cities average costs to each of the U.S. Environmental Protection Agency’s nine rainfall regions.

For the purposes of this study, the CWP twenty cities average cost equations were adjusted to the Seattle area (rainfall region adjustment factor = 1.04). In cases where cost equations were not developed in the CWP study for BMPs included in this manual, estimated costs were based on an extensive review of the literature, on the experience of the study team, and on contacts with suppliers and stormwater professionals in Washington State and Oregon. Sources are referenced in the text for all cost estimates. Costs in U.S. dollars were multiplied by a factor of 1.5 to convert to Canadian dollars.
4.2 BMP S1: Coalescing Plate Separator

4.2.1 Description

The coalescing plate interceptor (CPI), also referred to as the coalescing plate separator (CPS), typically consists of a bundle of closely spaced, corrugated plates contained in a baffled vault, which may be located above or below grade. The vault includes a forebay to trap sediment and debris, a separator section containing the bundle of coalescing plates, and an afterbay with an outlet structure. A schematic drawing of a typical CPS is shown on Figure 4-1 at the end of Section 4.2.

The coalescing plates may be horizontal or inclined, with an angle of 45° to 60° from the horizontal being most common. The spaces between the plates are typically 19 mm to 38 mm. Stormwater is directed to flow either upwards or downwards between the plates. Heavier sludge particles settle downward and contact the upper surface of the plates, where they tend to coalesce and form larger particles as they migrate downward. Similarly, small oil droplets rise and contact the lower surface of the plates, where they coalesce and migrate to the surface, where the oil is removed. In some cases, the plates are constructed of an oleophilic (oil-attracting) material such as polypropylene; oil droplets contacting this surface tend to coalesce into a film, which is said to migrate upwards to the surface. Others are constructed of neutral materials such as fiberglass; oil droplets rise until they contact the surface of a plate, and then agglomerate with other droplets as they migrate upwards along the plate surface. Accumulations of settled sludge and floating oil must be periodically removed.

4.2.2 Applications

- water quality improvement only – no attenuation of peak flows or volumes, no groundwater recharge
- special purpose BMP for removing high concentrations of oil and grease
- used to treat runoff from impervious areas only
- municipal maintenance and repair yards, industrial facilities or other locations where runoff is heavily contaminated (relative to most urban runoff) with oil and grease
- suitable for developed and redeveloping areas as well as new developments
- not suitable for treating general urban runoff
- suitable for ultra urban areas

4.2.3 Performance

- can achieve effluent concentrations as low as 10 mg/L oil and grease with removal of oil droplets as small as 5 microns (Horner et al., 1994)
- also removes settleable solids and heavy sludge
4.2.4 Pretreatment and/or Post-Treatment Requirements

- forebay to trap sediment and debris – length 1/3 to 1/2 total length of vault (KC, 1998), surface area 1.86 m² per 930 m² drainage area (Horner et al., 1994)
- may require trash rack upstream if twigs, plastics, paper etc. are expected
- afterbay with baffle and outlet structure – oil absorbent pillows may be placed in afterbay (Horner et al., 1994)

4.2.5 General Design Criteria

- see KC (1998), WEF (1998), CDM et al. (1993), and Horner et al. (1994) for detailed design guidance.

Sizing

- off-line facility, size for water quality volume only – bypass larger flows
- exclude runoff from roofs and other surfaces unlikely to contain oil
- exclude runoff from pervious areas
- the projected (horizontal) surface area of the plates \( A_p \) is estimated as follows:
  \[ A_p = \frac{\text{Design Flow Rate} \ (\text{m}^3/\text{min})}{\text{Rise Rate of Oil Droplets}}, \text{where Rise Rate of Oil Droplets} = 0.01 \text{ m/min} \] (WSDOE, 1992)
- size the separator based on the projected plate surface area \( A_p \), not the actual plate surface area \( A_a \), where \( A_p = A_a \cos H \), and \( H = \text{angle of plates to horizontal} \)

Dimensions

- design water depth to width ratio 0.3 to 0.5, width 1.8 m to 4.9 m (KC, 1998)
- plates should not be less than 19 mm apart (WSDOE, 1992 and KC, 1998)
- minimum diameter for inlet and outlet pipes 200 mm

Design Features

- place upstream of other facilities that may cause turbulence or otherwise emulsify oil
- typically provided as pre-manufactured units – consult vendors for package that meets design criteria
- locate to ensure ease of access by maintenance vehicles
- site at least 6 m from structures, property lines, septic tank fields
- site at least 15 m from steep slopes
- provide anti-floatation in areas with high groundwater table
4.2.6 Limitations

- only cost effective for treating runoff that is relatively heavily contaminated with oil and grease (at least 20 mg/L).
- not generally effective in removing emulsified or dissolved oil – avoid detergent use and turbulence upstream.
- solids, debris and accumulated oil may cause clogging of spaces between plates.
- the surfaces of oleophilic plates may become saturated with oil and/or sludge and require cleaning.
- horizontal plates require the least plate volume, but are more subject to plugging by settleable solids.

4.2.7 Capital Costs and Implementation Requirements

- budget construction cost $6,000 to $16,000 installed for design flow 415 L/min to 830 L/min. (UVC, 1998).
- for total capital cost add 35% to construction cost (engineering, contingencies, erosion and sediment control during construction, landscaping, etc) – does not include the cost of land.
- minimal staff training required.
- requires vactor truck and personnel for maintenance, capital cost $260,000 to $300,000 (Ferguson et al., 1997).

4.2.8 Operation and Maintenance Requirements and Costs

**Costs**

- smaller units (up to 2.3 m³ capacity) $1,200 to $1,500 per year, assuming inspection and skimming quarterly and cleaning with vactor truck annually (Spencer, 1998).
- larger units (up to 38 m³ capacity) $12,000 to $15,000 per year, assuming inspection and skimming monthly and cleaning with vactor truck annually (Spencer, 1998).

**Inspection and Cleaning Frequency**

- inspect separators quarterly and after large storms for proper functioning and accumulations of oil and sediments (KC, 1998).
- all oil-water separators should be cleaned before the onset of the wet season (KC, 1998; WSDOE, 1992; and WEF, 1998).
- clean separators after any spill of polluting substances.
- replace absorbent pillows before the onset of the wet season and in the spring (WSDOE, 1992).
- clean vaults when inspection reveals oil accumulation in the separation compartment equals or exceeds 25 mm, or when sediments at the bottom of the vaults exceed 150 mm depth (KC, 1998).

Other Requirements

- requires maintenance plan including scope, schedule, record keeping, and responsibilities

4.2.9 Benefits Vs Costs

- protects fish and wildlife habitat
- protects/enhances water quality – mainly through removal of oil and grease, petroleum hydrocarbons
- can produce an effluent with as low as 10 mg/L oil and grease
- good potential for community acceptance
- not normally constrained by site characteristics
- relatively expensive BMP in terms of capital costs and O&M costs
- can only be justified where a significant benefit can be demonstrated
- should only be applied where the influent runoff is expected to have concentrations of oil and grease well in excess of 10 mg/L (i.e., in industrial areas, vehicle maintenance and repair yards, heavily used parking lots etc.)
- significant benefits cannot be expected in using the CPS for treating the runoff from general urban areas, where oil grease concentrations typically do not significantly exceed 10 mg/L
- monitor runoff from potential application sites for oil and grease, to quantify the expected water quality improvement and determine if the use of this technology is justified
- See Section 4.21 for overview cost benefit comparison
FIGURE 4-1  COALESCING PLATE OIL/WATER SEPARATOR
(FROM KC, 1998)
4.3  BMP S2: Water Quality Inlet

4.3.1  Description

The water quality inlet (also known as the oil and grit separator) is designed to remove coarse sediment, oil and grease, and large particulates from stormwater. A schematic drawing of a typical water quality inlet is shown on Figure 4-2 at the end of Section 4.3. As shown, water quality inlets normally include three chambers. The first chamber is designed to trap sediment and floating debris, the second chamber is designed to contain floating oil and gas films, and the third chamber is the outlet to the downstream storm drain system.

An inverted elbow is normally used to maintain a permanent pool of water in the first two chambers; the third chamber may or may not contain a permanent pool, depending on the elevation of the overflow pipe (Figure 4-2). An alternative design does not maintain a permanent pool, and is designed to infiltrate captured stormwater (WCC et al., 1995); this design should not be used where high water tables or other conditions may cause contamination of groundwater. The retention time in water quality inlets is relatively short, typically less than 1 hour.

4.3.2  Applications

- use for pretreatment only to reduce loading of sediment, trash, and oil and grease on downstream treatment BMPs
- water quality enhancement only – no attenuation of peak flows or runoff volumes, no groundwater recharge
- suitable for developed and redeveloping areas as well as new developments
- residential areas, municipal office complexes and repair/maintenance yards
- suitable for ultra urban areas

4.3.3  Performance

- can remove coarse sediments and trash, some trapping of oil and grease
- removal efficiencies (from FHWA, 1996)
  - sediment 20%-40%
  - total phosphorus, total nitrogen, heavy metals all <10%
  - chemical oxygen demand and biochemical oxygen demand <10%
  - oil and grease 50%-80%

4.3.4  Pretreatment and/or Post-Treatment Requirements

- use for pretreatment only - requires additional treatment downstream to accomplish significant water quality improvement
4.3.5 **General Design Criteria**

- see FHWA (1996), WWC et al. (1995), and CDM et al. (1993) for detailed design guidance

**Sizing and Dimensions**

- off-line facility, size for water quality storm only - bypass larger flow
- minimum permanent pool volume = 28 m³/ha contributing drainage area (FHWA, 1996)
- permanent pool depth = 1 m to 2.4 m (FHWA, 1996)

**Design Features**

- locate to ensure ease of access by maintenance vehicles
- site at least 6 m from structures, property lines, septic tank fields
- site at least 15 m from steep slopes
- provide anti-floatation in areas with high groundwater table

4.3.6 **Limitations**

- maximum contributing area 0.4 ha (FHWA, 1996)
- settled sediment may be resuspended and trapped oil and grease may be washed out during heavier storms
- may exhibit odour problems during summer due to degradation of organic matter under anaerobic conditions in the permanent pool

4.3.7 **Capital Costs and Implementation Requirements**

- typical capital cost $7,500 to $22,500 (FHWA, 1996)
- for total capital cost add 35% to construction cost (engineering, contingencies, erosion and sediment control during construction, landscaping, etc.) – does not include the cost of land.
- minimal staff training requirements

4.3.8 **Operation and Maintenance Requirements and Costs**

- requires frequent (several times per year) removal of sediments, trash and trapped oil, clean before the onset of the dry season, after spills of polluting substances, and when inspection reveals oil accumulation greater than 25 mm or sediment accumulation greater than 150 mm or as recommended by manufacturer (KC, 1998)
$600 per unit per year (adapted from APWA, 1992)
- requires maintenance plan including scope, schedule, record keeping, and responsibilities

4.3.9 Benefits Vs Costs

- marginal water quality improvement compared to other treatment BMPs
- should only be considered as a pretreatment step to protect downstream conveyance and BMP facilities such as ponds and infiltration basins from trash, coarse sediments, and excessive concentrations of oil and grease
- relatively high capital and O&M costs
- see Section 4.21 for overview cost benefit comparison
FIGURE 4-2 WATER QUALITY INLET
(FROM FHWA, 1996)
4.4 **BMP S3: Manhole Sediment Trap**

4.4.1 **Description**

The manhole sediment trap is similar in structure to a conventional manhole, except that the sediment trapping manhole has a sump to maintain a permanent water pool to promote settling of solids and to store settled sediments. The sediment trapping manhole is normally located off-line, and is designed to handle relatively small flows, with larger flows being bypassed to the downstream drainage system. A schematic drawing of a typical sediment trapping manhole is shown on Figure 4-3 at the end of Section 4.4.

4.4.2 **Applications**

- use for pretreatment to reduce loading of sediment and floating trash to downstream facilities
- intersections of urban streets
- dirt or gravel parking lots where significant sediment load expected
- suitable for new storm sewer systems or can be retrofitted to existing systems
- suitable for developed and redeveloping areas as well as new developments
- residential areas, municipal office complexes and repair/maintenance yards

4.4.3 **Performance**

- sediment removal is a function of sediment storage volume, flow rate, and cleaning frequency
- contaminant removal efficiencies as follows (for single family residential, cleaned annually, from Sutherland):
  - sediments 15%-30%
  - heavy metals 10%-25%
  - nutrients 5%-15%
  - oxygen demand 10%-20%

4.4.4 **Pretreatment and/or Post-Treatment Requirements**

- use as pretreatment – requires additional treatment downstream to achieve significant water quality enhancement
- may use flow-splitter manhole upstream of sedimentation manhole to bypass peak flows

4.4.5 **General Design Criteria**

- see WWC et al. (1995) and Sutherland for detailed design guidance
Sizing and Dimensions

- size for water quality volume – bypass larger flows
- minimum 1,500 mm diameter manhole
- sump volume = 20 m³ per m³/s of design flow or 1.7 m³, whichever is greater (WWC et al., 1995)
- minimum sump depth 1 m, maximum sump depth 1.5 m

Design Features

- position manholes off-line (Sutherland) – note WWC et al. (1995) show both in-line and off-line layouts
- may have several inlets per manhole
- use standard manhole sizes to avoid special fabrication costs

4.4.6 Limitations

- limited removal of particulates, little or no removal of dissolved and colloidal contaminants
- high potential for flow resuspension
- limit impervious area served to 1.2 ha or less per manhole (WWC et al., 1995)
- suitable for ultra urban areas

4.4.7 Capital Costs and Implementation Requirements

- estimated typical construction cost $3,000 per unit, not including leads and tie-ins (estimated from Langley, 1992)
- for total capital cost add 35% to construction cost (engineering, contingencies, erosion and sediment control during construction, landscaping, etc.) –does not include the cost of land.
- minimal staff training requirements
- requires vactor truck for maintenance, capital cost $260,000 to $300,000 (Ferguson, et al., 1997).

4.4.8 Operation and Maintenance Requirements and Costs

- estimated cost per cleanout cycle per unit $50, not including disposal (adapted from GVRD, 1998 and Spencer, 1998)
- heavy reliance on maintenance - requires cleaning at least twice per year
- requires maintenance plan including scope, schedule, record keeping, and responsibilities
4.4.9 Benefits Vs Costs

- minimal water quality improvements
- should only be considered as a pretreatment step to protect downstream conveyance and BMP facilities such as ponds and infiltration basins from trash and coarse sediments.
- helps to prevent obstruction of drainage system by sediments
- limited protection of fish and wildlife habitat
- limited removal of trash and particulate contaminants (sediment, particulate metals and organics), little or no removal of soluble contaminants (soluble metals and organics, nutrients).
- high potential for flow resuspension if not maintained regularly
- some potential for odours if not maintained regularly.
- retrofitting is more expensive than installing with new storm sewers
- relatively expensive BMP in terms of capital and O&M costs
- see Section 4.21 for overview cost benefit analysis
FIGURE 4-3 OFF LINE SEDIMENTATION MANHOLE
(FROM WWC, 1995)
4.5 BMP S4: Trapped Catch Basin

4.5.1 Description

The trapped catch basin is similar to conventional catch basins, except that the trapped catch basin contains a sump with a baffle to maintain a permanent water pool and promote settling of sediments. A schematic drawing of a trapped catch basin is shown on Figure 4-4 at the end of Section 4.5.

4.5.2 Applications

- use for pretreatment only to reduce loading of sediment and trash on downstream facilities
- suitable for new storm sewer systems or can be retrofitted to existing systems
- suitable for developed and redeveloping areas as well as new developments
- residential areas, municipal office complexes and repair/maintenance yards
- suitable for ultra urban areas

4.5.3 Performance

- assume similar average contaminant removals to sediment trapping manholes if maintained regularly (see BMP S3)

4.5.4 Pretreatment and/or Post-Treatment Requirements

- provide a grated cover to prevent leaves and floating debris from entering catch basin
- use for pretreatment only - requires additional treatment downstream to achieve significant water quality improvements

4.5.5 General Design Criteria

- see WWC et al., (1995) for design guidance

Sizing and Dimensions

- recommended minimum sump depth below bottom of baffle 610 mm
- baffle should extend 330 mm below discharge pipe invert
- discharge pipe minimum diameter 200 mm
- approximate sump cross section 720 mm by 700 mm
Design Features

- use standard designs to reduce fabrication costs
- removable high-density 19 mm polyethylene baffle
- install baffle at catch basin outlet to trap floating debris

4.5.6 Limitations

- maximum impervious area served per catch basin 0.4 ha (WWC et al., 1995)
- limited contaminant removal capability (see Performance)

4.5.7 Capital Costs and Implementation Requirements

- estimated construction cost $800 per unit, not including leads and tie-ins (estimated from Langley, 1992)
- for total capital cost add 35% to construction cost (engineering, contingencies, erosion and sediment control during construction, landscaping, etc.) –does not include the cost of land.
- minimal staff training requirements
- requires vactor truck for maintenance, capital cost $260,000 to $300,000 (Ferguson et al., 1997).

4.5.8 Operation and Maintenance Requirements and Costs

- estimated cost of cleaning $25 per unit per cycle (adapted from GVRD, 1998).
- heavy reliance on maintenance
- requires maintenance plan including scope, schedule, record keeping and responsibilities

4.5.9 Benefits Vs Costs

- minimal water quality improvements
- should only be considered as a pretreatment step to protect downstream conveyance and BMP facilities such as ponds and infiltration basins from trash and coarse sediments.
- helps to prevent obstruction of drainage system by sediments
- limited protection of fish and wildlife habitat
- limited removal of trash and particulate contaminants (sediment, particulate metals and organics), little or no removal of soluble contaminants (soluble metals and organics, nutrients).
- high potential for flow resuspension if not maintained regularly
- some potential for odours if not maintained regularly.
• retrofitting is more expensive than installing with new storm sewers
• relatively expensive BMP in terms of capital and O&M costs
• see Section 4.21 for overview cost benefit analysis
FIGURE 4-4  TYPICAL TRAPPED CATCH BASIN
(FROM WWC, 1995)
4.6 BMP S5: Dry Detention Basin

4.6.1 Description

Detention basins are designed to temporarily store collected runoff water, and to slowly release the stored water at a controlled rate through one or more orifices. Dry detention facilities are designed to empty completely between storms. Some infiltration of captured water may occur, depending on the underlying soil conditions.

Conventional dry detention basins are normally designed to control the frequency of flooding downstream, normally by limiting the peak runoff flow rate for the developed condition to that of the pre-development condition. Conventional dry detention basins typically empty within a few hours following the design event. The design storm for flood control is typically a relatively large, infrequent event (e.g., the 5-year or 10-year event – see Section 4.1). Since no detention normally occurs until the inflow rate is greater than the design outflow rate, the runoff from smaller, more frequent events is not normally detained in conventional detention facilities. Conventional dry detention facilities designed strictly for control of peak flows do not necessarily reduce the frequency and duration of bankfull flows, nor do they significantly reduce the total annual mass loading of contaminants carried to receiving waters. A schematic drawing of a conventional detention basin is shown on Figure 4-5a at the end of Section 4.6.

Extended detention dry basins are typically designed to detain the runoff from smaller, more frequent storms. Larger flows may be bypassed, depending on the design objectives. Extended detention facilities employ lower release rates than conventional detention facilities, resulting in a longer storage time for the detained water. In contrast to conventional dry detention basins, extended detention basins are designed to retain stored water for up to 72 hours following the design event. The longer detention time has two potential benefits. The first is that the duration and frequency of bankfull flows can be reduced, and the second is that a significant reduction in particulate contaminants can be achieved through gravity settling during the time that the water is contained in the basin.

Multi-purpose dry detention basins can be designed to meet two or more of the above objectives in a single facility, by designing the outlet structure to achieve both extended detention of smaller, more frequent events and conventional short-term detention of larger flows. This may require a multiple combination of orifices, weirs and spillways in the outlet structure. A permanent micropool may be included at the outlet, to prevent resuspension of sediments. A schematic drawing of a multi-purpose dry detention basin is shown on Figure 4-5b at the end of Section 4.6.
4.6.2 Applications

- conventional dry detention applies to peak flow control only
- extended dry detention applies to streambank erosion protection and water quality enhancement
- suitable for new developments
- unsuitable for existing developments unless there is adequate space for retrofitting to existing parks and greenspace
- suitable for residential areas, municipal office complexes and municipal repair/maintenance yards
- not suitable for ultra urban areas

4.6.3 Performance

- conventional dry detention basins are effective in matching post development peak flows to predevelopment peak flows
- assume negligible removal of contaminants for conventional dry detention basins
- typical contaminant removal efficiency of extended detention dry basins (Horner et al., 1994) – note that this does not apply to conventional dry detention basins
  - suspended solids 50% to 70%
  - total phosphorus and total nitrogen 20% to 40%
  - lead 75% to 90%
  - zinc 30% to 60%
  - hydrocarbons 50% to 70%
  - bacteria 50% to 90%
- estimate contaminant removal as follows (FHWA, 1996):
  \[ R = a t_d^b, \]
  where
  \[ R \] = removal efficiency in percent
  \[ t_d \] = detention time, hours
  \[ a = 41.5 \text{ and } b = 0.2 \] for suspended solids and lead
  \[ a = 31.4 \text{ and } b = 0.12 \] for zinc, copper, phosphorus and COD
  \[ a = 15.2 \text{ and } b = 0.25 \] for nitrogen

4.6.4 Pretreatment and/or Post-Treatment Requirements

- sedimentation forebay with a volume equal to 10% of the total design volume recommended for extended detention basins (see Figure 4-5b)
- forebay should have stabilized access and bottom to prevent sinking of mechanical equipment
4.6.5 General Design Criteria and Considerations


**Sizing**

- size storage and outlet structure according to design objectives for flood control, streambank erosion control, or contaminant removal
- typical detention times for the design runoff event as follows:
  - conventional dry detention basin for flood control – 1 to 2 hours
  - extended detention dry basin for streambank protection – 24 hours
  - extended detention dry basin for contaminant removal – 24 to 72 hours
- note that the limiting detention volume will depend on the relative magnitudes of the design storms selected for flood control, streambank protection, and/or water quality protection
- allow an additional 20% storage volume to allow for sediment accumulation (WEF, 1998)
- for contaminant removal, provide an outlet to empty less than 50% of the design volume during the first 33% of the emptying period (WEF, 1998)

**Dimensions**

- minimum length to width ratio 2:1, up to 4:1 preferred
- two-stage basin recommended for extended detention – design volume of lower stage (micropool) should be 15% to 25% of total design volume with depth 1.1 to 2.7 m, upper stage 0.6 to 1.8 m deep with bottom sloping 2% toward low flow (pilot) channel - lower stage reduces standing water and sediment deposition in the rest of the basin and helps to prevent resuspension of settled sediments and clogging of the low flow orifice (Figure 4-5b)
- maximum basin side slopes 3:1 (preferably 4:1) for slope stability, ease of maintenance and safety
- maintenance access maximum grade 8% to 10%
- minimum 300 mm freeboard

**Design Features**

- provide low flow channel from forebay to outlet for erosion protection (Figure 4-5a and 4-5b)
- provide emergency spillway to pass storms larger than the design event
- provide trash rack, hood or other protection (e.g., gravel cone around perforated outlet riser) to prevent clogging of outlet with trash
**4.6.5 Vegetation and Landscaping**

- consider using landscape architect to integrate facility into neighborhood
- plant basin with native grasses or turf to enhance sediment entrapment and protect against erosion – may require water tolerant species on basin bottom
- design to minimize thermal impacts – small permanent pool, shading vegetation, north-south alignment, avoid excessive riprap and concrete

**4.6.6 Limitations**

- longer detention times may limit the survival of bottom vegetation and produce boggy areas that can be difficult to clean and maintain
- outlet structures may become clogged with trash and debris
- orifice diameter may preclude use in small watersheds
- space requirement for basin 0.5% to 2% of total contributing area for extended detention dry basins (FHWA, 1996)
- maximum site slope 15% (CWP, 1998)
- hydraulic head loss 1.8 m to 2.4 m (CWP, 1998)
- not normally restricted by soil type – high clay content may cause standing water problems
- vegetation may be difficult to establish and sustain in areas with extremely sandy soils, impermeable layers and/or bedrock outcrops

**4.6.7 Capital Costs and Implementation Requirements**

- budget construction cost $11.65 x \((35.31V)^{0.78}\)
  where \(V\) = storage volume (adapted from Brown and Schueler, 1997 and CWP, 1998)
- typical construction cost $26 to $53 per m\(^3\) (adapted from Brown and Schueler, 1997)
- for total capital cost add 35% to construction cost (engineering, contingencies, erosion and sediment control during construction, landscaping, etc) – does not include the cost of land
- minimal staff training requirements
4.6.8 Operation and Maintenance Requirements and Costs

Costs

- budget 1% of construction cost per year (Livingston et al., 1997 and Brown and Schueler, 1997)

Inspection and Cleaning Frequency

- annual - inspect hydraulic and structural facilities – expected life of outlet structures 25 yr for corrugated metal and 50-75 yr for structural concrete (FHWA, 1996)
- inspect at outset of rainy season and after each significant storm - remove floatables, correct erosion problems, unclog outlet structures
- inspect periodically during wet weather to observe function
- remove sediments from lower stage every 5-15 years as required

Other Requirements

- routine mowing – maintain irrigated grass to 50-100 mm tall and non-irrigated native grasses to 100-150 mm tall
- requires maintenance plan including scope, schedule, record keeping, and responsibilities

4.6.9 Benefits Vs Costs

- conventional dry detention – control of peak flows only – may not provide adequate streambank protection, no significant removal of contaminants
- extended dry detention – can be used to control duration and frequency of bankfull flows and/or remove particulate contaminants (sediments, particulate metals and organics) and floatable material – little or no removal of soluble and colloidal contaminants (soluble metals and organics, nutrients)
- can be configured as a multi-use facility – flood protection, streambank protection, contaminant removal, sports fields, wildlife habitat
- not as effective in removing contaminants as wet ponds and engineered wetlands
- not as aesthetically pleasing as wet ponds and engineering wetlands.
- equal to other BMPs such as wet ponds for flood control and streambank erosion protection.
- less desirable than wet ponds and engineered wetlands from a public standpoint (aesthetics, fish and wildlife habitat, recreation property values)
- some safety concerns, particularly with larger basins – side slopes, flow velocities, pool depth, integrity of impounding embankment
- some aesthetic concerns – accumulation of trash and debris, boggy areas, odours
- possible mosquito nuisance in facilities with standing water
• more expensive than vegetated swales/grassed channels and vegetated filter strips but less expensive than wet ponds and engineered wetlands
• see Section 4.21 for overview cost benefit comparison
FIGURE 4-5a
EXAMPLE OF CONVENTIONAL DRY DETENTION BASIN
(FROM CWP et al., 1997)
FIGURE 4-5b
EXAMPLE OF MICRO POOL EXTENDED DETENTION DRY BASIN
(FROM CWP et al., 1997)
4.7  **BMP S6: Wet Pond**

4.7.1  **Description**

Wet ponds are similar to extended detention dry basins in that both are designed to temporarily detain collected runoff, and both can provide flood control, streambank erosion protection, and water quality improvements. Unlike dry detention basins, wet ponds are designed to maintain a permanent pool of water between storms. During runoff events, the permanent pool helps to minimize turbulence for enhanced settling of particulates, and helps to prevent scour and resuspension of sediments. Between runoff events, flocculation and settling of fine particulates occurs under quiescent conditions in the permanent pool. In addition, non-settleable and soluble contaminants can be removed from solution or converted to less harmful forms through chemical transformations and biological action by bacteria and vegetation that develop in the permanent pool.

Wet ponds can be designed to include flood control and streambank erosion protection as well as water quality enhancement. In these facilities, the live storage is designed above the permanent pool. Wet ponds may be designed as off-line facilities to contain the water quality volume (or the streambank protection volume) while bypassing larger flows, or they may be designed on-line to include flood control and streambank erosion protection as well. Some infiltration of water may occur, depending on the nature of the pond lining and the underlying soil conditions.

Wet ponds lend themselves to multi-purpose facilities that include fish and wildlife habitat, recreational use, and aesthetic enhancements, as well as stormwater management. A schematic drawing of a typical wet pond is shown on Figure 4-6a, and a multiple pond system is shown on Figure 4-6b at the end of Section 4.7.

4.7.2  **Applications**

- peak flow control, streambank erosion protection, water quality enhancement, community enhancement (recreation, aesthetic value)
- suitable for new developments
- unsuitable for existing developments unless space is available for retrofitting to existing parks and greenspace
- suitable for residential areas, municipal office complexes and municipal repair/maintenance yards
- suitable for small on-site facilities and large regional facilities
- not suitable for ultra urban areas

4.7.3  **Performance**

- wide range in observed contaminant removal efficiencies
• removal efficiency depends to some extent on the size of the permanent pool
• there is often a distinction between wet ponds designed for removal of particulates only and those designed for removal of nutrients as well as particulates (see V_B/V_R under design considerations)
• median contaminant removal efficiencies for wet ponds based on 30 performance monitoring studies as follows (Schueler, 1997b):
  - total suspended solids 77%
  - organic carbon 45%
  - total phosphorus 47%
  - soluble phosphorus 51%
  - total nitrogen 30%
  - nitrate 24%
  - lead 73%
  - copper 57%
  - zinc 51%
  - cadmium 24%
  - hydrocarbons 83%
  - bacteria 65%

4.7.4 Pretreatment and/or Post-Treatment Requirements

• provide sedimentation forebay with stabilized inlet – volume 10% of permanent pool storage, 1.2 m to 1.8 m deep with fixed sediment depth marker to monitor sediment accumulation (Figure 4-6a)
• forebay should have stabilized access and bottom to prevent sinking of mechanical equipment
• inlet structure should dissipate flow energy and diffuse inflow plume
• provide stilling basin to reduce flow velocities or streambed erosion protection at pond outfall (Figure 4-6a and 4-6b)

4.7.5 General Design Criteria and Considerations


Sizing

• design volume depends on objective (flood control, streambank erosion protection, and/or water quality protection)
• the permanent pool is designed for water quality only – design additional live storage above permanent pool for streambank erosion protection and/or flood control
• the Washington State Dept. of Ecology recommends the runoff from the 24-hour, 6 month event as the water quality volume (WSDOE, 1992)

BMP S6: Wet Pond

- one design approach is to size the permanent pool volume to hold the runoff from the design water quality storm (Horner et al., 1994)
- alternatively, size the storage pool volume based on the “volume ratio” as follows: volume ratio = \( V_B / V_R \), where
  \( V_B \) = permanent pool volume
  \( V_R \) = volume of runoff from the long-term average storm
- King County recommends \( V_B / V_R = 3 \) for 80% removal of suspended solids and \( V_B / V_R = 4.5 \) for 50% removal of total phosphorus (KC, 1998)
- note that, in the Seattle area where the long-term average storm is about 12 mm, ponds sized for the 6-month, 24 hour (30 mm) storm have a \( V_B / V_R \) of about 2.5 (Horner et al., 1994)
- other methods of sizing wet ponds are available (eg., FHWA, 1996 and WEF, 1998)

**Area Requirements**

- total land consumption including buffers 2% to 3% of watershed area
- maximize surface area to gain volume rather than deepening pool for best performance (Horner et al., 1994)

**Dimensions**

- average pond depth 1 m to 2 m, maximum pond depth 2.5 m (FHWA, 1996)
- minimum 300 mm freeboard (CWP et al., 1997)
- include two or more distinct cells and baffles if necessary to minimize short-circuiting (Horner et al., 1994)
- minimum length to width ratio 3:1, preferably up to 5:1 (CWP et al., 1997)
- maximum side slope 3:1 (CWP et al., 1997)
- maintenance access maximum grade 8% to 10%

**Inlet and Outlet**

- low inlet velocity, uniform flow distribution across inlet
- design discharge from mid-depth with minimum turbulence (Horner, et al., 1994)
- protect low-flow orifice from clogging – use submerged reverse-slope pipe (Figure 4-6a and 4-6b), trash rack, or, if perforated pipe is used for the outlet, protect with wire cloth and stone jacket (geotextile not recommended) – CWP (1997)
- place anti-seep collar around outlet pipe, provide anti-vortex device at outlet for large facilities
- provide drain capable of completely emptying pond where possible
Design Features

- allow a safety bench at least 4.5 m wide around pond perimeter extending outward from edge of permanent pool to toe of embankment, maximum slope 6% (Figure 4-6a and 4-6b)
- allow an aquatic bench 3 m to 4.5 m wide around pool perimeter extending inward from edge of permanent pool, maximum water depth 600 mm – encourage aquatic vegetation on bench (Figure 4-6a and 4-6b)
- provide emergency spillway to pass storms larger than the design event (Figure 4-6a and 4-6b)
- design to minimize thermal impacts – shading vegetation, north-south alignment, avoid excessive riprap and concrete

Soils and Vegetation

- plant native turf-forming grasses or irrigated turf on sloped area
- use vegetated buffers to discourage small children from approaching pool and post warning signs
- prohibit woody vegetation within 5 m of toe of embankment and within 7.5 m of spillway principal structure (CWP et al., 1997)
- if soils are severely compacted during construction, excavate planting sites and backfill with uncompacted topsoil
- avoid plant species that require full shade, are susceptible to winterkill, or are prone to wind damage
- use extra mulching around trees and shrubs to contain moisture and discourage weeds

4.7.6 Limitations

- maximum removal of soluble contaminants such as phosphorus approximately 60% (Horner et al., 1994)
- requires adequate baseflow to maintain permanent pool
- minimum contributing drainage area 4 ha, 10 ha preferred, unless groundwater confirmed as primary water source (FHWA, 1996)
- maximum contributing drainage area typically 25 km² (FHWA, 1996)
- pond surface area requirement varies with design – typically 1% to 3% of contributing area (FHWA, 1996) but can be up to 7% for V_B/V_R = 5, depending on catchment and rainfall characteristics (Horner et al., 1994)
- maximum site slope 15% (CWP, 1998)
- hydraulic headloss 1.8 m to 2.4 m (CWP, 1998)
- may require liner to sustain permanent pool in permeable soils
4.7.7 Capital Costs and other Implementation Requirements

- budget construction cost $28.90 \times (35.31V)^{0.70}
  where \( V \) = storage volume, including permanent pool and live storage (adapted from Brown and Schueler, 1997 and CWP, 1998)
- typical construction cost $26 to $53 per m\(^3\) (adapted from Brown and Schueler, 1997)
- for total capital cost add 35% to construction cost (engineering, contingencies, erosion and sediment control during construction, landscaping, etc) – does not include the cost of land
- minimal staff training requirements

4.7.8 Operation and Maintenance Requirements and Costs

Costs

- budget 3% to 6% of construction cost per year (Wiegand et al., 1986, Schueler et al., 1987 and SWRPC, 1991)

Inspection and Cleaning Frequency

- inspect periodically during wet weather to observe function
- clean sediment forebay every 5-7 years or when 50% of capacity has been lost (CWP et al., 1997)
- remove accumulated sediments from pond bottom when 10% to 15% of pool volume is lost - typical volume loss to sedimentation 1% per year
- inspect hydraulic and structural facilities annually – expected life of outlet structures 25 yr for corrugated metal and 50-75 yr for structural concrete (FHWA, 1996)
- provide maintenance access or easement, minimum width 3.7 m (Figure 4-6a and 4-6b)
- at outset of rainy season and after each significant storm - remove floatables, correct erosion problems, unclog outlet structures

Other Requirements

- mow side-slopes, embankments and spillways annually or as required to prevent woody growth and weeds, manage remaining buffer as meadow (mow every other year) or forest
- control nuisance insects and weeds as required
- vegetation on the pond fringes may have to be harvested periodically and the clippings removed
- requires maintenance plan including scope, schedule, record keeping, and responsibilities