

# Stormwater Management Manual for the Puget Sound Basin

(The Technical Manual)



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**Editor's Note**

Many thanks to those of you who reviewed and commented on the previous drafts of the manual. Much of the continued improvement of the manual has been, and will continue to be, the result of reviewers' comments and constructive criticisms.

The final version of the manual has been prepared following review of the June, 1991 "Public Review Draft" that was distributed to some 900 reviewers last summer. Technical workshops were held in Everett, Bellevue, Tacoma, and Olympia during August and September, 1991. Written comments were received from 55 reviewers.

**Changes in the Puget Sound Stormwater Management Program**

The Puget Sound Stormwater Management Program mandated by the Puget Sound Water Quality Management Plan (PSWQMP) has changed substantially since the release of the 1991 draft manual. There are no longer two "companion" rules. The language requiring the adoption of local stormwater management programs has been placed in the PSWQMP instead of being contained in rule form.

The Puget Sound Water Quality Management Plan states that local stormwater management programs are to be consistent with the Plan, as well as Ecology's guidance, model ordinances and Stormwater Management Manual. Ecology is to monitor compliance with the Plan requirements, reviewing the status of each local program every two years. Information on implementation schedules and procedures for reviewing local programs are provided in the "Stormwater Program Guidance Manual for the Puget Sound Basin" (hereafter referred to as the Guidance Manual), a companion to this manual. Copies of either this manual or the Guidance Manual can be obtained by calling (206) 438-7116 or (206) 438-7059. The cost is not known for certain as we go to press, but should be approximately \$40.00 (U.S.) for either manual. Do not send us funds, as a bill will be sent with the manual.

**Changes Made to the Manual**

Changes were made to the 1991 draft manual based both on new information available and comments received. Some things didn't change: for example, we are still emphasizing the use of infiltration where appropriate. A reduced release rate of 50% of the pre-developed discharge rate has been retained for streambank erosion control. The correction factors have been kept but they are only necessary for streambank erosion control BMPs. The 7-day design storm has not been incorporated at this time. Further hydrologic modelling and analysis is planned for this year with the goal of providing more accurate and easy-to-use methods (see "Unfinished Business", below).

### New Development/Redevelopment

- The threshold for land disturbing activities between small parcels and large parcels has been increased to 1 acre (page I-2-2).
- The size threshold of 11.5% for redevelopment sites greater than 1 acre in size was dropped. 5,000 square feet is used as the trigger, regardless of the size of the development (page I-2-4).
- A "documented water quality problem" is now defined (page I-2-4).

### Minimum Requirements

- Many editorial changes were made to better clarify the content and rationale for the Minimum Requirements. The modifiers "General" and "Special" for Minimum Requirements were dropped, and the requirements arranged in a more logical order. Objectives were added for each Minimum Requirement.
- The Erosion and Sediment Control "General Criteria" were moved from Chapter II-4 to Chapter I-2, and consolidated as Minimum Requirement #1, Erosion and Sediment Control.
- The off-site analysis requirement (now Minimum Requirement #8, Off-site Analysis and Mitigation) was simplified.
- The ability to use an implemented and adopted basin plan to modify the Minimum Requirements was included (see Minimum Requirement #9, Basin Planning).

### Remainder of Chapter I-2

- More specific information and two examples of experimental BMPs have been provided.

### Chapter I-3

- A Small Parcel BMP checklist which can be used "as-is" or modified by the local government has been added. Completion of this checklist can be considered to have met the Small Parcel Erosion and Sediment Control Requirements.
- Large parcels require the development of a "Stormwater Site Plan" which is in turn made up of a Large Parcel Erosion Control Plan (LPESC) and a Permanent Stormwater Quality Control Plan (PSQC). The LPESC addresses erosion and sediment control during the construction phase, and the PSQC plan addresses permanent stormwater management facilities.

### Chapter I-4

- The BMP selection process has been revised to more clearly define the type of pollution problem that a BMP is targeted to control. The problem may be water quality (WQ), which addresses either nutrients or conventional pollutants, streambank erosion control (SBEC), source control or, as is most likely, a combination of these types.

- A clear distinction is now made between BMPs which are designed to treat the water quality design storm (6-month, 24-hour storm) and those which are designed for streambank erosion control, which are significantly larger events.

## Volume II

- Information on development of ESC plans has been added back in Chapter II-4. A sample ESC plan will eventually be included in the Guidance Manual.
- An explanation of the requirements for NPDES stormwater permits based on the proposed industrial baseline general permit is also included in Chapter II-4.
- Changes were made to the filter fabric BMP based on research done by the King County Conservation District (Chapter II-5).

## Volume III

- The Rational Method has been dropped from use.
- The procedure for designing infiltration BMPs has been simplified.
- Sand filters have been added as a BMP.
- Aquatards are now considered to be an experimental BMP.
- A new design procedure is provided for presettling basins.
- The sizing criteria for wet ponds has been changed to reflect the amount of runoff generated by a site rather than a "1.5% of drainage area" approach applied across the board. Less intensely developed sites have smaller ponds, while sites with more impervious area require larger ponds. Previously the ponds were the same size regardless of the site impervious cover.
- The use of oil/water separators has been restricted. On an interim basis, sand filters may be used as a substitute.
- The constructed wetland BMP has been moved from the chapter on wetlands to the chapter on detention systems to emphasize its relationship to detention systems rather than the relationship to natural wetlands.
- Biofiltration is now a stand-alone BMP for treatment of conventional pollutants but not for nutrient control.
- Filter strip design has been separated from biofiltration swale design. The existing design method, however, has not been changed.
- Biofilter design now uses the 6-month event instead of the 2-year event in order to be consistent with other BMPs.

## Volume IV

- Information on golf courses has been included.
- Street sweeping has been added as a BMP.

### **Status Reports**

Detailed information on NPDES, the Sediment Standards, the relationship of BMPs to the water quality standards, and information on program requirements can be found in the Guidance Manual. Included below are some other status reports.

#### Training and Technical Assistance

In July, 1992 we will be conducting our first workshops for local government staff. These day-long workshops will be sited throughout the basin and provide an overview of Ecology's stormwater management program. Based on input received at these workshops, we will develop other training sessions.

Eventually we will be providing a wide range of training and technical assistance to both local government staff and others. As a start, funds have been committed to the Center for Urban Water Resources Management at the University of Washington for three different tasks. The first is to continue their popular on-site visits to local jurisdictions. The second task will be to develop a half day (approximate) course on erosion and sediment control which would be appropriate for construction site personnel. The course would then be taped and distributed. The third task is to implement a "hotline" for local government personnel questions. This task would also include cataloging the information that the Center now has available, and includes funding for some applied research. We hope to continue some form of this funding from year to year.

We also anticipate developing a videotape of approved erosion and sediment control BMPs.

#### Vector Waste Disposal Issues

We recognize that the lack of accepted procedures and locations for the disposal of waste from maintenance activities is one of the greatest problems confronting stormwater operation and maintenance programs. Disposal of the liquid and solid waste material from vector trucks and other maintenance operations is a concern because of the potential to contaminate surface or ground water. Some existing disposal practices may violate dangerous waste regulations, or otherwise be harmful to the environment.

In order for Ecology to develop guidelines that address appropriate disposal practices, more information is needed on the nature of vector wastes. In response to this data gap, two grants from EPA have been used to collect and analyze vector waste samples. Final results of the sampling will be available in September, 1992.

We will be using the sampling results and other available data to develop disposal options. At this time it is not known if disposal procedures will be issued as guidelines or a rule (regulation).

Ecology's Solid and Hazardous Waste program is currently working on revisions to Ch. 173-304 WAC, the minimum functional standards for solid waste facilities. These revisions may be an appropriate mechanism for addressing vector waste. Contaminated soils have been identified as one of five issues that are to be addressed in the proposed revisions, and vector waste will be looked at as part of this issue. The proposed process for these revisions is to collect information this summer, publish a draft EIS with draft rule language in December of 1992, a final EIS in April of 1993, and adopt final rules in September of 1993.

We intend to prepare a supplemental guidance paper on disposal procedures when we have enough information to begin to answer key questions about the characteristics of these materials.

#### SEPA Checklist and DNS

A SEPA checklist was filled out for the Stormwater Management Manual as it was determined that the manual was subject to SEPA review as a non-project action. The DNS was published in the March 16-20, 1992 SEPA Register. There was no comment period required.

#### Status of the WSDOT Manual

WSDOT is required to develop their Highway Runoff Manual within 6 months after this manual is published. Roads and right-of-way issues will be addressed in this manual, and we anticipate that local governments will also be able to make use of this information.

#### Technical Advisory Committee

The technical advisory groups (TAGs) that were originally constituted by Ecology need to be reconstituted. We anticipate developing those TAGs into a standing advisory committee to review experimental BMPs in consultation with Ecology and provide review of the many technical questions still on our agenda. We expect to reformulate this committee later this year as part of the manual update process.

### **Unfinished Business**

In a field as complex and rapidly changing as stormwater management, there will always be "unfinished business". The PSWQMP requires that the manual be updated yearly. Based on the progress of some ongoing research projects, we anticipate that the next version of the manual will include the results of the HSPF runoff files research done at the University of Washington.

Other additions we hope to make are the use of the 7-day storm for streambank erosion control, and the inclusion of more detailed isopleth maps for the entire Puget Sound basin.

We still do not have a definitive answer as to the cost of implementing these new procedures. We have funds available for development of a document similar to a Small Business Economic Impact Statement (SBEIS), and hope to have this complete within the next year. Related to the economic question as a whole is whether or not the cost is relatively higher for small commercial sites than for larger sites. This is one of the major problems we hope to address with the SBEIS.

Because of problems with the use of small (less than 1 inch) orifice sizes, runoff from small commercial developments cannot now be adequately controlled through the use of wet ponds. There is no easy solution to this problem, and we hope that local governments will work together with developers to develop and implement alternatives to site-specific wet ponds in the future.

Lastly, we hope to be able to desktop publish the manual in order to make it more user friendly than it currently is. In time, we may also have both a "pocket" version of the manual and a computerized version available.

Peter B. Birch, Ph.D., Helen E. Pressley and Patrick D. Hartigan  
Editors and Compilers

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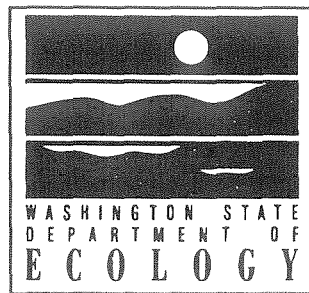


# **Stormwater Management Manual for the Puget Sound Basin**

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(The Technical Manual)

*Volume I - Minimum Technical  
Requirements*





## FOREWORD

For years stormwater management has meant controlling water quantity. Increased runoff is directly related to an increase in impervious surfaces (roads, parking lots and rooftops) which prevent runoff from soaking into the ground.

Today we recognize that stormwater runoff also contributes to water quality degradation. Stormwater carries excessive amounts of sediment from exposed construction sites, and other pollutants which wash off streets and parking lots, industrial sites and residential lawns and gardens. These pollutants include oil and grease, pesticides and fertilizers, harmful bacteria and metals such as lead, cadmium and copper.

### What is the State Doing About Urban Stormwater?

In response to stormwater quality problems, the Puget Sound Water Quality Management Plan directed Ecology to:

- Develop guidance consisting of program implementation guidance for local governments including model ordinances;
- Develop a technical manual addressing erosion and sediment control, runoff control and control of pollution from urban land uses; and
- Work with the Washington State Department of Transportation (WSDOT) on a program to control runoff from state highways in the Puget Sound basin.

This manual, which is essentially a stormwater Best Management Practices (BMP) manual, has been developed in response to the above requirements. It is intended for use by local governments, tribes, and WSDOT in the Puget Sound basin (see Figure 1). A more complete description of Ecology's program is found in Chapter I-1.

### Acknowledgements

This manual could never have been completed without the contributions of many local government public works and planning officials, representatives from other state agencies, and other affected and interested parties including industries and tribes. Their insights and practical knowledge gained from years of experience in the field have been particularly valuable. In addition, their useful comments and thorough review of earlier drafts improved the quality and utility of the manual.

We would also like to thank the Puget Sound Water Quality Authority for their successful endeavors to obtain support and funding for stormwater as an element of the Puget Sound Water Quality Management Plan. In particular, we would like to thank Vallana Piccolo who has diligently attended technical advisory group meetings and provided helpful review throughout the manual development process.

Figure 1 Puget Sound Basin



**PUGET SOUND BASIN**

Members of each of the three technical advisory groups are acknowledged in the appropriate volume of the manual. In addition, we would like to express our appreciation to the following persons, all of whom contributed extensively to the manual.

Randall Parsons (now in another position with King County), as Senior Engineer with the King County Storm and Surface Water Division, was responsible for developing the King County Surface Water Design Manual which formed the basis for much of the information contained in this manual.

Dr. Gary Minton, of Resource Planning Associates, was the principal author of Volume IV - Urban Land Use BMPs, and thus made a substantial contribution to the development of this manual.

Dr. Richard Horner, director of the Center for Urban Water Resources Management at the University of Washington, provided the basis for the biofiltration chapter in Volume III. Together with the Puget Sound Wetlands and Stormwater Research Committee, he authored the guidance for the management of natural wetlands found in the same volume.

Thomas Schueler, author of the Urban Land Uses BMP Manual published by the Metropolitan Washington (D.C.) Council of Governments graciously consented to the use of some illustrations and text from that manual.

All other references are noted as they occur in the manual and are listed at the end of each chapter.

We are particularly grateful to the other members of Ecology's Urban Nonpoint Management Unit: Gerald Anderson (now with Ecology's Southwest Regional Office), Ann Wessel, Melany Lee, Gary Kruger, Gary Cooper, Kim Van Zwalenburg (now with Ecology's Shoreland Program), Heather Saunders (now with Thurston County) and many other Ecology staff members for their help and suggestions during the development of this manual.

We would like to apologize in advance for any errors of omission or commission; while all due diligence has been exercised, inevitably errors creep in to a work of this size and complexity. Any questions or further comments regarding the manual should be directed to either Helen Pressley (206) 438-7089 or Pat Hartigan (206) 493-9454.

Peter B. Birch, Ph.D, Helen E. Pressley and Patrick D. Hartigan  
Compilers and Editors



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GLOSSARY AND NOTATION

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CHAPTER I-1

INTRODUCTION

I-1.1 EFFECTS OF URBANIZATION

The pre-settlement Puget Sound basin was primarily forested in alder, maple, fir, hemlock and cedar. The area's bountiful rainfall supported the forest and the many creeks, springs, ponds, lakes and wetlands. The forest system provided protection by intercepting rainfall in the canopy, reducing the possibility of erosion and the deposition of sediment in waterways. The trees and the forest duff layer absorbed large amounts of runoff releasing it slowly to the streams through interflow in the soil.

As settlement occurred and the population grew, trees were logged and land was cleared for buildings, parking lots and pasture. Roads were cut through slopes, and low spots, often wetlands, were filled. Drainage patterns were irrevocably altered.

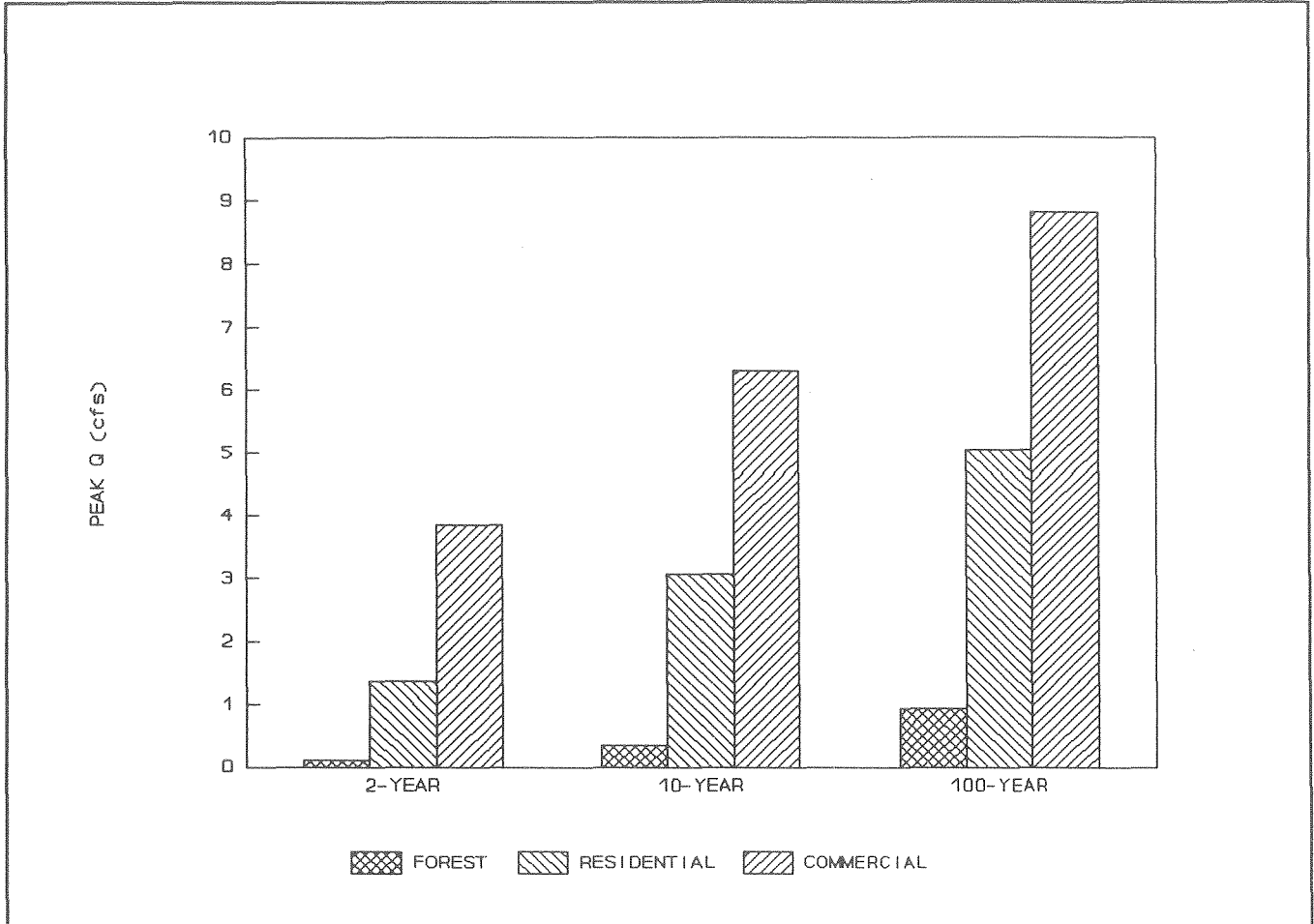
Once areas are cleared, the increase in compacted and impervious surfaces in turn increases both the volume of surface runoff, the peak rate of flow, and decreased ground water recharge. Runoff that was previously slowly released to streams through interflow now runs quickly off the surface directly into the streams. This increases both the velocity and total quantity of flow causing streambank erosion and general habitat destruction. Sediment from increasingly eroded and unstable streambanks and cleared areas is deposited downstream filling ponds, streambeds and stormwater facilities. An additional consequence is that summer base flows are greatly reduced because of a lack of interflow.

Runoff from urban areas has been shown to contain many different types of pollutants, depending on the nature of the activities in those areas. The runoff from roads and highways is contaminated with oil and grease, lead, cadmium and other pollutants. Uncontrolled runoff from industrial areas can contain PCBs, heavy metals, high pH concrete dust, and many other toxic chemicals. Residential areas contribute herbicides, pesticides, fertilizers and animal waste to runoff. All of these contaminants can seriously impair beneficial uses of receiving waters.

Aquatic life is greatly affected by urbanization within an ecosystem. Habitats are drastically altered when a stream changes its configuration and deposits its sediment load in response to urbanization. Natural riffles, pools, gravel bars and other areas are altered or destroyed. Spawning areas, particularly those of salmonids, are lost. Urbanization also tends to cause an increase in water temperature as vegetation which shades the water is removed. A rise in water temperature may cause algal blooms which reduces the amount of dissolved oxygen in the water. The lack of dissolved oxygen can cause fish and other aquatic organisms to die. When a species' habitat requirements are not met they either move elsewhere or die off, and other species, often exotic and undesirable, move in to take their place.

While the impacts of urbanization can be readily conceptualized, the magnitude of the problem may not be generally realized. This can be illustrated by looking at the hydrologic regime and the pollutant loads of different land use types. Figure I-1.1 illustrates the former by showing the increases in peak flow rates resulting from the conversion of forest land to residential and commercial development. The changes in flow rates and hydrologic regimes can cause severe erosion of streambanks and severely degrade aquatic habitat. Figure I-1.2 illustrates the change in the pollutant load (the product of runoff volume and pollutant concentration) of total phosphorus for different land uses as compared to pre-development conditions. It is not unusual for loads to increase by several hundred to several thousand percent

FIGURE I-1.1<sup>1</sup>  
 PEAK RUNOFF FLOW RATES FOR DIFFERENT LAND USES  
 FOR THE 2, 10, AND 100-YEAR, 24-HOUR DESIGN STORM EVENTS



over pre-development conditions. Thus, two primary objectives of stormwater management programs need to be the control of runoff flows and the reduction of pollutant loads.

It can be difficult to quantify cause-and-effect relationships when evaluating changes in hydrologic regimes and pollutant loads caused by urbanization. Experiences locally and elsewhere have shown, however, that urbanization can be a significant cause of pollution problems with both short-term and long-term impacts prevailing. Short term changes in water quality can restrict contact recreation, stress aquatic organisms, and damage shellfish beds. Long-term impacts on stream morphology often occur when urbanization changes natural hydrologic conditions. The long-term accumulation of pollutants into receiving waters can also create problems which can be particularly difficult to correct, such as eutrophication, polluted groundwater, and contaminated sediments.

source control BMPs include methods as various as using mulches and covers on disturbed soil, putting roofs over outside storage areas, tracking down and eliminating illicit connections to storm drains. Runoff treatment BMPs include facilities that remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, and soil adsorption. Streambank erosion control BMPs typically control the rate, frequency, and flow duration of stormwater runoff releases. Examples of runoff treatment and streambank erosion control BMPs detention ponds, biofiltration swales, infiltration trenches, and dry vaults.

The primary purpose of using BMPs is to protect beneficial uses of water resources through the reduction of pollutant loads and concentrations, and by reducing streambank erosion and protecting stream habitat in general. If it is found that, after the implementation of BMPs, beneficial uses are still threatened or impaired, then additional controls may be required.

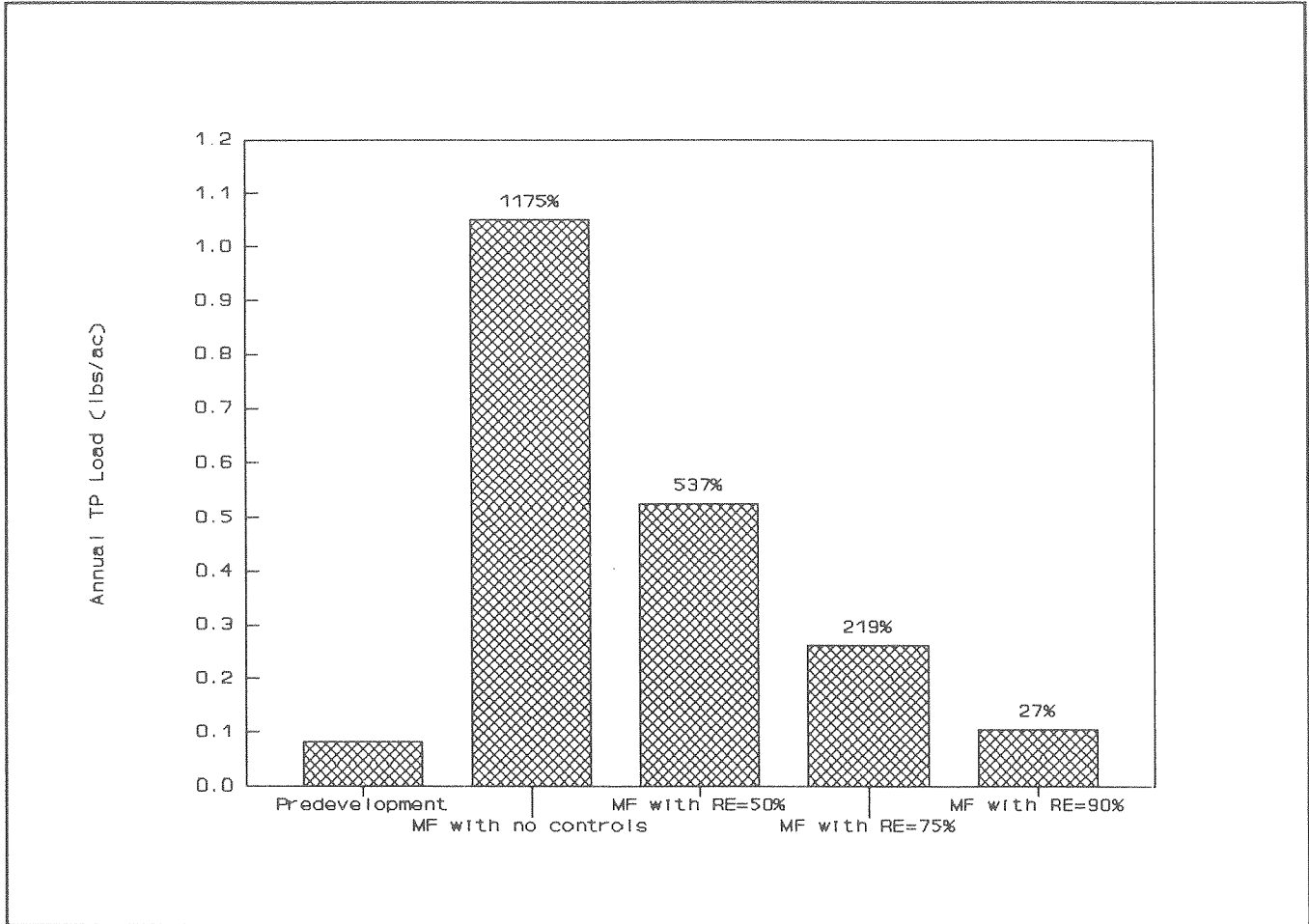
Stormwater management programs should keep in mind that it is generally more cost effective to prevent impacts using source control than using runoff treatment to remove pollutants. However, since source controls cannot prevent all impacts, some combination of measures will always be needed. The need to provide streambank erosion control BMPs depends on whether a development site discharges to a stream system, either directly or indirectly.

Runoff treatment BMPs can accomplish impressive levels of pollutant load reductions if properly designed and maintained. However, the increase in pollutant loads from urban areas is typically so large that, even with the use of BMPs, it is unlikely they will be reduced to levels approximating pre-development conditions. Figure I-1.3 illustrates this by presenting a typical pre-development pollutant load and comparing it with loads from a multi-family (MF) development. With no controls, the urban load increases nearly 1200 percent above the pre-development level. The figure illustrates the loads which theoretically would result if BMPs were applied with removal efficiencies of 50, 75, and 90 percent, respectively (the latter an extremely high level which may not be generally attainable, though infiltration can achieve this). As can be seen, even at high levels of treatment, substantial increases over pre-development levels occur, e.g., with a 75 percent removal efficiency the load is over 200 percent higher than the pre-development load. While using pre-development conditions as a basis of comparison may not be always justified, it does offer insight into the potential impacts of urbanization.

Streambank erosion control can be accomplished by BMPs which detain runoff flows and also by those which physically stabilize eroding streambanks. Both types of measures may be necessary in urban watersheds. BMPs which detain runoff can reduce peak flow rates to near pre-development conditions and are to be designed attempt to replicate the natural hydrologic regime. The need to control streambank erosion is gaining widespread attention as it is often the single largest source of sedimentation within a watershed and is a major factor contributing to the destruction of aquatic habitat.

Streambank erosion is largely due to increases in bankfull flow conditions which occur in urban watersheds. In undisturbed watersheds the bankfull condition generally occurs only about once in every two years on average. In urbanized watersheds both the frequency and duration of the bankfull condition can increase many fold, because of the effect of impervious surfaces on surface runoff. Bankfull conditions are a highly erosive state and, as the frequency and duration of their occurrence increases, the greater the amount of erosion results. While it may be impossible to totally recreate the frequency and duration of the pre-development bankfull condition, BMPs should be designed with that as an objective. Conventional detention practices which control peak flow rates from large, infrequent storms for flood control purposes are only partially effective at reducing the frequency and duration of bankfull flow conditions. One particularly effective practice which is

FIGURE I-1.3<sup>1</sup>  
 HYPOTHETICAL INCREASE IN ANNUAL POLLUTANT LOADS FOR A  
 MULTI-FAMILY DEVELOPMENT OVER PRE-DEVELOPMENT  
 CONDITIONS UNDER VARIOUS CONTROL SCENARIOS



RE = Annual Removal Efficiency

gaining attention is infiltration, because of it's ability to decrease both peak rates and volumes, and increase summer stream baseflows. If infiltration is not feasible the alternative is large detention ponds that store runoff and release it at a very slow rate to minimize erosion and habitat destruction in general.

In summary, it is clear that treatment BMPs alone cannot normally be expected to solve all water quality problems caused by stormwater runoff. They must be complemented with source controls. The effectiveness of comprehensively implemented BMP programs have yet to be demonstrated. Many doubt their effectiveness. However, given the large number of measures now available (and new ideas that are being generated) future results may be surprising. The key will be the correct balance between education and enforcement for source control, and proper design and operation and maintenance for treatment.

### I-1.3 ECOLOGY'S STORMWATER PROGRAM

The 1991 Puget Sound Water Quality Management Plan requirements form the foundation of the stormwater program developed by the Department of Ecology. The Plan was first adopted in 1987, updated in 1989, and again in 1990, 1991 and 1992. The Plan and Ecology's stormwater programs apply to the cities and counties, and WSDOT, in the Puget Sound basin. What follows is a summary of the major elements of the Plan requirements.

#### I-1.3.1 Local Stormwater Program

##### Basic Stormwater Program for All Counties and Cities

The 1992 revisions to the PSWQMP changed the implementation of Ecology's program from a rules-based program to one implemented through language contained in the Plan. RCW 90.70.070(1) states "In conducting planning, regulatory, and appeals actions, the state agencies and local governments identified in the plan must evaluate, and incorporate as applicable, subject to the availability of appropriated funds or other funding sources, the provisions of the plan, including any guidelines, standards, and timetables contained in the plan."

The 1992 Plan language calls for all jurisdictions in Puget Sound to adopt a basic stormwater program (Plan element SW-1). Densely populated urbanized areas in the Sound are to implement additional requirements for comprehensive urban stormwater programs, and, in accordance with EPA regulations, meet the requirements of municipal stormwater NPDES permits (Plan element SW-2). Supplemental guidance, including model ordinances, and this technical manual are being prepared to describe how local governments can implement their stormwater programs and meet the requirements of the rules.

The Plan requires all 111 local jurisdictions to implement stormwater management programs which include:

- Ordinances for all new development and redevelopment which address control of off-site water quality, the use of source control BMPs, the effective treatment of the water quality design storm, the use of infiltration where appropriate, the protection of stream channels and wetlands, and erosion and sediment control.
- Operation and maintenance programs for new and existing public and private stormwater systems.
- Record keeping of new public and private drainage systems and facilities.
- Adoption of either Ecology's technical manual or a manual with substantially equivalent technical standards.
- Education programs to educate citizens about stormwater and its effects on water quality, flooding, and fish/wildlife habitat, and to discourage illicit dumping into storm drains.
- Coordination with provisions of the Growth Management Act, where appropriate.
- Basin planning.

##### Proposed schedule:

All cities and counties will be required to adopt ordinances and a technical manual that is "substantially equivalent" to this manual, and meet operation and maintenance requirements by July 1, 1994.

##### Comprehensive Stormwater Programs for Urban Areas

The Plan also sets standards and procedures for comprehensive stormwater programs

that will be implemented by all urbanized areas. This program is in addition to the requirements of the basic stormwater programs described above.

Urbanized areas will be identified by the U.S. Bureau of Census definition.

These programs will address runoff from new and existing industrial, commercial, public facilities and residential areas, including streets and roads.

At minimum, each urban stormwater program shall include:

- Identification and ranking of potentially significant pollutant sources and their relationship to the drainage system and water bodies through an ongoing assessment program.
- Investigations and corrective actions of problem storm drains, including sampling.
- Programs for operation and maintenance of storm drains, detention systems, ditches, and culverts.
- A water quality response program, to investigate sources of pollutants, spills, fish kills, illegal hookups, dumping, and other water quality problems. These investigations should be used to support compliance/enforcement efforts.
- Assurance of adequate local funding for the stormwater program through surface water utilities, sewer charges, fees, or other revenue-generating sources.
- Local coordination arrangements such as interlocal agreements, joint programs, consistent standards, or regional boards or committees.
- Ordinances requiring implementation of stormwater controls for new development and redevelopment.
- A stormwater public education program aimed at residents, businesses, and industries in the urban area.
- Inspection, compliance, and enforcement measures.
- An implementation schedule.
- If, after implementation of the control measures listed above, there are still discharges that cause significant environmental problems, retrofitting of existing development and/or other water quality controls of discharges from new and existing development may be required.

**Schedule:**

Ecology shall review municipal NPDES Part 1 and 2 applications on the schedule established by EPA. Ecology shall write and issue individual NPDES permits on the following schedule: November 1993 for large municipalities; and May 1994 for medium municipalities. All urbanized areas shall implement programs by the year 2000.

I-1.3.2 Technical Manual and Guidance

This manual is part of the guidance package being developed by Ecology. Along with this manual, supplemental guidance will be provided to assist local governments in implementing their stormwater management programs. Examples include:

- Guidance on stormwater utility formation
- An example Erosion and Sediment Control Plan
- Model ordinances
- Guidance for an education program
- NPDES stormwater permit guidance
- Maintenance program guidance
- Guidance on developing a manual that is "substantially equivalent" to Ecology's manual



This guidance is currently in draft form and will be released at approximately the same time that this version of the manual is released.

#### I-1.3.3 Puget Sound Highway Runoff Program

Ecology has worked with the Washington State Department of Transportation (WSDOT) to adopt a rule and develop a program to control the quality of runoff from state highways in the Puget Sound basin. WSDOT will:

- Adopt a Highway Runoff Manual equivalent to Ecology's technical manual to use as guidance for managing highway runoff
- Adopt a vegetation management program
- Include BMPs a part of new construction projects
- Inventory and retrofit existing state highways with water quality BMPs where practicable
- Monitor where applicable
- Submit biennial reports to Ecology

Public workshops were held on the draft rule in January 1990, at Port Townsend, Everett and Tacoma, and meetings were held with the tribes. Public hearings were held in Bremerton on March 13, in Everett on March 14, and in Tacoma on March 15, 1991.

#### Schedule:

The Highway program was signed May 21, 1991 and became effective on June 21, 1991.

#### I-1.4 DEVELOPMENT OF THIS MANUAL

The Puget Sound Water Quality Authority (PSWQA) recognized the need for overall guidance for stormwater quality improvement, and incorporated requirements to implement a cohesive, integrated approach in the Puget Sound Water Quality Management Plan (PSWQMP or Plan). This technical manual, as mentioned above, has been developed in response to one of the plan's stormwater elements (SW-3.1). It emphasizes source control BMPs as the first and most cost effective method of eliminating or reducing pollution of stormwater. Source control BMPs are the more desirable method of controlling pollution and reducing erosion than are treatment BMPs because once sediment or pollutants enter runoff it is considerably more difficult and expensive to remove them. Treatment BMPs should only be used as a second line of defense to remove pollutants that could not be controlled by source control BMPs.

A primary purpose of this manual is to set out the Minimum Requirements and provide guidance on how to prepare and implement stormwater site plans. These plans are required for new development and redevelopment on both large subdivisions and small parcels, and must meet all of the applicable Minimum Requirements contained in Chapter I-2. These requirements are, in turn, satisfied by the application of BMPs. In doing so the plans will address the impacts of new development and redevelopment on stormwater runoff, and to the maximum extent practicable, mitigate deleterious effects.

The stormwater site plans developed by using this manual are not a substitute for an adopted and implemented comprehensive basin plan. Knowledge gained from a basin plan can be used to better select locations for on-site facilities, and plan regional facilities where needed. In addition, basin plans allow for the construction and siting of facilities so that environmentally sensitive areas are not affected by unwise development.

A second important purpose of the manual is to provide information for users who are retrofitting BMPs to existing development. Retrofitting will primarily occur when a local government or Ecology has detected a stormwater drainage problem emanating from existing development and, as a result, has directed the implementation of BMPs to correct the problem.

A third purpose of the manual is to provide a reference source for users who wish to prepare technical bulletins, leaflets, etc. for purposes of education and/or specialized BMP implementation. Examples would include technical leaflets for individual homeowners, local governments, homeowners' associations, and business operators.

#### I-1.5 USERS OF THE MANUAL

The users of this manual will be engineers, planners and environmental scientists from local government and private industry. Local government officials will use the manual as a reference for reviewing stormwater site plans, for retrofitting of BMPs, and for providing technical advice in general. Private industry will primarily use the manual for information on how to develop and implement stormwater site plans, and as a reference for technical specifications of BMPs.

We anticipate that Ecology's NPDES stormwater permit writers will use this manual as a reference, and affected industries and municipalities will also use it to determine design criteria for the BMPs required as part of their permit.

#### I-1.6 ORGANIZATION OF THE MANUAL

The manual is organized into four volumes. Volume I provides an introduction and overview, a description of the Minimum Requirements, guidance on preparation of a stormwater site plan, and a method for selecting BMPs according to the requirements and the needs of the site. The glossary and notation information are found at the back of Volume I.

Volume II covers erosion and sediment control. BMPs for construction sites and other areas are covered, and BMPs for Small Parcels are also included. Information on NPDES construction permits, and the methodology for developing an Erosion and Sediment Control plan are also discussed.

The two topics covered in Volume III are runoff treatment and streambank erosion control. BMPs for infiltration, detention, conveyance systems, and other stormwater facilities are covered. Also included are hydrologic methods for calculating flow rates and volumes for sizing of drainage facilities.

Volume IV addresses control of runoff pollution produced by urban land uses. These include commercial, industrial, residential and public agency land uses.

#### I-1.7 HOW TO USE THIS MANUAL

The chapters in Volume I should be read first. Once a preliminary selection of BMPs has been made, those specific BMPs (found in Volumes II, III or IV) should be reviewed.

The Minimum Requirements contained in Chapter I-2 form the basis for all stormwater site plans. They are indicated in bold print. The standards set by this manual are the minimum requirements, and all other manuals will have to be substantially equivalent to that minimum standard. Local governments have the option of enacting stricter standards than those outlined in this manual, using parts of this manual

and developing appropriate other sections for their local area, or developing an entirely new manual for use by their government.

An effort has been made to be as flexible as possible to enable local governments to tailor site plans to their specific requirements. As long as Minimum Requirements in Chapter I-2 are met, the exact methods used to meet them are up to the local government. If other technical manuals are developed and used, they must be reviewed by Ecology as part of the local government's basic stormwater program and determined to be "substantially equivalent". Supplementary guidelines which will be issued at or around the time of this version of this manual will describe the process for determining whether or not a manual is of an equivalent technical standard.

Once the preliminary BMP selection is made a stormwater site plan including an ESC plan can be completed. Overall stormwater site plan requirements are found in Chapter I-3. A final BMP selection should be made taking into account the appropriateness to the site, the cost, and the relative advantages and disadvantages of each BMP. Much of the information needed to assist in this decision is found under each specific BMP entry.

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<sup>1</sup> Figure I-1.1 was developed from the SBUH model for a 10-acre site with the following conditions: Forest with CN = 64; Residential site with 25% impervious cover, CN = 75 and 98 for pervious and impervious areas, respectively; Commercial site with 75% impervious cover (same CN's as for residential site).

<sup>2</sup> Data for Figures I-1.2 and I-1.3 were derived from the EPA's National Urban Runoff Program and work by Thomas Schueler. The following assumptions were made:

Annual rainfall = 40 inches      Annual runoff coefficient  $R_v = P_j * (.05 + .009 * IC)$   
 Annual fraction of rainfall which generates runoff ( $P_j$ ) = 0.9

Land Use Condition	Impervious Cover (%)	Annual Runoff Coefficient $R_v$	Concentration TP (mg/L)
Pre-development	2	0.07	0.15
Residential	30	0.32	0.26
Multi-family	50	0.50	0.26
Shopping Center	95	0.91	0.26

CHAPTER I-2

MINIMUM REQUIREMENTS FOR ALL NEW DEVELOPMENT AND REDEVELOPMENT

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CHAPTER I-2

MINIMUM REQUIREMENTS FOR ALL NEW DEVELOPMENT AND REDEVELOPMENT

I-2.1 INTRODUCTION

The 1991 Puget Sound Water Quality Management Plan (as amended) requires all counties and cities within the Puget Sound drainage basin to adopt ordinances to control runoff from new development and redevelopment by July 1994. The Plan also directs local governments to adopt stormwater programs which include minimum requirements for new development and re-development set by the Plan and in guidance developed by Ecology. These ordinances are to address:

*"... at a minimum: (1) the control of off-site water quality and quantity (as related to quality) impacts; (2) the use of source control best management practices and treatment best management practices; (3) the effective treatment, using best management practices of the storm size and frequency (design storm) as specified in the manual for proposed development; (4) the use of infiltration, with appropriate precautions, as the first consideration in stormwater management; (5) the protection of stream channels and wetlands; and (6) erosion and sedimentation control for new construction and re-development projects."*

This chapter has been developed in response to the direction in the Plan. The reader is also referred to Volume II of the "Stormwater Program Guidance Manual for the Puget Sound Basin" (hereafter referred to as the Guidance Manual), a companion to this technical manual, which contains a model ordinance that incorporates these Minimum Requirements.

There are several sets of requirements for proposed new development and redevelopment that are applied depending on the type and size of the proposed development. In general, small sites are required to control erosion and sedimentation from construction activities while larger sites must also provide permanent control of stormwater runoff. Sites being redeveloped must generally meet the same minimum requirements as new development sites for the portion of the site being redeveloped. In addition, redevelopment sites must provide source control BMPs for the entire site. There may also be situations in which additional controls are required for sites, regardless of type or size, as a result of basin plans or special water quality concerns.

Development sites are to demonstrate compliance with the Minimum Requirements through the preparation of Stormwater Site Plans (SSP). The plans are described in detail in Chapter I-3 and in the Guidance Manual.

Two major components of these plans are an Erosion and Sediment Control (ESC) Plan and a Permanent Stormwater Quality Control (PSQC) Plan. The ESC plan is intended to be temporary in nature to control pollution generated during the construction phase only, primarily erosion and sediment. The PSQC is intended to provide permanent BMPs for the control of pollution from stormwater runoff after construction has been completed. For small sites, this requirement is met by implementing a Small Parcel Erosion and Sediment Control Plan.

A flow chart demonstrating these requirements is shown in Figure I-2.1.

Definitions:

**New development - means the following activities: land disturbing activities, structural development, including construction, installation or expansion of a building or other structure; creation of impervious surfaces; Class IV - general forest practices that are conversions from timber land to other uses;**

and subdivision, short subdivision and binding site plans, as defined in Ch.58.17.020 RCW. All other forest practices and commercial agriculture are not considered new development.

**Redevelopment** - means, on an already developed site, the creation or addition of impervious surfaces, structural development including construction, installation or expansion of a building or other structure, and/or replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities associated with structural or impervious redevelopment.

**Impervious surface** - means a hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces.

**Land disturbing activity** - means any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to demolition, construction, clearing, grading, filling and excavation.

**Source control BMP** - A BMP that is intended to prevent pollutants from entering stormwater. A few examples of source control BMPs are erosion control practices, maintenance of stormwater facilities, constructing roofs over storage and working areas, and directing wash water and similar discharges to the sanitary sewer or a dead end sump.

Throughout this Chapter, guidance to meet the requirements of the 1991 Puget Sound Water Quality Management Plan (as amended) is written in **bold** and supplemental guidelines that serve as advice and other materials are not in bold.

#### I-2.2 EXEMPTIONS

- **Commercial agriculture, and forest practices regulated under Title 222 WAC, except for Class IV General forest practices that are conversions from timber land to other uses, are exempt from the provisions of the minimum requirements. All other new development is subject to the minimum requirements.**

#### I-2.3 SMALL PARCEL MINIMUM REQUIREMENTS

- **The following new development shall be required to control erosion and sediment during construction, to permanently stabilize soil exposed during construction, to comply with Small Parcel Requirements 1 through 4, and to prepare a Small Parcel Erosion and Sediment Control Plan:**
  - (a) **Individual, detached, single family residences and duplexes.**
  - (b) **Creation or addition of less than 5,000 square feet of impervious surface area.**
  - (c) **Land disturbing activities of less than one acre.**

**Objective:** The objective of this requirement is to address the cumulative effect of sediment coming from a large number of small sites.

**Supplemental Guidelines:** Small parcels under 5,000 sq.ft. in size and individual, detached, single family residences and duplexes, require the simplified erosion and sediment controls contained in a Small Parcel Erosion and Sediment Control Plan (SPESC). This plan is required to fulfil the Small Parcel Minimum Requirements outlined below in Section I-2.3. The Small Parcel BMPs found in Section II-5.10 in Volume II are used to develop the plan. A complete description of a Small Parcel ESC Plan can be found in Section I-3.3. The SPESC plan is meant to be temporary in nature to deal with erosion and sediment generated during the construction phase only. Local governments may choose to apply additional permanent, site-specific stormwater controls to small parcels.

One method of proof of compliance could be the use of a checklist similar to that found in Figure I-3.1. This list can be adapted as necessary to include individual requirements of a local government.

#### **SMALL PARCEL REQUIREMENT #1 Construction Access Route**

- Construction vehicle access shall be, whenever possible, limited to one route. Access points shall be stabilized with quarry spall or crushed rock to minimize the tracking of sediment onto public roads.

**Supplemental Guidelines:** If sediment is inadvertently transported onto public roads, roads shall be cleaned thoroughly at the end of the day by shoveling or sweeping. Street washing should only be done after the bulk of the sediment has been removed by sweeping.

#### **SMALL PARCEL REQUIREMENT #2 Stabilization of Denuded Areas**

- Soil stabilization. All exposed and unworked soils shall be stabilized by suitable application of BMPs, including but not limited to sod or other vegetation, plastic covering, mulching, or application of ground base on areas to be paved. All BMPs shall be selected, designed and maintained in accordance with an approved manual. From October 1 through April 30, no soils shall remain exposed for more than 2 days. From May 1 through September 30, no soils shall remain exposed for more than 7 days.

**Supplemental Guidelines:** BMPs should be selected which are appropriate for the time of the year and anticipated duration of use.

#### **SMALL PARCEL REQUIREMENT #3 Protection of Adjacent Properties**

- Adjacent properties shall be protected from sediment deposition by appropriate use of vegetative buffer strips, sediment barriers or filters, dikes or mulching, or by a combination of these measures and other appropriate BMPs.

#### **SMALL PARCEL REQUIREMENT #4 Maintenance**

- All erosion and sediment control BMPs shall be regularly inspected and maintained to ensure continued performance of their intended function.

#### **SMALL PARCEL REQUIREMENT #5 Other BMPs**

- As required by the local Plan Approval Authority, other appropriate BMPs to mitigate the effects of increased runoff shall be applied.

I-2.4 NEW DEVELOPMENT AND REDEVELOPMENT - APPLICATION OF MINIMUM REQUIREMENTS

I-2.4.1 New Development

All new development that includes the creation or addition of 5,000 square feet, or greater, of new impervious surface area, and/or land disturbing activity of one acre or greater, shall comply with Minimum Requirements #1 through #11 in Sections I-2.5 through I-2.15 and prepare a Stormwater Site Plan.

All new development that includes the creation or addition of 5,000 square feet, or greater, of new impervious surface area, and land disturbing activity of less than one acre, shall comply with Minimum Requirements #2 through #11 in Sections I-2.6 through I-2.15 and the Small Parcel Minimum Requirements found in section I-2.2, above. This category of development shall also prepare a Stormwater Site Plan that includes a Small Parcel Erosion and Sediment Control Plan.

This section does not apply to the construction of individual, detached, single family residences and duplexes. Those types of new development are included in the Small Parcel Minimum Requirements.

Objective: The objective of this standard is to define the application of the Minimum Requirements. The objective of these requirements is to reduce pollution and minimize erosion and sedimentation from new development.

Supplemental Guidelines: Basin planning is encouraged and may be used to tailor certain of the Minimum Requirements to a specific basin (see Minimum Requirement #9). The Minimum Requirements for Small Parcels are found in Section I-2.2. See page I-2-1 for the definition of new development. See Chapter I-3 for a description of Stormwater Site Plans.

I-2.4.2 Redevelopment

A. Where redevelopment of  $\geq 5,000$  square feet occurs:

The new development Minimum Requirements #1 through #11, Sections I-2.5 through I-2.15, shall apply to that portion of the site that is being redeveloped, and source control BMPs shall be applied to the entire site, including adjoining parcels if they are part of the project. A Stormwater Site Plan shall be prepared.

B. In addition to the above requirements, where one or more of the following conditions apply, a Stormwater Site Plan shall also be prepared that includes a schedule for implementing the Minimum Requirements to the maximum extent practicable, for the entire site, including adjoining parcels if they are part of the project. An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop redevelopment requirements that are tailored to a specific basin.

1. Existing sites greater than 1 acre in size with 50% or more impervious surface.
2. Sites that discharge to a receiving water that has a documented water quality problem. Subject to local priorities, a documented water quality problem includes, but is not limited to water bodies:
  - (i) Listed in reports required under section 305(b) of the Clean Water Act, and designated as not supporting beneficial uses;



- (ii) Listed under section 304(1)(1)(A)(i), 304(1)(1)(A)(ii), or 304(1)(1)(B) of the Clean Water Act as not expected to meet water quality standards or water quality goals;
- (iii) Listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act that, without additional action to control nonpoint sources of pollution cannot reasonably be expected to attain or maintain water quality standards.

3. Sites where the need for additional stormwater control measures have been identified through a basin plan, the watershed ranking process under Ch. 400-12 WAC, or through Growth Management Act planning.

Objective: The objective of the redevelopment standard is to reduce pollution from existing sites. The long-term goal of this standard is to accomplish this reduction through development and implementation of basin plans.

Supplemental Guidelines: Minimum Requirements 1 through 11 always apply to the portion of the site that is being redeveloped, if the redevelopment is over 5,000 sq. ft. in size. In addition, source control BMPs are always required for the entire site. A basin plan could be used to vary the thresholds for application of the minimum requirements to the entire site, beyond the portion of the site that is being redeveloped. See Chapter I-3 for the description of a Stormwater Site Plan.

#### I-2.5 MINIMUM REQUIREMENT #1: EROSION AND SEDIMENT CONTROL

- All new development and redevelopment that includes land disturbing activities of  $\geq 1$  acre shall comply with Erosion and Sediment Control Requirements 1 through 14, below. Compliance with the Erosion and Sediment Control Requirements shall be demonstrated through implementation of a Large Parcel Erosion and Sediment Control Plan.

All new development and redevelopment that includes land disturbing activities of  $< 1$  acre shall comply with the Small Parcel Minimum requirements found in section I-2.2, above. Compliance with the Small Parcel Requirements shall be demonstrated through implementation of a Small Parcel Erosion and Sediment Control Plan.

Objective: To control erosion and prevent sediment from leaving the site.

Supplemental Guidelines:

Large parcels are defined as those  $> 1$  acre in size. Parcels of this size are required to implement a Large Parcel ESC plan which meets the Erosion and Sediment Control Requirements found in Minimum Requirement #1. Additionally, a Permanent Stormwater Quality Control Plan (PSQC) must be developed which meets Minimum Requirements 2 through 11. An acceptable Stormwater Site Plan (SSP) for a large parcel contains both of these elements, the ESC plan, and the PSQC, and fulfills all the Minimum Requirements.

If an ESC plan is found to be inadequate (with respect to the Erosion and Sediment Control Requirements), then the Plan Approval Authority<sup>1</sup> within the Local Government will require that other BMPs be implemented, as appropriate.

Erosion and Sediment Control Minimum Requirements

Guidance to meet the requirements of the 1991 Puget Sound Water Quality Management Plan (as amended) is written in bold, and supplemental guidelines that serve as advice and other materials are not in bold.

The following erosion and sediment control requirements shall be met:

**EROSION AND SEDIMENT CONTROL REQUIREMENT #1: Stabilization and Sediment Trapping**

- All exposed and unworked soils shall be stabilized by suitable application of BMPs. From October 1 to April 30, no soils shall remain unstabilized for more than 2 days. From May 1 to September 30, no soils shall remain unstabilized for more than 7 days. Prior to leaving the site, stormwater runoff shall pass through a sediment pond or sediment trap, or other appropriate BMPs.

Supplemental Guidelines: This criterion applies both to soils not yet at final grade and soils at final grade. The type of stabilization BMP used may be different depending on the length of time that the soil is to remain unworked.

Soil stabilization refers to BMPs which protect soil from the erosive forces of raindrop impact and flowing water. Applicable practices include vegetative establishment, mulching, plastic covering, and the early application of gravel base on areas to be paved. Soil stabilization measures should be selected to be appropriate for the time of year, site conditions, and estimated duration of use. Soil stockpiles must be stabilized or protected with sediment trapping measures to prevent soil loss.

These requirements are especially important in areas adjacent to streams, wetlands or other sensitive or critical areas.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #2: Delineate Clearing and Easement Limits**

- In the field, mark clearing limits and/or any easements, setbacks, sensitive/critical areas and their buffers, trees and drainage courses.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #3: Protection of Adjacent Properties**

- Properties adjacent to the project site shall be protected from sediment deposition.

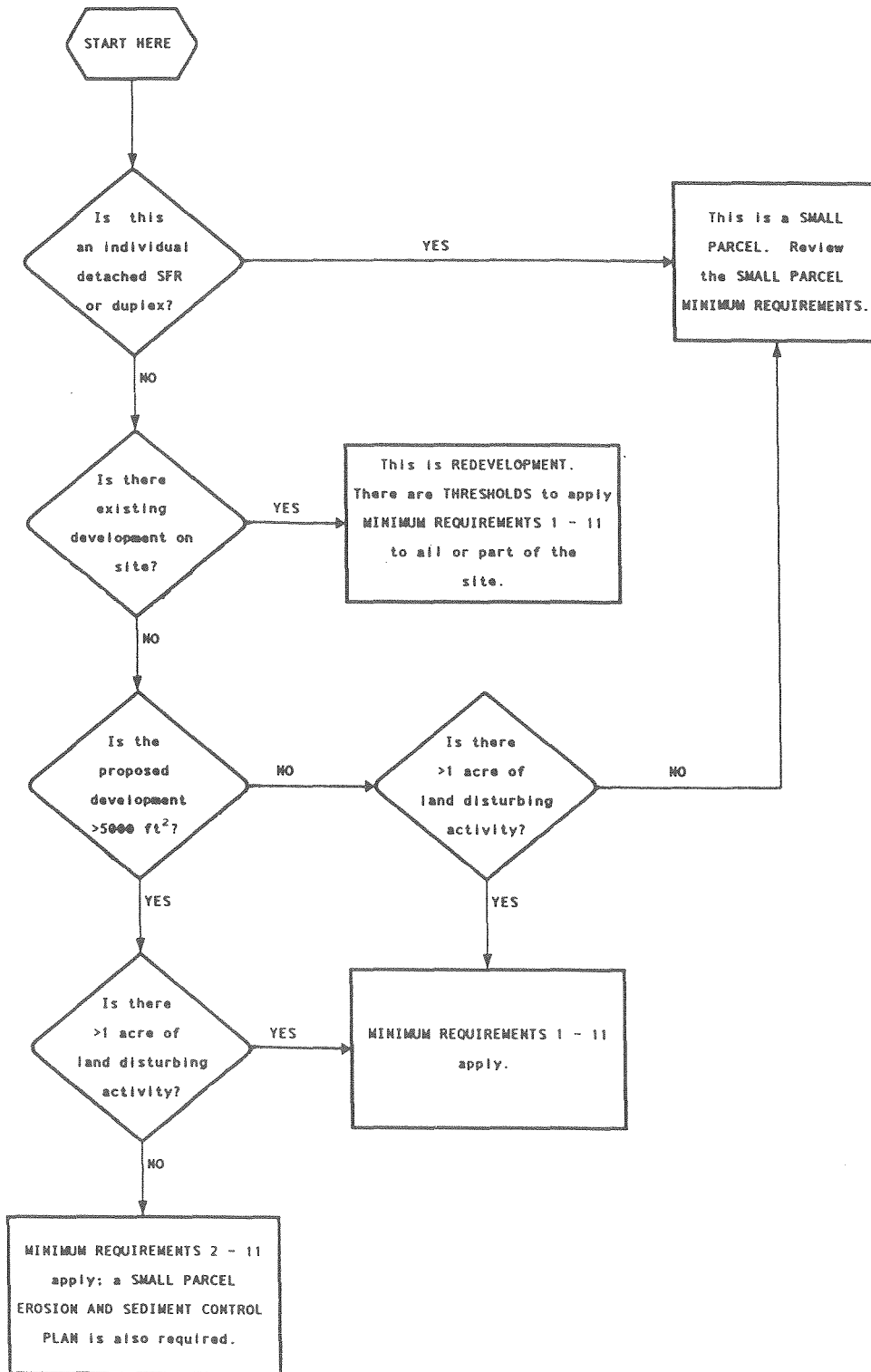
Supplemental Guidelines: This may be accomplished by preserving a well-vegetated buffer strip around the lower perimeter of the land disturbance, by installing perimeter controls such as sediment barriers, filters or dikes, or sediment basins, or by a combination of such measures.

Vegetated buffer strips may be used alone only where runoff in sheet flow is expected. Buffer strips should be at least 25 feet in width. If at any time it is found that a vegetated buffer strip alone is ineffective in stopping sediment movement onto adjacent property, additional perimeter controls must be provided.

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<sup>1</sup> The Plan Approval Authority is defined as that department within a local government that has been delegated authority to approve erosion and sediment control plans.

Figure I-2.1 Flowchart Demonstrating Minimum Requirements



**EROSION AND SEDIMENT CONTROL REQUIREMENT #4: Timing and Stabilization of Sediment Trapping Measures**

- Sediment ponds and traps, perimeter dikes, sediment barriers, and other BMPs intended to trap sediment on-site shall be constructed as a first step in grading. These BMPs shall be functional before land disturbing activities take place. Earthen structures such as dams, dikes, and diversions shall be seeded and mulched according to the timing indicated in Erosion and Sediment Control Requirement #1.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #5: Cut and Fill Slopes**

- Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. In addition, slopes shall be stabilized in accordance with Erosion and Sediment Control Requirement #1.

Supplemental Guidelines: Consideration should be given to the length and steepness of the slope, the soil type, upslope drainage area, ground water conditions, and other applicable factors. Slopes which are found to be eroding excessively within two years of construction must be provided with additional slope stabilizing measures until the problem is corrected.

1. Roughened soil surfaces are preferred to smooth surfaces on slopes (see BMP E2.35 in Chapter II-5).
2. Interceptors (see BMP E2.55 in Chapter II-5) should be constructed at the top of long steep slopes which have significant drainage areas above the slope. Diversions or terraces may also be used to reduce slope length.
3. Concentrated stormwater should not be allowed to flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, or pipe slope drain (see BMP E2.25 in Chapter II-5).
4. Wherever a slope face crosses a water seepage plane which endangers the stability of the slope, adequate drainage or other protection should be provided (BMPs E2.30 and E2.75 in Chapter II-5).

**EROSION AND SEDIMENT CONTROL REQUIREMENT #6: Controlling Off-site Erosion**

- Properties and waterways downstream from development sites shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #7: Stabilization of Temporary Conveyance Channels and Outlets**

- All temporary on-site conveyance channels shall be designed, constructed and stabilized to prevent erosion from the expected velocity of flow from a 2-year, 24-hour frequency storm for the developed condition. Stabilization adequate to prevent erosion of outlets, adjacent streambanks, slopes and downstream reaches shall be provided at the outlets of all conveyance systems.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #8: Storm Drain Inlet Protection**

- All storm drain inlets made operable during construction shall be protected so that stormwater runoff shall not enter the conveyance system without first being filtered or otherwise treated to remove sediment.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #9: Underground Utility Construction**

- The construction of underground utility lines shall be subject to the following criteria:
  - (i) Where feasible, no more than 500 feet of trench shall be opened at one time.
  - (ii) Where consistent with safety and space considerations, excavated material shall be placed on the uphill side of trenches.
  - (iii) Trench dewatering devices shall discharge into a sediment trap or sediment pond.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #10: Construction Access Routes**

- Wherever construction vehicle access routes intersect paved roads, provisions must be made to minimize the transport of sediment (mud) onto the paved road. If sediment is transported onto a road surface, the roads shall be cleaned thoroughly at the end of each day. Sediment shall be removed from roads by shoveling or sweeping and be transported to a controlled sediment disposal area. Street washing shall be allowed only after sediment is removed in this manner.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #11: Removal of Temporary BMPs**

- All temporary erosion and sediment control BMPs shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #12: Dewatering Construction Sites**

- Dewatering devices shall discharge into a sediment trap or sediment pond.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #13: Control of Pollutants Other Than Sediment on Construction Sites**

- All pollutants other than sediment that occur on-site during construction shall be handled and disposed of in a manner that does not cause contamination of stormwater.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #14: Maintenance**

- All temporary and permanent erosion and sediment control BMPs shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

**EROSION AND SEDIMENT CONTROL REQUIREMENT #15: Financial Liability**

- Performance bonding, or other appropriate financial instruments, shall be required for all projects to ensure compliance with the approved erosion and sediment control plan.

**I-2.6 MINIMUM REQUIREMENT #2: PRESERVATION OF NATURAL DRAINAGE SYSTEMS**

- Natural drainage patterns shall be maintained, and discharges from the site shall occur at the natural location, to the maximum extent practicable.

**Objective:** To preserve and utilize natural drainage systems to the fullest extent because of the multiple stormwater benefits these systems provide.

**Supplemental Guidelines:** Natural drainage systems provide many water quality benefits and should be preserved to the fullest extent possible. In addition to conveying and attenuating stormwater runoff, these systems are less erosive, provide ground water recharge, and support important plant and wildlife resources. Effective utilization of the natural system can maintain environmental and aesthetic attributes of a site as well as be a cost-effective measure to convey stormwater runoff.

Creating new drainage patterns requires more site disturbance and can upset stream dynamics of the drainage system, thus tending to increase erosion and sedimentation. Creating new discharge points can create significant streambank erosion problems as the receiving water body typically must adjust to the new flows. Newly created drainage patterns can seldom, if ever, provide the multiple benefits of natural drainage systems. Where no conveyance system exists at the adjacent downstream property line and the discharge was previously unconcentrated flow or significantly lower concentrated flow, then measures must be taken to prevent downstream impacts. Necessary drainage easements may be obtained from downstream property owners.

#### I-2.7 MINIMUM REQUIREMENT #3: SOURCE CONTROL OF POLLUTION

- Source control BMPs shall be applied to all projects to the maximum extent practicable. Source control BMPs shall be selected, designed, and maintained according to an approved manual.

An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop source control requirements that are tailored to a specific basin, however, in all circumstances, source control BMPs shall be required for all sites.

**Objective:** The intention of source control BMPs is to prevent stormwater from coming in contact with pollutants. They are a cost effective means of reducing pollutants in stormwater, and, therefore, should be a first consideration in all projects.

**Supplemental Guidelines:** A list of many source control BMPs is provided in the BMP selection chapter, Chapter I-4. For construction sites see Chapter II-5; for post-construction development sites see Volume III; for specific urban land uses see Volume IV.

#### I-2.8 MINIMUM REQUIREMENT #4: RUNOFF TREATMENT BMPs

- All projects shall provide treatment of stormwater. Treatment BMPs shall be sized to capture and treat the water quality design storm, defined as the 6-month, 24-hour return period storm. The first priority for treatment shall be to infiltrate as much as possible of the water quality design storm, only if site conditions are appropriate and ground water quality will not be impaired. Direct discharge of untreated stormwater to ground water is prohibited. All treatment BMPs shall be selected, designed, and maintained according to an approved manual.

Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop runoff treatment requirements that are tailored to a specific basin.

Objective: The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms. When site conditions are appropriate infiltration can potentially be the most effective BMP for runoff treatment.

Supplemental Guidelines: See Volume III. The water quality design storm (see Appendix AI-2.1) is intended to capture more than 90 percent of the annual runoff.

Infiltration can provide both treatment of stormwater, through the ability of certain soils to remove pollutants, and volume control of stormwater, by decreasing the amount of water that runs off to surface water. Infiltration can be very effective at treating stormwater runoff but soil conditions must be appropriate to achieve effective treatment while not impacting ground water resources. Methods currently in use such as direct discharge into dry wells do not achieve adequate water quality treatment and are therefore not permitted.

If stormwater is being discharged to a stream, see I-2.9, Streambank Erosion Control for additional requirements.

If stormwater is being discharged to a wetland, see I-2.10, Wetlands for additional requirements.

#### I-2.9 MINIMUM REQUIREMENT #5: STREAMBANK EROSION CONTROL

- The requirement below applies only to situations where stormwater runoff is discharged directly or indirectly to a stream, and must be met in addition to meeting the requirements in Minimum Requirement #4, Runoff Treatment BMPs:

Stormwater discharges to streams shall control streambank erosion by limiting the peak rate of runoff from individual development sites to 50 percent of the existing condition 2-year, 24-hour design storm while maintaining the existing condition peak runoff rate for the 10-year, 24-hour and 100-year, 24-hour design storms. As the first priority, streambank erosion control BMPs shall utilize infiltration to the fullest extent practicable, only if site conditions are appropriate and ground water quality is protected. Streambank erosion control BMPs shall be selected, designed, and maintained according to an approved manual.

Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop streambank erosion control requirements that are tailored to a specific basin.

Objective: To reduce streambank erosion which results from increased runoff due to development. The standard is intended to reduce the frequency and magnitude of bankfull flow conditions, which are highly erosive and increase dramatically as a result of development. Conventional flood detention practices do not adequately control streambank erosion because only the peak rate of flow is decreased, not the frequency and duration of bankfull conditions.

Supplemental Guidelines: See Chapter III-4. Reduction of flows through infiltration decreases streambank erosion and helps to maintain base flow throughout the summer months. However, infiltration should only be used where ground water

quality is not threatened by such discharges. The use of an artificial treatment system, such as an aquatard (see Chapter III-3) shall be considered in areas with highly permeable soils. Treatment of the water quality design storm must be accomplished prior to discharge to these soils. If highly permeable soils are present they should be utilized for streambank erosion control by infiltrating flows greater than the water quality design storm.

#### I-2.10 MINIMUM REQUIREMENT #6: WETLANDS

- The requirements below apply only to situations where stormwater discharges directly or indirectly through a conveyance system into a wetland, and must be met in addition to meeting the requirements in Minimum Standard #4, Runoff Treatment BMPs.
  - (a) Stormwater discharges to wetlands must be controlled and treated to the extent necessary to meet the State Water Quality Standards, Ch. 173-201 WAC, or Ground Water Quality Standards, Ch. 173-200 WAC, as appropriate.
  - (b) Discharges to wetlands shall maintain the hydroperiod and flows of existing site conditions to the extent necessary to protect the characteristic uses of the wetland. Prior to discharging to a wetland, alternative discharge locations shall be evaluated, and natural water storage and infiltration opportunities outside the wetland shall be maximized.
  - (c) Created wetlands that are intended to mitigate for loss of wetland acreage, function and value shall not be designed to also treat stormwater.
  - (d) In order for constructed wetlands to be considered treatment systems, they must be constructed on sites that are not wetlands and they must be managed for stormwater treatment. If these systems are not managed and maintained in accordance with an approved manual for a period exceeding three years these systems may no longer be considered constructed wetlands. Discharges from constructed wetlands to waters of the state (including discharges to natural wetlands) are regulated under Ch. 90.48 RCW, Ch. 173-201 WAC, and Ch. 173-200 WAC.
  - (e) Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop requirements for wetlands that are tailored to a specific basin.

**Objective:** To ensure that wetlands receive the same level of protection as any other waters of the state. Wetlands are extremely important natural resources which provide multiple stormwater benefits, including ground water recharge, flood control, and streambank erosion protection. They are easily impacted by development unless careful planning and management are conducted. Wetlands can be severely degraded by stormwater discharges from urban development due to pollutants in the runoff and also due to disruption of natural hydrologic functioning of the wetland system. Changes in water levels and the duration of inundations are of particular concern.

**Supplemental Guidelines:** See Chapter III-5. These requirements are a management tool to assist in meeting the state water quality standards. While it is always necessary to pre-treat stormwater prior to discharge to a wetland, there are limited circumstances where wetlands may be used for detention of stormwater.



Definitions: See glossary for definitions of wetlands, constructed wetland, created wetland, and abandonment.

**I-2.11 MINIMUM REQUIREMENT #7: WATER QUALITY SENSITIVE AREAS**

- Where local governments determine that the Minimum Requirements do not provide adequate protection of water quality sensitive areas, either on-site or within the basin, more stringent controls shall be required to protect water quality.

Stormwater treatment BMPs shall not be built within a natural vegetated buffer, except for necessary conveyance systems as approved by the local government.

An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop requirements for water quality sensitive areas that are tailored to a specific basin.

Objective: To ensure protection of water quality in sensitive areas.

Supplemental Guidelines: Water quality sensitive areas are areas that are sensitive to a change in water quality, including but not limited to, lakes, ground water management areas, ground water special protection areas, sole source aquifers, critical aquifer recharge areas, well head protection areas, closed depressions, fish spawning and rearing habitat, wildlife habitat, and shellfish protection areas. Areas such as steep or unstable slopes or erosive stream banks which can cause water quality problems should also be included. Water quality sensitive areas may be identified through jurisdiction-wide inventories, the watershed planning process required under Ch. 400-12 WAC, critical area designation in accordance with Ch. 365-190 WAC, local drainage basin planning, and/or on a site-by-site basis (e.g. using a threshold determination under SEPA).

**I-2.12 MINIMUM REQUIREMENT #8: OFF-SITE ANALYSIS AND MITIGATION**

- All development projects shall conduct an analysis of off-site water quality impacts resulting from the project and shall mitigate these impacts. The analysis shall extend a minimum of one-fourth of a mile downstream from the project. The existing or potential impacts to be evaluated and mitigated shall include, at a minimum, but not be limited to:
  - (i) excessive sedimentation
  - (ii) streambank erosion
  - (iii) discharges to ground water contributing or recharge zones
  - (iv) violations of water quality standards
  - (v) spills and discharges of priority pollutants

Objective: To ensure that future impacts from the project will be controlled and/or existing impacts will not be aggravated by the project.

Supplemental Guidelines: Further information on off-site analysis is being developed.

**I-2.13 MINIMUM REQUIREMENT #9: BASIN PLANNING**

- Adopted and implemented watershed-based basin plans may be used to modify any or all of the Minimum Requirements, provided that the level of protection for surface or ground water achieved by the basin plan will equal or exceed that which would be achieved by the Minimum Requirements in the absence of a basin

plan. Basin plans shall evaluate and include, as necessary, retrofitting of BMPs for existing development and/or redevelopment in order to achieve watershed-wide pollutant reduction goals. Standards developed from basin plans shall not modify any of the above requirements until the basin plan is formally adopted and fully implemented by local government. Basin plans shall be developed according to an approved manual.

Objective: To promote watershed-based planning as a means to develop and implement comprehensive water quality protection measures. Primary objectives of basin planning are to reduce pollutant loads and hydrologic impacts to streams and wetlands.

Supplemental Guidelines: While Minimum Requirements #3 through #7 establish protection standards for individual sites, they do not evaluate the overall pollution impacts and protection opportunities which could exist at the watershed level. In order for a basin plan to serve as a means of modifying the minimum requirements it must be formally adopted by all jurisdictions that have responsibilities under the basin plan, and construction and regulations called for by the plan must be complete. This is what is meant by an adopted and implemented basin plan.

Basin planning provides a mechanism by which the on-site standards can be evaluated and refined based on an analysis of an entire watershed. Basin plans are especially well-suited to develop control strategies to address impacts from future development and to correct specific problems whose sources are known or suspected. Basin plans can be effective at addressing both long-term cumulative impacts of pollutant loads and short-term acute impacts of pollutant concentrations, as well as hydrologic impacts to streams and wetlands.

In general, the standards established by basin plans will be site-specific but may be augmented with regional solutions for Source Control (Minimum Requirement #2) and Streambank Erosion Control (Minimum Requirement #4).

#### I-2.14 MINIMUM REQUIREMENT #10: OPERATION AND MAINTENANCE

- An operation and maintenance schedule shall be provided for all proposed stormwater facilities and BMPs, and the party (or parties) responsible for maintenance and operation shall be identified.

Objective: To ensure that stormwater control facilities are adequately maintained and operated properly.

Supplemental Guidelines: Inadequate maintenance is likely the leading cause of failure for stormwater control facilities. The description of each BMP in Volume II and III includes a section on maintenance. The Guidance Manual also includes a section on developing an operation and maintenance program and a model operation and maintenance ordinance.

#### I-2.15 MINIMUM REQUIREMENT #11: FINANCIAL LIABILITY

- Performance bonding or other appropriate financial instruments shall be required for all projects to ensure compliance with these standards.

Objective: To ensure that development projects have adequate financial resources to fully implement stormwater management plan requirements and that liability is not unduly incurred upon local governments.

Supplemental Guidelines: The type of financial instrument required is less important than ensuring that there are adequate funds available in the event that non-compliance occurs.

#### I-2.16 EXCEPTIONS

- **Exceptions to Minimum Requirements #1 through #10 may be granted prior to permit approval and construction. An exception may be granted following a public hearing, provided that a written finding of fact is prepared, that addresses the following:**
  - (i) **The exception provides equivalent environmental protection and is in the overriding public interest; and that the objectives of safety, function, environmental protection and facility maintenance, based upon sound engineering, are fully met;**
  - (ii) **That there are special physical circumstances or conditions affecting the property such that the strict application of these provisions would deprive the applicant of all reasonable use of the parcel of land in question, and every effort to find creative ways to meet the intent of the Minimum Requirements has been made;**
  - (iii) **That the granting of the exception will not be detrimental to the public health and welfare, nor injurious to other properties in the vicinity and/or downstream, and to the quality of waters of the state; and**
  - (iv) **The exception is the least possible exception that could be granted to comply with the intent of the Minimum Requirements.**

Supplemental Guidelines: Ecology encourages the Plan Approval Authority to impose additional or more stringent criteria as appropriate for their area. Additionally, criteria which may be inappropriate or too restrictive for an area may be modified through basin planning (Minimum Requirement #9). Modification of any of the minimum requirements which are deemed inappropriate for the site may be done by granting an exception.

The exception procedure is an important element of the plan review and enforcement programs. It is intended to maintain a necessary flexible working relationship between local officials and applicants. Plan Approval Authorities should consider these requests judiciously, keeping in mind both the need of the applicant to maximize cost-effectiveness and the need to protect off-site properties and resources from damage.

#### I-2.17 EXPERIMENTAL BMPs

Experimental best management practices are defined as BMPs which have not been tested and evaluated by the Department of Ecology in collaboration with local governments and technical experts. Some so-called Experimental BMPs will likely be minor variations on an existing theme. In that case, Ecology would review and approve or disapprove the BMP in as timely a manner as possible. Where new designs are developed (examples as below, in Section I-2.17.2), the review will be extended through the use of a standing committee of technical experts. These persons will review and comment on the practice, and Ecology will then determine whether or not these BMPs should be approved and/or added to this manual.

### I-2.17.1 Approval of Experimental BMPs

Approval to use an Experimental BMP may be granted subject to initial approval by the Department of Ecology and the local government. If such Experimental BMPs prove useful they may be incorporated into later editions of this manual following appraisal of the results and appropriate technical review conducted by Ecology in collaboration with local governments and other interested parties. Approval to use an Experimental BMP will only be granted when a suitable contingency plan using approved BMPs has been provided by the applicant to be used in the event that the Experimental BMP does not perform adequately.

In addition, several Experimental BMPs have been included in the manual. People may wish to use these BMPs on a trial basis, subject to approval by the local government and provision of a contingency plan. In any event, use of Experimental BMPs is encouraged whenever applied research is being undertaken so that more information is made available to facilitate judgement on their applicability and possible adoption as an approved.

### I-2.17.2 Example Experimental BMPs

The two BMPs described below are examples of Experimental BMPs where a thorough design review and monitoring process is occurring. Both designs have undergone significant modification based on the monitoring data collected and both are still in the prototype stage. Please note that these examples are presented for informational purposes only. While these Experimental BMPs appear to be effective at controlling some types of pollutants, Ecology is not in a position to confirm or deny their efficacy at this time.

The two Experimental BMPs that are currently under development are a catchbasin filter system designed by Emcon Northwest, and a compost stormwater treatment system designed by W&H Pacific.

#### Catchbasin Filter System

EMCON Northwest, Inc. has recently developed a catchbasin filter (patent pending) that prevents sediments and other contaminants from entering storm drainage systems. The catchbasin filter is inserted in the catchbasin just below the grating. The catchbasin filter is equipped with a sediment trap and up to three layers of a fiberglass filter material (see Figure II-5.26). This type of system may not be

applicable in all catchbasins but would work well at construction sites, industrial facilities, service stations, marinas/boatyards, etc.

During research and development of the catchbasin filter, EMCON Northwest, Inc. has found that particulates as small as 15 microns are retained by the filter. Additionally, high levels of particulate heavy metals, oil and grease and TSS have been removed at both industrial facilities and construction sites. This system would be useful in small drainage areas, and for treatment of highly turbid runoff prior to discharge.

For further information, contact John MacPherson at EMCON Northwest Inc., (206) 485-5000.

#### Compost Stormwater Treatment System

W&H Pacific worked with the Washington County Dept. of Land Use and Transportation (WCDLUT), Oregon, to develop this experimental BMP. The United Sewage Agency (USA) provided sampling and laboratory analysis for the project; the Portland Metropolitan Service District (Metro) provided additional funding; and the University of Washington College of Forest Resources was contracted to perform bench-scale

leaching and adsorption capacity tests on selected composts. The compost chosen for the prototype facility was made from deciduous leaves collected in the fall; other types of compost evaluated were not satisfactory.

This project is a good example of intergovernmental cooperation and interaction between public and private sectors in developing new and potentially cost-effective technology for stormwater pollution control. The goal of the project was to effectively treat road runoff using a BMP which reduced the amount of land necessary.

The prototype test facility is located at S.W. 185th Avenue in Washington County, Oregon, and serves a total drainage area of 72 acres. The facility is designed for a peak hydraulic loading of 6.7 cfs (one-third the 2-year design storm). Higher flows are bypassed. Nine storms were monitored in 1991, and the system has been successful in removing, to low levels, many types of conventional pollutants .

The prototype facility utilized 3% of the land area required for a properly designed stormwater detention pond sized for the same site conditions.

The project recently won an Engineering Excellence Grand Award from the Consulting Engineers Council of Oregon, as well as a national Grand Award from the American Consulting Engineers Council.

For further information on this experimental BMP, contact Bill Stewart at W&H Pacific, (503) 626-0455.

## APPENDIX AI-2.1

## DERIVATION OF THE WATER QUALITY DESIGN STORM

In instances where the stormwater management requirement is treatment to remove pollutants only without an additional requirement to control peak rate discharge there arises the need to establish an appropriate design storm for sizing of treatment BMPs. This design storm needs to be the minimum size to provide treatment of all the runoff volume from the site except that from relatively rare floods. Sizing a treatment facility for infrequent storms would result in a large facility that would be greatly under-utilized most of the time. The cost becomes prohibitive to treat a few extra percent of the total runoff volume.

TABLE AI-2.1 ANALYSIS OF SEA-TAC RAINFALL FROM 1950 - 1977 (Prepared by Resource Planning Associates (1))

Storm Event Size	Precip. Amount	# of Events	Rainfall Amount of Larger Events	Proportion of Total <sup>2</sup>
1-month, 24-hr.	0.65"	390	415"	62%
6-month, 24-hr.	1.35"	58	101"	91%
1-year, 24-hr.	1.60"	31	55"	95%
2-year, 24-hr.	2.00"	9	23"	98%

<sup>2</sup> The total rainfall from 1950 to 1977 was 1,100". The proportion of total represents the amount of rainfall accounted for by that storm size, and smaller sizes. For example the 1-month, 24-hour storm, and smaller storms, accounted for 1,100 - 415/1,100 = 62%.

Table AI-2.1 shows that relatively small storms account for a considerable proportion of the total rainfall; for example the 6-month, 24-hour, and smaller storms, accounted for over 90% of the total rainfall during the period 1950 through 1977; 98% of the rainfall was accounted for by storm sizes up to the 2-year, 24-hour storm. Of course the proportion of runoff produced by the rainfall for any particular surface type will increase with increasing storm size. On the other hand, smaller storms may tend to produce runoff with higher concentrations of some pollutants because of the "first flush" effect which may occur in highly impervious areas following a dry spell. Therefore, as a first approximation, it seems reasonable to simply assume that the proportion of rainfall is approximately equal to the proportion of runoff.

Having arrived at this point, the next step is to decide what is an appropriate runoff proportion to use in sizing the water quality storm. Ideally we would want to treat 100% of all runoff but the data in Table AI-2.1 show that the incremental proportion of rainfall (and hence runoff) accounted for rapidly diminishes for storm sizes larger than the 6-month, 24-hour storm. This means that the marginal costs for treating stormwater will rapidly increase when facilities are sized for storms larger than the 6-month, 24-hour storm. This point is demonstrated by considering a simple example using a one acre urban site with a curve number of 95 and time of concentration of 10 minutes. Using the SBUH method the following peak runoff rates and runoff volumes were obtained:

<u>Storm Event</u>	<u>Precip.</u>	<u>Peak Runoff</u>	<u>Volume</u>
1-mo., 24-hr.	0.65"	0.061 cfs	1000 cu-ft
6-mo., 24-hr.	1.3"	0.21 cfs	3000 cu-ft
1-yr., 24-hr.	1.6"	0.28 cfs	4010 cu-ft
2-yr., 24-hr.	2.0"	0.38 cfs	5380 cu-ft

Since the treatment facility size will be in proportion to the peak runoff or runoff volume we can next compare the facility size required for each design storm with the proportion of total runoff generated by that and smaller storms (estimated from Table AI-2.1). (For this example we can use the total runoff volume as the indicator of required facility size.)

<u>Storm Event</u>	<u>Facility Size</u>	<u>Proportion of Runoff</u>
1-mo., 24-hr.	1000 cu-ft	62%
6-mo., 24-hr.	3000 cu-ft	91%
1-yr., 24-hr.	4010 cu-ft	95%
2-yr., 24-hr.	5380 cu-ft	98%

From this we can calculate that greatly diminishing returns are achieved by increasing the facility size beyond that needed for the 6-month, 24-hour storm. Sizing the facility for a 1-year, 24-hour storm instead of a 6-month storm requires an increase of about 33% for an increase of only 4% of volume treated from an already high value of approximately 90%. Further increasing the size to that required for the 2-year, 24-hour storm requires a further increment of about 36% for a further gain of only 3% in the long term runoff volume treated.

Therefore, as a first approximation, it seems reasonable to select the 6-month, 24-hour design storm as the Water Quality design storm.

(However, protection of beneficial uses in receiving waters will always be required. Therefore there may be instances, depending on the nature of the pollutants to be controlled and the receiving waters, that the 6-month storm will be deemed inadequate by the local government and/or Ecology or other State agencies. In these instances a larger design storm shall be chosen.)

Having selected the 6-month, 24-hour design storm as the first approximation, the next step is to determine a method for estimating the size of the storm, given that the isopluvial maps do not provide values for less than the 2-year storm. One method is to plot the logarithm of the return period against the precipitation value for the published storms - the 2, 5, 10, 25, 50 and 100-year frequencies. This was done for several locations around the Puget Sound basin - Bellingham, Everett, Seattle, Tacoma and Olympia. In each case a near perfect regression line was obtained, except that the slope and intercept varied in accordance with the differences in rainfall received at the various locations. Each regression line was then extrapolated to the 6-month frequency and rainfall value estimated. The ratio of the 6-month value to the 2-year value was then determined for each station. This ratio was found to average 0.64 with little variation between the stations. Therefore, for a rule of thumb method, the 6-month, 24-hour design storm can be estimated for any location within the Puget Sound basin as 0.64 times the 2-year, 24-hour storm value.

References:

- (1) Resource Planning Associates, Water Quality Best Management Practices Manual for the City of Seattle, 1989.

APPENDIX AI-2.2

ADDITIONAL BASIN PLANNING GUIDANCE AS APPLIED TO THE MINIMUM REQUIREMENTS

Basin Planning Applied to Source Control (Minimum Requirement #3)

Basin plans should identify potential sources of pollution and develop strategies to eliminate or control these sources to the fullest extent possible. At a minimum, a basin plan should include the following source control strategies:

- (1) Detection and correction of illicit discharges to storm sewer systems, including the use of dry weather sampling and dye-tracing techniques;
- (2) Identification of existing businesses, industries, utilities, and other activities which may store materials susceptible to spillage or leakage of pollutants into the storm sewer system;
- (3) Elimination or control of pollutant sources identified in (2);
- (4) Identification and control of future businesses, industries, utilities, and other activities which may store materials susceptible to spillage or leakage of pollutants into the storm sewer system;
- (5) Training and Public education

Basin Planning Applied to Runoff Treatment (Minimum Requirement #4)

Basin plans should develop runoff treatment standards to reduce pollutant loads based on an evaluation of the water resources to be protected within or downstream of a watershed. The evaluation must include an analysis of existing and future conditions. Additional levels of control beyond Minimum Requirement #4 may be justified in order to control the impacts of future development. While direct cause-and-effect impacts will rarely be known for future development, standards should be developed based on an evaluation of pollutant loads and modeling of receiving water conditions.

Runoff treatment standards developed from a basin plan must apply to individual development sites. Regional treatment BMPs, in general, will not be considered an acceptable substitute for on-site treatment standards for two primary reasons. One is the stream systems upstream of regional facilities are defined as waters of the state and shall be protected (i.e., they are not to be considered as simply conveyance systems to the regional facility). Second, the pollutant removal effectiveness of regional treatment BMPs has not been demonstrated to be equivalent to on-site treatment BMPs. Regional BMPs may offer some advantages in construction and operation and maintenance costs and Ecology may approve such BMPs on a case-by-case basis.

On-site standards developed from basin planning can be flexible provided that the level of runoff treatment for all sites in a watershed is equivalent to that which would be achieved by Minimum Requirement #3. For example, site A may be able to achieve a higher pollutant load reduction goal than site B and this is acceptable provided that the two sites together achieve the equivalent level of treatment provided by the Minimum Requirement #3.

Basin plans shall evaluate retrofitting opportunities, such as installation of extended detention outlets for existing stormwater detention facilities.

Basin Planning Applied to Streambank Erosion Control (Minimum Requirement #5)

Basin planning is well-suited to control streambank erosion for both existing and future conditions. Streambank erosion control standards developed from a basin plan may include a combination of on-site, regional, and stream protection/rehabilitation



measures. On-site standards shall be the primary mechanism to protect streambanks from the impacts of future conditions. Regional streambank erosion control BMPs are to be used primarily to correct existing downstream streambank erosion problems. Stream protection/rehabilitation measures may be applied wherever streambank erosion problems currently exist which will not be corrected by on-site or regional BMPs.

Basin Planning Applied to Wetlands and Water Quality Sensitive Areas (Minimum - Requirements #6 and #7, respectively)

Basin planning should be used to develop additional protection standards for wetlands and water quality sensitive areas. These standards must include source control, runoff treatment, and streambank erosion control standards. Additional standards may also be developed which are specific to the needs of the wetland or sensitive area to be protected, such as management of a wetland's hydrology and hydroperiods, establishment of buffer zones for wellheads, and ground water contributing and recharge zones, and management of streamflows for the benefit of fish populations.

CHAPTER I-3

PREPARATION OF STORMWATER SITE PLANS

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## CHAPTER I-3

## PREPARATION OF STORMWATER SITE PLANS

## I-3.1 INTRODUCTION

The purpose of this chapter is to provide summarized guidelines on how Erosion and Sediment Control (ESC) Plan and Permanent Stormwater Quality Control (PSQC) Plans, the plans which make up a Stormwater Site Plan (SSP) can be prepared. The thresholds and Minimum Requirements for these plans are described in detail in Chapter I-2. More details on plan preparation with examples of forms and submittal requirements are provided in the "Stormwater Program Guidance Manual for the Puget Sound Basin", (known hereafter as the Guidance Manual), a companion manual to this technical manual available from the Urban Nonpoint Management Unit.

The goal of this chapter is to provide a framework for uniformity in plan preparation. Such uniformity will promote predictability throughout the region and help secure prompt governmental review and approval. Properly drafted engineering plans and supporting documents will also facilitate the operation and maintenance of the proposed system long after its review and approval.

Please note that this chapter describes how to prepare a Stormwater Site Plan - the specific BMPs and design methods and standards to be used are contained in Volumes II-IV. ESC plans are covered in detail in Chapter II-4, and an example ESC plan is shown (to be drafted) in the Guidance Manual. Guidelines for selecting BMPs are given in Chapter I-4. Note also that all plans, except small parcel plans, shall be stamped by a professional engineer licensed in the State of Washington. All land boundary surveys used, and any legal descriptions prepared, except those for small parcels, must be stamped by a professional land surveyor licensed in the State of Washington.

## I-3.2 REQUIREMENTS AND CONTENTS OF STORMWATER SITE PLANS

Three types of stormwater site plans are covered here. The first is a Small Parcel Erosion and Sediment Control (SPESC) Plan. Small parcels, such as individual single family dwellings cause water quality problems during the construction period rather than after construction (except in aggregate, which is addressed elsewhere). As a result, the small parcel Minimum Requirements (Chapter I-2) and Small Parcel BMPs (Chapter II-4) intentionally address ESC-related concerns.

The second type of plan is a hybrid of the simpler Small Parcel ESC and the more elaborate Stormwater Site Plan (SSP). Proposed developments with  $>5,000$  ft<sup>2</sup> of impervious surface and land disturbing activities of  $<1$  acre planned shall implement the Small Parcel ESC Plan. The Minimum Requirements for these plans are found in section I-2.2. In addition to the Small Parcel ESC Plan, developments of this size are required to implement a full-scale Permanent Stormwater Quality Control Plan (PSQC) which satisfies the remaining Minimum Requirements found in Chapter I-2.

Lastly, new development or redevelopment which meets the criteria set forth in Section I-2.4 must develop and implement both a full-scale ESC and SSP.

## I-3.3 SMALL PARCEL EROSION AND SEDIMENT CONTROL PLANS

The following new development shall be required to control erosion and sediment during construction, to permanently stabilize soil exposed during construction, to comply with the Small Parcel Requirements 1 through 4, and to prepare a SPESC:

Figure I-3.1 Checklist for Small Parcel Minimum Requirements  
(adapted from the City of Redmond)

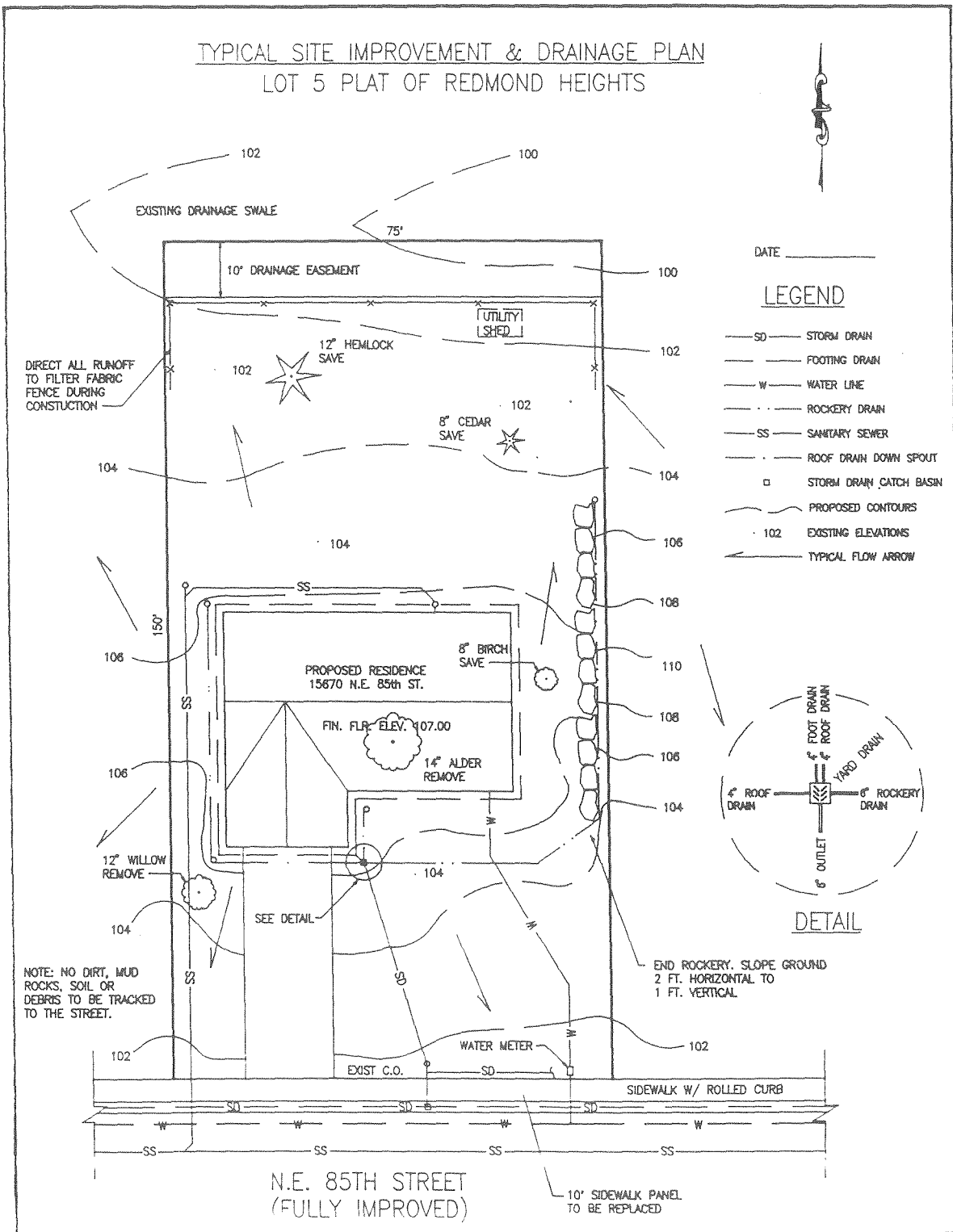
The applicant shall submit two copies of a site improvement and drainage plan on 8½ by 11" paper showing the following:

- Provide the name, address, and phone number of owner or contact person.
- Designate north arrow, lot number and plat, address, date and street name fronting structure.
- Show all proposed structures and any existing structures on the site.
- Locate and size all streams, swales or drainage channels on or within 25 feet of the site which may involve or affect the drainage of the site to be developed. Indicate all existing stormwater pipes.
- Indicate the direction and location of surface water runoff entering the site from all adjacent property.
- Indicate what type of system(s) will be used to convey runoff away from the proposed structures.
- Phase clearing so that only those areas that are actively being worked are uncovered. From October 1 through April 30, no soils shall remain exposed for more than 2 days. From May 1 through September 30, no soils shall remain exposed for more than 7 days.
- Indicate where excavated basement soil stockpiles (if applicable) will be located. The stockpile should be covered until the stockpile is either used or removed. Piles should be situated so that sediment does not run into the street or adjoining yards.
- Backfill basement walls, where applicable, as soon as possible and rough grade the lot.
- Remove excess soil from the site as soon as possible after backfilling.
- Stabilize denuded areas of the site by mulching, seeding, planting, or sodding.
- Adjacent properties shall be protected from sediment deposition by appropriate use of vegetative buffer strips, sediment barriers or filters, dikes or mulching, or by a combination of these measures and other appropriate BMPs.
- If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing a storage and settling area for stormwater.
- Construction vehicle access shall be, whenever possible, limited to one route. Indicate the location of the construction entrance. Apply gravel or crushed rock to the driveway area and restrict truck traffic to this one route. Driveway paving can be installed directly over the gravel. This measure requires periodic inspection and maintenance including washing, top-dressing with additional stone, reworking and compaction.

- Provide for periodic street cleaning to remove any sediment that may have been tracked out. Sediment should be removed by shovelling or sweeping and carefully removed to a suitable disposal area where it will not be re-eroded.
- Inspect all erosion and sediment control BMPs installed regularly, especially after any large storm. Maintenance, including removal and proper disposal of sediment should be done as necessary (generally when one-half or more of the total capacity of the system is filled with sediment).

For further information on small parcel BMPs, please see Chapter II-5, Section II-5.10.

Figure I-3.2 Typical Site Improvement and Drainage Plan



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DRWN: BLC JANUARY 14, 1991

- (a) Individual, detached, single family residences and duplexes.
- (b) Creation or addition of less than 5,000 square feet of impervious surface area.
- (c) Land disturbing activities of less than 1 acre.

The contents of a Small Parcel ESC Plan will depend upon the exact nature of the project. It will generally contain some elements of the full ESC as determined by the local government. The Small Parcel ESC must describe how the small parcel erosion control requirements will be met.

A Small Parcel ESC Plan should contain a plot plan which includes:

- A vicinity map to clearly locate property
- An accurate location of the structure and its access
- All applicable setback requirements
- Location of all applicable ESC BMPs
- Existing site features or water quality sensitive areas, if appropriate.

The checklist found in Figure I-3.1 can also be used.

All proposed developments where >5,000 ft<sup>2</sup> of impervious surface and land disturbing activities of <1 acre are planned, shall implement the Small Parcel Requirements found in section I-2.2. In addition to the Small Parcel ESC Plan, developments of this size are required to implement a full-scale Stormwater Site Plan which satisfies the remaining Minimum Requirements found in Chapter I-2.

#### I-3.4 LARGE PARCEL EROSION AND SEDIMENT CONTROL PLANS

As set forth in Chapter I-2, all new development and redevelopment that includes *land disturbing activities* over an area 1 acre and greater requires an ESC Plan as a subset of the Stormwater Site Plan (SSP). Land disturbing activities are defined as any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing topography. Land disturbing activities include construction, clearing, grading, filling, and excavation.

A Large Parcel Erosion and Sediment Control Plan (ESC Plan) shall provide for the interception and treatment of all potential silt-laden runoff that could occur during clearing, grading, construction and site stabilization. The ESC Plan must provide measures to assure that no silt-laden runoff leaves the site during construction and stabilization. As mentioned earlier, if only land disturbing activities are proposed, only a LPESC Plan is required. Also, relevant parts of the SSP should be included when only a ESC Plan is required, these include a plot plan and preliminary conditions summary.

A Large Parcel Erosion and Sediment Control Plan should, at a minimum, include the following:

- Location of clearing limits and easements, setbacks, water quality sensitive areas and their buffers.
- Locations and descriptions of all erosion and sediment control measures for each phase of construction.
- Cross sections of fill or excavations.

Figure I-3.3 Flowchart Showing Various Development Types

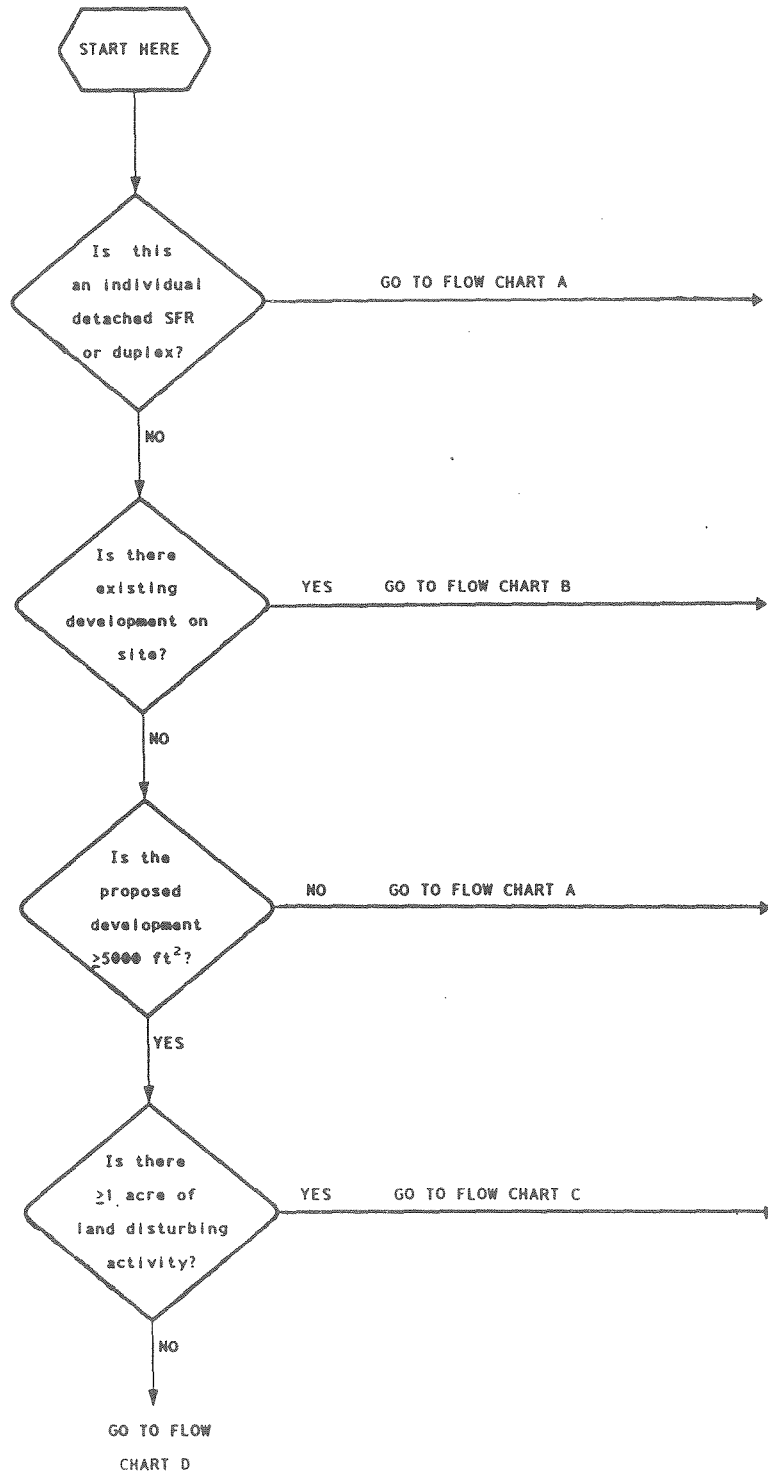




Figure I-3.4 Flowchart Showing Steps for Small Parcels

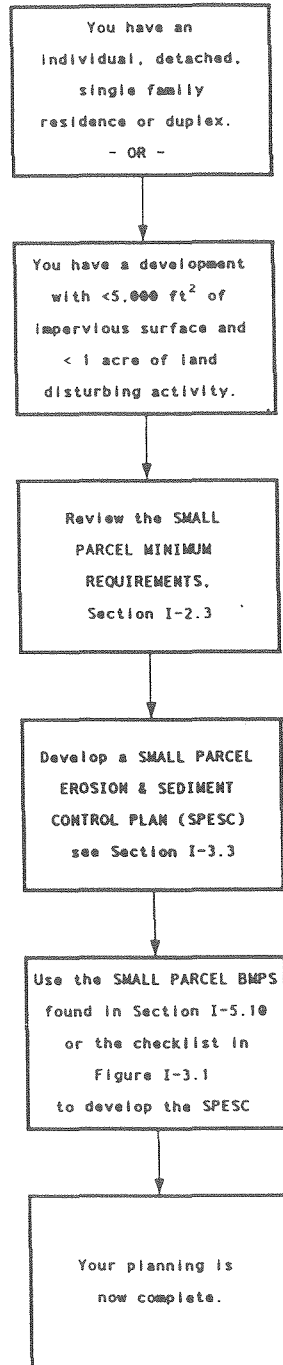
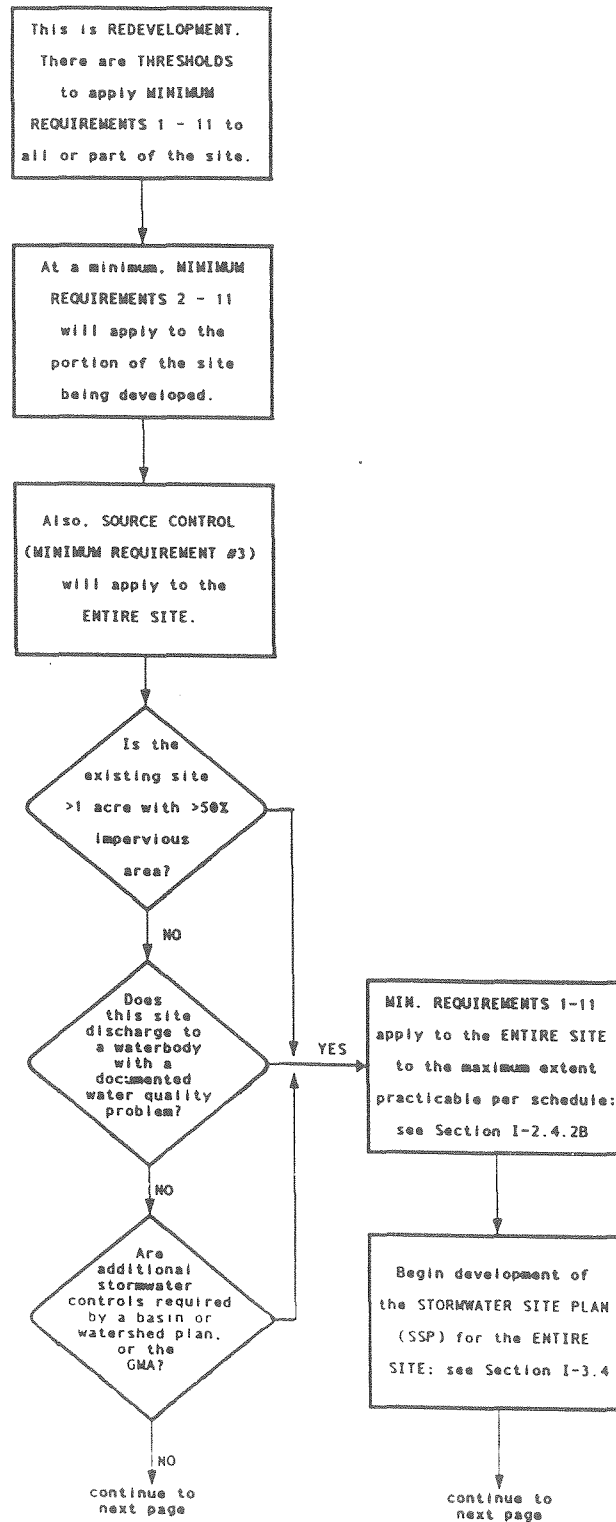


Figure I-3.5 Flowchart Showing Steps for Redevelopment



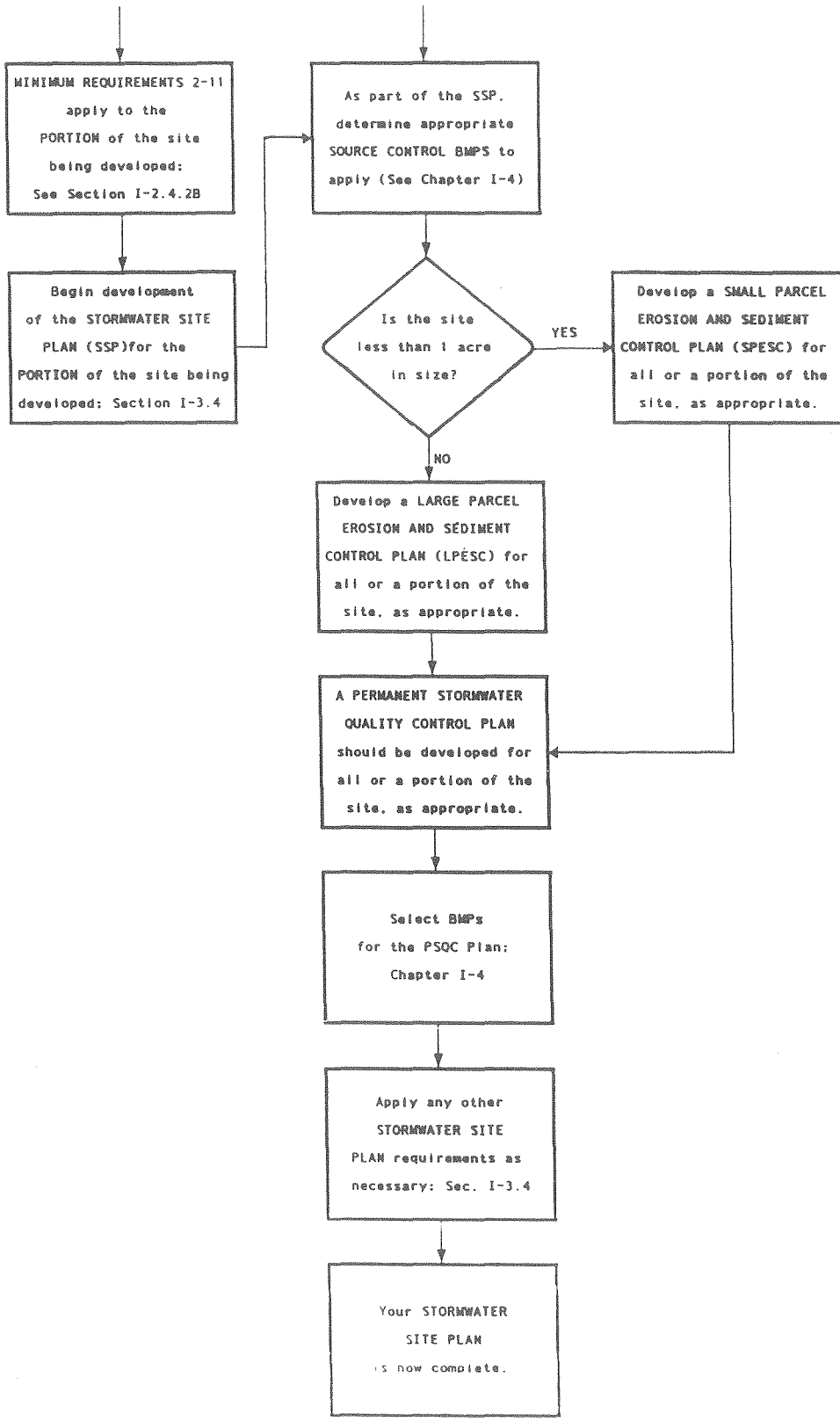


Figure I-3.6 Flowchart Showing Steps for New Development

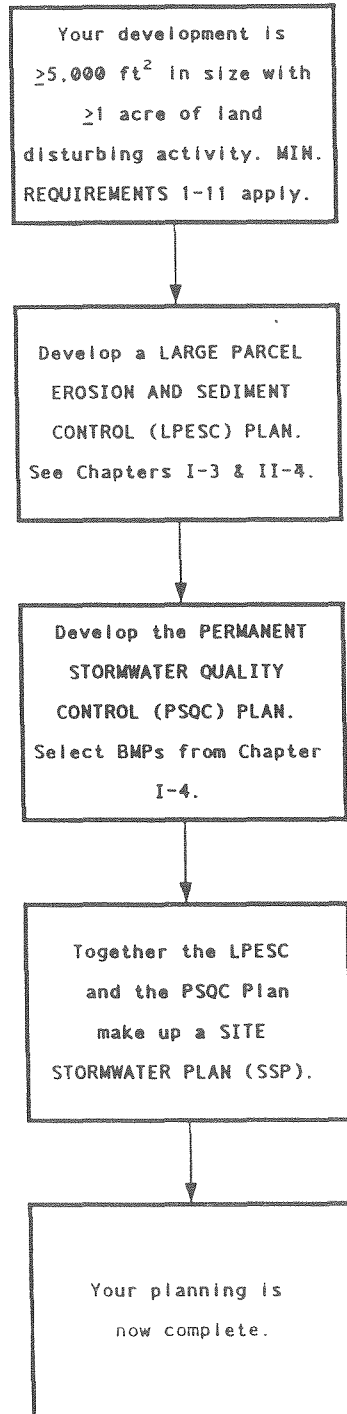
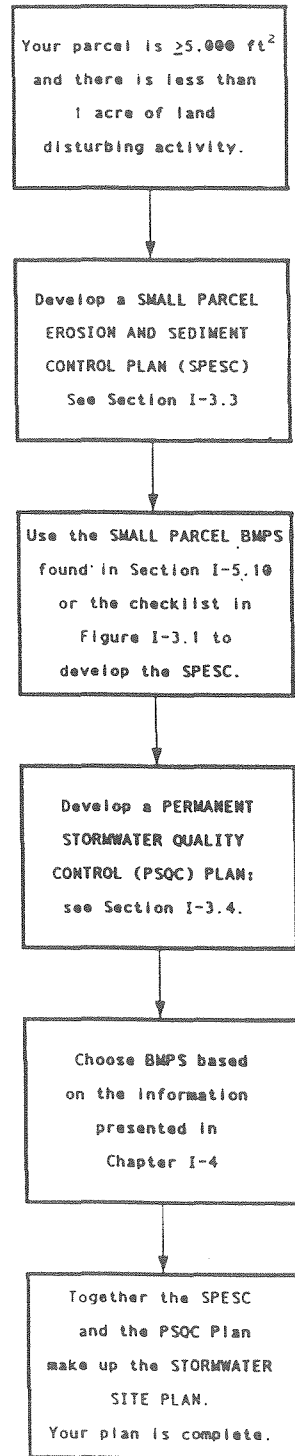


Figure I-3.7 Flowchart Showing Steps for "Hybrid" Projects



ESC plans are explained in detail in Chapter II-4, and an example ESC Plan (to be drafted) is shown in the Guidance Manual.

### I-3.5 STORMWATER SITE PLANS

The Puget Sound Water Quality Management Plan (PSWQMP) requires that all jurisdictions within the Puget Sound Basin adopt ordinances requiring stormwater controls (for example, site plans, including ESC plans) for all new development and redevelopment as defined below.

#### New Development Standard

New development - means the following activities: land disturbing activities, structural development, including construction, installation or expansion of a building or other structure; creation of impervious surfaces; Class IV - general forest practices that are conversions from timber land to other uses; and subdivision, short subdivision and binding site plans, as defined in Ch.58.17.020 RCW. All other forest practices and commercial agriculture are not considered new development.

All new development that includes the creation or addition of 5,000 square feet, or greater, of new impervious surface area, and/or land disturbing activity of one acre or greater, shall comply with Minimum Requirements #1 through #11 in Sections I-2.5 through I-2.15 and prepare a Stormwater Site Plan.

All new development that includes the creation or addition of 5,000 square feet, or greater, of new impervious surface area, and land disturbing activity of less than one acre, shall comply with Minimum Requirements #2 through #11 in Sections I-2.6 through I-2.15 and the Small Parcel Minimum Requirements found in section I-2.2, above. This category of development shall also prepare a Stormwater Site Plan that includes a Small Parcel Erosion and Sediment Control Plan.

This section does not apply to the construction of individual, detached, single family residences and duplexes. Those types of new development are included in the Small Parcel Minimum Requirements.

#### Redevelopment Standard

Redevelopment - means, on an already developed site, the creation or addition of impervious surfaces, structural development including construction, installation or expansion of a building or other structure, and/or replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities associated with structural or impervious redevelopment.

A. Where redevelopment of  $\geq$  5,000 square feet occurs:

The new development Minimum Requirements, Sections I-2.5 through I-2.15, shall apply to that portion of the site that is being redeveloped, and source control BMPs shall be applied to the entire site, including adjoining parcels if they are part of the project.

B. Where one or more of the following conditions apply, a Stormwater Site Plan shall be prepared that includes a schedule for implementing the Minimum Requirements to the maximum extent practicable, for the entire site, including adjoining parcels if they are part of the project. An adopted and implemented basin plan (Minimum Requirement #9) may be used to develop redevelopment requirements that are tailored to a specific basin.

1. Existing sites greater than 1 acre in size with 50% or more impervious surface.
2. Sites that discharge to a receiving water that has a documented water quality problem.

A documented water quality problem includes, but is not limited to water bodies:

- (i) Listed in reports required under section 305(b) of the Clean Water Act, and designated as not supporting beneficial uses;
  - (ii) Listed under section 304(1)(1)(A)(i), 304(1)(1)(A)(ii), or 304(1)(1)(B) of the Clean Water Act as not expected to meet water quality standards or water quality goals;
  - (iii) Listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act that, without additional action to control nonpoint sources of pollution cannot reasonably be expected to attain or maintain water quality standards.
3. Sites where the need for additional stormwater control measures has been identified through a basin plan.

The Stormwater Site Plan (SSP) should be a comprehensive report containing all technical information and analysis necessary to evaluate the proposed stormwater facilities. In addition, the SSP should provide the necessary information to prepare final construction plans, profiles, details, notes and specifications for all stormwater facilities.

The Stormwater Site Plan contains the following sections:

- I. Project Overview
- II. A plot plan, including:
  - locations of structures, other impervious surfaces
  - locations of stormwater runoff control facilities
  - lot layout
  - setback requirements
  - existing site features
  - water quality sensitive areas
  - road rights-of-way and easements
- III. Preliminary Conditions Summary
- IV. Off-Site Analysis
- V. Analysis and design of proposed stormwater runoff control facilities, including treatment and source control BMPs, and streambank erosion control requirements.
- VI. Special Reports and Studies
- VII. Basin and Community Planning Areas
- VIII. Other Permits
- IX. Erosion and Sediment Control Plan (see I-3.4)
- X. Bond Quantities Worksheet, Retention/Detention Facility Summary Sheet and Sketch, and Declaration of Covenant
- XI. Maintenance and Operations Manual

The SSP must be stamped and dated by a professional civil engineer licensed in the State of Washington. Every SSP should contain each of the sections listed above.

If a section does not apply, the applicant may simply mark with "N/A." This standardized format will allow a quicker, and more efficient review of information. A consistent format will also provide accurate, time efficient researching of SSPs approved for other projects in the same basin.

Additional information may be required if the development impacts water quality sensitive areas. The extent of the additional information which will be required can be estimated at the initial application screening, but not determined definitively until as late as the SEPA Threshold Determination.

*For further details on the SSP consult the local government, and the Guidance Manual.*

### I-3.6 OTHER PERMITS AND PLAN REQUIREMENTS

Other agencies, such as those listed below, may require a stormwater site plan to describe the proposed project's impact on surface, ground and stormwater. The applicant should take care to note that these other agency requirements are separate from, and in addition to, the local government's requirement for a stormwater site plan. The applicant is responsible to coordinate joint agency review. Some permits or applications can be reviewed simultaneously by more than one agency; others may require the applicant to obtain one type of permit or approval prior to another agency's review. Agency Permit/Approvals that may be necessary include but are not limited to:

AGENCY	REQUIREMENT
Washington State Department of Transportation	Developer/Local Agency Agreement
Washington State Department of Ecology	Short Term Water Quality Modification Approval and/or Dam Safety Permit
Washington State Department of Fisheries	Hydraulic Project Approval
Washington State Department of Wildlife	Hydraulic Project Approval
United States Army Corps of Engineers	Section 404 Permit & Section 10 Permit/letter of permission

The publication "Commonly Required Environmental Permits for Washington State" #90-29 is now available from the Department of Ecology. It covers these permit requirements (and many more) in a general fashion, and directs the reader to the proper agency for assistance.

### I-3.7 PLAN REVIEW PROCEDURES: FORMS AND WORKSHEETS

The Guidance Manual provides examples of the following forms and worksheets:

- A Predesign meeting form
- B Stormwater site plan worksheet
- C Summary of site drainage conditions
- D Retention/detention summary sketch and sheet



E Declaration of covenant  
F Bond quantities worksheets  
G Drainage release covenant  
H Drainage easements

**CHAPTER I-4**  
**BMP SELECTION PROCESS FOR**  
**PERMANENT STORMWATER QUALITY CONTROL PLANS**

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## CHAPTER I-4

## BMP SELECTION PROCESS FOR PERMANENT

## STORMWATER QUALITY CONTROL PLANS

## I-4.1 INTRODUCTION

The purpose of this chapter is to provide guidance for selecting permanent BMPs for new development and redevelopment sites (including retrofitting of redevelopment sites). The task of selecting BMPs is necessary in order to complete the Permanent Stormwater Quality Control Plan, an important component of the Stormwater Site Plan (see Chapters I-2 and I-3 for guidance on these plans). Please note that guidelines for the Erosion and Sediment Control Plan and appropriate BMPs are not covered in this chapter; for guidance on these BMPs refer to Volume II of this manual.

Ecology's pollution control strategy is to first emphasize *pollution prevention* and, second, *pollution treatment*. By preventing pollution from occurring in the first place the need for treatment can be reduced or, in some cases, eliminated. The three stormwater control objectives that are intended to implement this strategy, and the classification of BMPs for each objective, are the following:

- (i) Pollution prevention using *source control* BMPs
- (ii) Pollution treatment using *runoff treatment* BMPs
- (iii) Protection of stream ecosystems from erosion and sedimentation using *streambank erosion control* BMPs

The classification system for BMPs is presented in Section I-4.2. A step-by-step process for selecting BMPs is provided in Section I-4.3.

## I-4.2 CLASSIFICATION OF BMPs

BMPs have been classified based on their ability to implement the pollution control strategy described above. Pollution prevention is accomplished through the use of source control BMPs. Treatment is provided by runoff treatment BMPs. A third classification that overlaps both prevention and treatment is that of streambank erosion control. Figure I-4.1 provides a schematic of the classification system and Table I-4.1 lists the BMPs according to this system.

*Note: Table I-4.1 does not include natural and created wetlands as these are not considered to be BMPs. The primary stormwater management objective for natural wetlands will be to protect or enhance the beneficial uses of these systems. This means that stormwater must be treated prior to discharge to these wetlands. It does not mean that stormwater discharges to natural wetlands are prohibited; if this were to occur then these wetlands would be severely damaged or lost. See Minimum Requirement #6 and Chapter III-5 for stormwater management guidance for natural wetlands.*

*Table I-4.1 does include a Constructed Wetland (BMP RD.09); this is an artificial wetland located on a non-wetland site for the exclusive purpose of managing stormwater. Created wetlands designed for a mitigation project should not be used for stormwater treatment as stormwater may be detrimental to the beneficial uses being mitigated for (e.g. wildlife habitat or contact recreation).*

Table I-4.1  
List of All Source Control, Runoff Treatment, and Streambank Erosion Control BMPs

BMP Category and Name	Source Control	Runoff Treatment	Streambank Erosion Control
<b>(a) Infiltration and Filtration BMPs (Chapter III-3)</b>			
BMP RI.05      WQ Infiltration Basin		X	0
BMP RI.06      SBEC Infiltration Basin			X
BMP RI.10      WQ Infiltration Trench		X	0
BMP RI.11      SBEC Infiltration Trench			X
BMP RI.15      Roof Downspout System		X	0
BMP RI.20      WQ Porous Pavement		X	0
BMP RI.21      SBEC Porous Pavement			X
BMP RI.30      WQ Concrete Grid/Modular Pavement		X	0
BMP RI.31      SBEC Concrete Grid/Modular Pavement			X
BMP RF.05      Sand Filtration Basin		X	
BMP RF.10      Sand Filtration Trench		X	
BMP RF.15E     Aquatard System (Experimental)		X	
<b>(b) Detention BMPs (Chapter III-4)</b>			
BMP RD.05      Wet Pond (Conventional Pollutants)		X	0
BMP RD.06      Wet Pond (Nutrient Control)		X	0
BMP RD.09      Constructed Wetland		X	0
BMP RD.10      Presettling Basin		X(p)	
BMP RD.11      Extended Detention Dry Pond		X(p)	X
BMP RD.15      Wet Vault/Tank		X	0
BMP RD.20      Extended Detention Dry Vault/Tank			X
<b>(c) Biofiltration BMPs (Chapter III-6)</b>			
BMP RB.05      Biofiltration Swale		X	
BMP RB.10      Vegetative Filter Strip		X	

WQ = "Water Quality"

SBEC = "Streambank Erosion Control"

X - Provided by this BMP

X(p) - Provides pretreatment only

0 - Option; can be provided with proper planning and design

Table I-4.1 (continued)  
List of All Source Control, Runoff Treatment,  
and Streambank Erosion Control BMPs

BMP Category and Name	Source Control	Runoff Treatment	Streambank Erosion Control
<b>(d) Oil/Water Separators (Chapter III-7)</b>			
BMP RO.05 Spill Control (SC) Oil/Water Separator		X	
BMP RO.10 API Oil/Water Separator		X	
BMP RO.15 CPS Oil/Water Separator		X	
<b>(e) Stream Stabilization BMPs (Chapter III-8)</b>			
BMP RS.05 Vegetative Streambank Stabilization	X		X
BMP RS.10 Bioengineering Methods	X		X
BMP RS.15 Structural Streambank Stabilization	X		X
<b>(f) Source Control for Urban Land Uses (Chapter IV-4)</b>			
BMP S1.10 Fueling Stations	X		
BMP S1.20 Vehicle/Equipment Washing and Steam Cleaning	X		
BMP S1.30 Loading and Unloading Liquid Materials	X		
BMP S1.40 Above Ground Tanks for Liquid Storage	X		
BMP S1.50 Container Storage of Liquids, Food Wastes or Dangerous Wastes	X		
BMP S1.60 Outside Storage of Raw Materials, By products or Finished Products	X		
BMP S1.70 Outside Manufacturing Activities	X		
BMP S1.80 Emergency Spill Cleanup Plans	X		
BMP S1.90 Vegetation Management/Integrated Pest Management	X(n)		
BMP S2.00 Maintenance of Storm Drainage Facilities	X(n)		
BMP S2.10 Locating Illicit Connections to Storm Drains	X		
BMP S2.20 Street Sweeping	X(n)		

WQ = "Water Quality"

SBEC = "Streambank Erosion Control"

X - Provided by this BMP

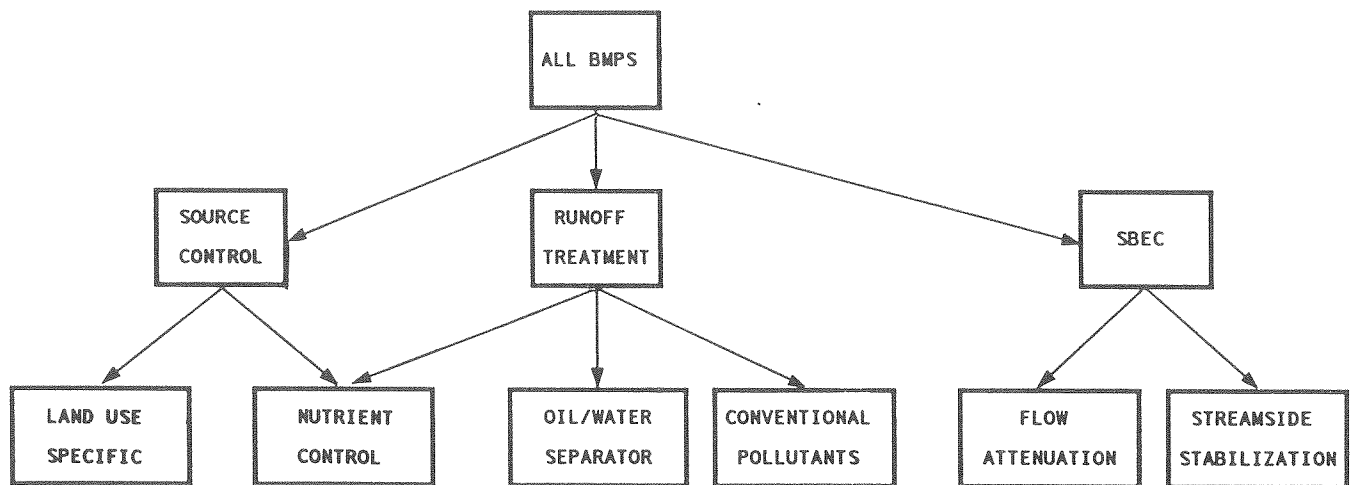
X(n) - These may also be used as source control BMPs when nutrient control is required by the Plan Approval Authority

0 - Option; can be provided with proper planning and design

### I-4.2.1 Source Control BMPs

Source control BMPs are designed to prevent pollutants from entering stormwater by eliminating the source of pollution or preventing contact of pollutants with rainfall and runoff. Source control BMPs are either specific to the type of land use being proposed for development or are intended to control a specific type of pollution problem existing within a watershed, such as nutrients that may contribute to eutrophication. Examples of source control BMPs include reducing or eliminating use of a pesticide, covering areas used to store chemicals, and street sweeping during dry weather conditions.

Figure I-4.1  
Classification of Stormwater BMPs



### I-4.2.2 Runoff Treatment BMPs

Runoff treatment BMPs are designed to remove pollutants that are contained in runoff. Treatment BMPs utilize a variety of mechanisms to remove pollutants from stormwater including sedimentation, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Examples of runoff treatment BMPs include infiltration trenches, wet ponds, biofiltration swales, and vegetative filter strips. The goal of runoff treatment BMPs is to provide effective treatment of at least 90 percent of the runoff generated by development. To achieve this goal, these BMPs are sized to treat the 6-month, 24-hour design storm (also referred to as the water quality design storm, or the runoff treatment design storm).

Ecology has identified two categories of pollutants that are targeted for runoff treatment; "conventional" pollutants and "nutrients." Conventional pollutants are those that are typically associated with particulates and that can be treated by a range of BMPs. Examples of conventional pollutants are total suspended solids, heavy metals, and fecal coliform. Nutrients, on the other hand, exist in both suspended and dissolved phases and can be more difficult to control. Examples of

nutrients are phosphorus and nitrogen. Nutrients can be a concern for both surface water and ground water. Eutrophication of lakes is typically caused by nutrients and ground water contamination by nitrates is also a common problem.

A subcategory of runoff treatment BMPs is those that provide pretreatment in order to protect primary treatment BMPs from siltation. The selection of pretreatment BMPs is described further in the BMP selection process (Section I-4.3) and illustrated in Table I-4.6.

A special category of runoff treatment BMPs includes those designed to remove oil contained in runoff. Oil, being lighter than water, typically floats on top of the water column and different removal techniques may be needed for treatment. Oil will, however, often adhere to suspended solids. Oil concentrations in urban runoff are often too low to justify the use of oil/water separators, but some land uses may require these BMPs, especially when the possibility of spills is present. There are three basic types of oil/water separators. Spill control (SC-type) are designed only to capture spills, while API and CPS-type separators are specifically designed to remove free oil from the water column. Sand filtration BMPs are currently allowed as an interim alternative to API and CPS oil/water separators in this edition of the manual. The ability of sand filtration to remove free oil shows promise but is under further investigation.

#### I-4.2.3 Streambank Erosion Control BMPs

Streambank erosion control (SBEC) BMPs are designed to prevent or control the excessive erosion that typically occurs in streams located in urbanizing watersheds. This erosion results not only because of the dramatic increase in peak flow rates from runoff but also due to increases in the frequency and duration of high flow conditions. Conventional flood control ponds are only marginally effective at controlling streambank erosion because they control only peak flow rates. The goal of streambank erosion control BMPs is to replicate, to the extent possible, the pre-existing hydrologic regime in streams by attenuating runoff from development sites and slowly releasing it back to the natural system.

The two-year return period storm has been identified as a key event for controlling streambank erosion. The two-year storm is typically the event in which streams are flowing "bankfull," a highly erosive condition. Urbanization increases the frequency and duration of bankfull conditions, thus greatly accelerating the streambank erosion process. Larger storms, such as the 10-year and 100-year events, are also important for streambank erosion control. These storms may periodically alter the morphology of streams and are important for the transport and deposition of sediments necessary for the ecological health of stream systems.

Ecology's streambank erosion control standards attempt to replicate, to the extent practicable, the stream flow conditions that would occur under natural conditions for specified design storms. Accordingly BMPs are to be designed to meet the following on-site detention requirements:

- Limit the peak rate of runoff to 50 percent of the *existing site condition* 2-year, 24-hour design storm, with a correction factor applied;
- Maintain the peak flow rate of runoff for the *existing site condition* 10-year and 100-year, 24-hour storms, with a correction factor applied.

The correction factor is applied to the BMP volume and should range from 20 to 50 percent for sites with impervious cover ranging from 20 to 100 percent. A correction factor is necessary to account for the inadequacies of current hydrologic analysis methods. Improved methods are under development and should be available no later than 1993. See Chapter III-1 for more details.

Definition: Existing site condition means - (a) For developed sites with stormwater facilities that have been constructed to meet the standards in the Minimum Requirements of this manual, existing site conditions shall mean the existing conditions on the site.

(b) For developed sites that do not have stormwater facilities that meet the Minimum Requirements, existing site conditions shall mean the conditions that existed prior to local government adoption of a stormwater management program. If in question, the existing site conditions shall be documented by aerial photograph records, or other appropriate means.

(c) For all sites in water quality sensitive areas as identified under Minimum Requirement #7, Water Quality Sensitive Areas, existing site conditions shall mean undisturbed forest, for the purpose of calculating runoff characteristics.

(d) For all undeveloped sites outside of water quality sensitive areas, existing site conditions shall mean the existing conditions on the site.

Ecology recognizes, however, that the flow attenuation criteria described above may not be adequate in itself to protect streams since, in many cases, damage may have already occurred. To partially address this, a group of *streamside stabilization* BMPs are provided that are designed to correct *existing* problems (see Table I-4.1).

An additional point to keep in mind is that site-specific BMPs designed to meet the above criteria may only be partially effective at controlling the cumulative effects of runoff from all sites in a watershed. For effective control of streambank erosion it may be necessary to develop and implement watershed-wide strategies that address impacts from both new and existing development on a regional level. Minimum Requirement #9, Basin Planning, is intended to facilitate such strategies.

#### I-4.2.4 Infiltration

Infiltration is Ecology's highest priority for both runoff treatment and streambank erosion control, provided proper conditions exist for its use. Infiltration can provide multiple benefits, including pollution removal, control of streambank erosion, ground water recharge, and flood control. One condition that can limit the use of infiltration is the need to protect ground water quality. No discharge of *untreated* stormwater to ground water will be allowed. To adequately address the protection of ground water when evaluating infiltration it is important to understand the difference between soils that are suitable for runoff treatment or streambank erosion control, or both. Sufficient organic content to remove pollutants must be present for soils to provide runoff treatment. Examples are silty and sandy loams. These soils may have fairly low percolation rates that could render them infeasible for infiltrating the large volumes of runoff required for streambank erosion control. Coarser soils, such as gravelly sands, can provide streambank erosion control but are wholly inadequate for providing treatment of runoff. The use of coarser soils for infiltrating runoff is allowable, but runoff treatment must *always* precede discharge to these soils. Thus, there will be instances when soils are suitable for treatment but not streambank erosion control, and vice versa.

#### I-4.2.5 On-line vs. Off-line Configuration

Some BMPs can combine runoff treatment and streambank erosion control into the same facility or can be located together in series; either of these configurations will be called "on-line" systems. In other cases runoff treatment must be provided separate from streambank erosion control; an "off-line" system. On-line systems are typically detention-type BMPs that maintain a "permanent pool" of water for runoff treatment purposes and also have a "live storage" volume above the permanent pool to temporarily detain runoff for streambank erosion control purposes (See Figure I-4.2



for an illustration of "dead" and "live" storage concepts). Off-line systems are typically those that are not capable of providing streambank erosion control (e.g., water quality infiltration trench) or whose pollutant removal mechanisms are not compatible with providing streambank erosion control (e.g., oil/water separator). The decision as to which configuration to use is discussed in the description of each individual BMP provided in Chapters III-3 through III-7.

The ability of detention-type BMPs to provide both runoff treatment and streambank erosion control into the same facility can be an important one. This feature can be useful for controlling stormwater pollution from existing development sites by retrofitting existing flood control ponds to provide extended detention of the 6-month, 24-hour storm.

#### I-4.3 STEP-BY-STEP SELECTION PROCESS FOR BMPs

A five step BMP selection process is presented that uses the classification scheme presented in Figure I-4.1. A summary of the steps is depicted in Figure I-4.3; a detailed description follows.

##### I-4.3.1 STEP 1: DETERMINE STORMWATER CONTROL SCENARIO FROM TABLE I-4.2

The purpose of Step 1 of the BMP selection process is to determine if some or all of the three stormwater control objectives are to be achieved by an individual development, i.e., Source Control, Runoff Treatment, and Streambank Erosion Control.

Use Table I-4.2 to evaluate the eight possible stormwater control scenarios that could apply to a development site. The table presents the appropriate classification and sequence of runoff control BMPs required for each scenario. Upon completion, the user can then proceed to Step 2 to select individual BMPs.

##### *STEP 1A: Determine if Oil/Water Separator BMPs are Required Based on Land Use Type*

The requirement to use oil/water separators is dependent upon the specific land use proposed for development. Volume IV describes all of the major urban land use types (both public and private) that are likely to occur in either a proposed new development or in an existing development. While a number of activities may require the use of spill control (SC-type) separators, only a few will necessitate API or CPS-type separators. At a minimum, the following land use types have been identified as requiring API or CPS-type oil/water separators:

- Industrial Machinery and Equipment, Trucks and Trailer Aircraft, Parts and Aerospace, Railroad Equipment
- Log Storage and Sorting Yards
- Airfields and Aircraft Maintenance
- Fleet Vehicle Yards
- Railroads
- Gas Stations
- Retail/Wholesale Vehicle and Equipment Dealers
- Vehicle Maintenance and Repair
- Construction Businesses (paving, heavy equipment storage and maintenance, storage of petroleum products)

As an alternative to an API or CPS-type oil/water separator, a sand filtration BMP may be used to provide treatment of oil (*Note: This alternative is being recommended on an interim basis and further evaluation is necessary*). See Chapter III-3 for more information on sand filters.

Figure I-4.2  
Conceptual Detention BMP Providing Both Runoff Treatment  
and Streambank Erosion Control

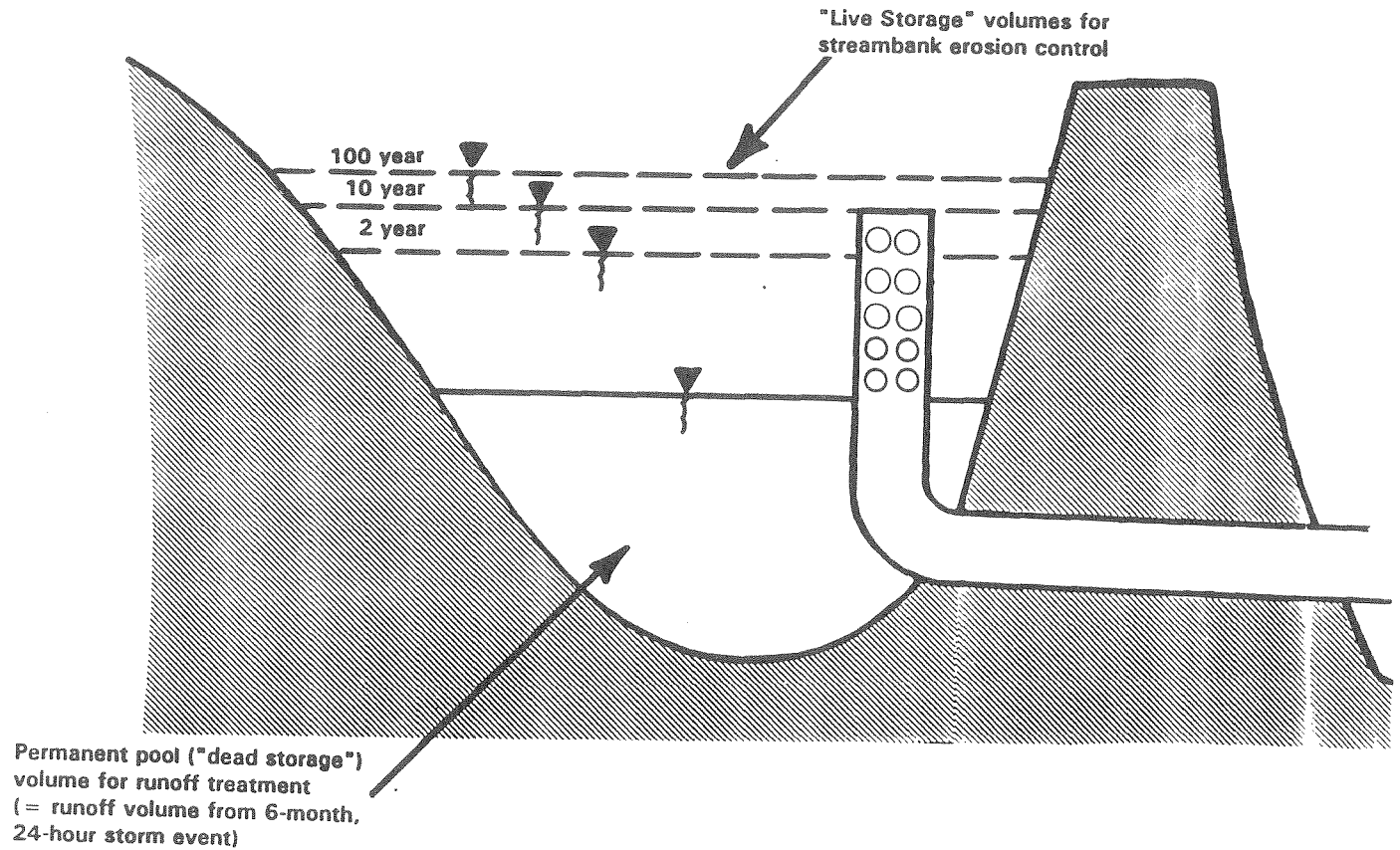


Figure I-4.3 Summary of Steps for BMP Selection Process

PRELIMINARY STEP: Review Chapter I-2 prior to starting the BMP selection process.

STEP 1: Determine Stormwater Control Scenario from Table I-4.2

STEP 1A: Determine if Oil/Water Separator BMPs are Required based on Land Use Type

STEP 1B: Determine if Nutrient Control is Required *in addition* to Treatment of Conventional Pollutants

STEP 1C: Determine if Streambank Erosion Control is Required

STEP 1D: Determine Final Stormwater Control Scenario from Table I-4.2

STEP 2: Select Source Control BMPs

STEP 2A: Select Source Control BMPs based on Land Use Type

STEP 2B: Select Source Control BMPs for Nutrient Control, if required, as determined from Step 1B

STEP 2C: Prepare Final Source Control BMP List

STEP 3: Select Runoff Treatment and Streambank Erosion Control BMPs

STEP 3A: Select type of Oil/Water Separator, if required, as determined in Step 1A

STEP 3B: Determine initial order of preference of runoff treatment BMPs from Table I-4.4

STEP 3C: Determine initial order of preference of streambank erosion control BMPs from Table I-4.5

STEP 3D: Screen BMPs based on Comparative Stormwater Benefits and Restrictions using Table I-4.6

STEP 3E: Screen Runoff Treatment and Streambank Erosion Control BMPs based on Other Physical Factors

STEP 3F: Prepare Modified BMP List

STEP 3G: Prepare Final BMP List

STEP 4: Complete Stormwater Site Plan

STEP 4A: Complete Permanent Stormwater Quality Control Plan

STEP 4B: Review other Stormwater Site Plan requirements

STEP 4C: Complete Stormwater Site Plan

STEP 5: Submit Final Stormwater Site Plan to the Plan Approval Authority

TABLE I-4.2  
STORMWATER CONTROL SCENARIOS

Scenario	BMP Sequence and Selections
1. O/W Separator Required: NO Nutrient Control Required: NO Streambank Erosion Control: NO	Source Control → Runoff Treatment (Conventional)
2. O/W Separator Required: NO Nutrient Control Required: NO Streambank Erosion Control: YES	Source Control → Runoff Treatment → SBEC (Conventional)
3. O/W Separator Required: NO Nutrient Control Required: YES Streambank Erosion Control: YES	Source Control → Runoff Treatment → SBEC (including nutrients) (Nutrients)
4. O/W Separator Required: NO Nutrient Control Required: YES Streambank Erosion Control: NO	Source Control → Runoff Treatment (including nutrients) (Nutrients)
5. O/W Separator Required: YES Nutrient Control Required: NO Streambank Erosion Control: NO	Source Control → O/W Separator → Runoff Treatment (Conventional)
6. O/W Separator Required: YES Nutrient Control Required: NO Streambank Erosion Control: YES	Source Control → O/W Separator → Runoff Treatment → SBEC (Conventional)
7. O/W Separator Required: YES Nutrient Control Required: YES Streambank Erosion Control: YES	Source Control → O/W Separator → Runoff Treatment → SBEC (including nutrients) (Nutrients)
8. O/W Separator Required: YES Nutrient Control Required: YES Streambank Erosion Control: NO	Source Control → O/W Separator → Runoff Treatment (including nutrients) (Nutrients)

Explanation:

SBEC = "Streambank Erosion Control"

O/W separator requirement is based on specified land uses. See Step 1A.

Runoff treatment requirement is to provide treatment of the 6-month, 24-hour design storm. Requirement for nutrient control is determined by local government of Plan Approval Authority. See Step 1B.

Streambank erosion control requirement determined by local government of Plan Approval Authority. See Step 1C.

Nutrient treatment is *in addition* to treatment of conventional pollutants. See Step 1B.

*STEP 1B: Determine if Nutrient Control is Required in Addition to Treatment of Conventional Pollutants*

The requirement to provide nutrient control is determined by the Plan Approval Authority. In general, nutrient control will be needed for surface waters if eutrophication is a concern, or for drinking water supplies (surface or ground) if the threat of nitrate contamination exist. The decision to require nutrient control should be based on an assessment of receiving water bodies within the local government's jurisdiction. Should nutrient control be mandated then both Source Control and Runoff Treatment BMPs shall be required. Sources of information used to make this determination should include, at a minimum, the following:

- (i) Those waterbodies reported under section 305(b) of the Clean Water Act, and designated as not supporting beneficial uses;
- (ii) Those listed under section 304(1)(1)(A)(i), 304(1)(1)(A)(ii), or 304(1)(1)(B) of the Clean Water Act;
- (iii) Those listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act.
- (iv) Sites where the need for additional stormwater control measures has been identified through a basin plan, the watershed ranking process under Ch. 400-12 WAC, or through Growth Management Act planning.

*STEP 1C: Determine if Streambank Erosion Control is Required*

There are two decisions that must be made in this step. First, is attenuation of peak flows required per Minimum Requirement #5? Second, is there an existing streambank erosion problem that requires corrective action?

For attenuating runoff flows, streambank erosion control will be required when stormwater discharges are made either directly or indirectly through a conveyance system into a stream. The streambank erosion control requirement is established by the Plan Approval Authority. Situations where streambank erosion control may not be required are when there is a direct discharge to a bay, lake, or Puget Sound. A discharge to a regional detention pond could also waive this requirement, but only if the pond is designed to provide a level of protection to downstream segments equivalent to Ecology's streambank erosion control requirement.

In cases where a streambank erosion problem already exists, streamside stabilization measures may be required. The selection and design of these BMPs will be made on a case-by-case basis. Where basin plans (see Minimum Requirement #9) have been implemented there may be different or additional streambank erosion control standards.

*STEP 1D: Determine Stormwater Control Scenario from Table I-4.2*

There are eight (8) possible outcomes, or stormwater control scenarios, from the determinations made in Steps 1A, 1B, and 1C. Table I-4.2 summarizes each scenario and defines the classification and sequence of BMPs that are to be used for each.

**I-4.3.2 STEP 2: SELECT SOURCE CONTROL BMPs**

Two different source control selections must be made in this step. First, select BMPs based on the type of land use proposed for development. Land use-specific source control BMPs are required for all developments. Second, select source control BMPs to provide control of nutrients, if necessary, as determined in Step 1B.

*STEP 2A: Select Source Control BMPs based on Land Use Type*

The first task for the user is to fill out a checklist that identifies the key activities that may result in stormwater contamination (see Table I-4.3). If the user is a private business, then examine the table of contents of Chapter IV-2 to locate the particular grouping in which that business falls. If the user is a public entity, then examine Chapter IV-3. After locating the particular grouping in which that business or public entity falls, turn to the page indicated to identify the appropriate source control BMPs (Table I-4.1 lists source control BMPs).

Table I-4.3 Activities Checklist

CHECK ACTIVITIES THAT ARE OCCURRING OR WILL BE OCCURRING  
(see Chapter IV-2 for the appropriate land use, and Chapter IV-5  
for relevant BMPs)

Uncovered vehicle parking \_\_\_\_\_

Indicate number of parking spaces \_\_\_\_\_

Washing of vehicles or equipment \_\_\_\_\_

Vehicle or equipment fueling \_\_\_\_\_

Loading or unloading of liquid materials \_\_\_\_\_

Storage of raw materials, byproducts or products  
of manufacturing processes \_\_\_\_\_

Above-ground bulk storage of fuel, petroleum  
or chemicals \_\_\_\_\_

Use of underground tanks \_\_\_\_\_

Use of pesticides or fertilizers \_\_\_\_\_

Livestock husbandry \_\_\_\_\_

Temporary storage of liquid or solid wastes \_\_\_\_\_

Indicate type of waste: \_\_\_\_\_

Dangerous/Extremely Hazardous waste \_\_\_\_\_

Food wastes \_\_\_\_\_

Used oil \_\_\_\_\_

Other (briefly describe) \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Do you have or will you be obtaining a permit from the Department of  
Ecology to store Dangerous or Extremely Hazardous wastes?

\_\_\_\_\_

Do you intend to connect inside drains to the public sanitary sewer? Will  
you be discharging process water directly to a surface water?

\_\_\_\_\_

DESCRIBE ANY OTHER OUTSIDE ACTIVITIES NOT COVERED ABOVE \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Effective maintenance programs must be considered an integral part of a source control program. See, in particular, Chapters IV-3 and IV-4 for guidance on conducting maintenance.

*STEP 2B: Select Source Control BMPs for Nutrient Control, if required, as determined from Step 1B*

Sources of nutrients in urban runoff include fertilizers used for landscaping, grass clippings, leaf litter, car washing operations, and pet wastes. These sources should be managed to prevent contact with and transport by stormwater. Impervious areas adjacent to landscaped areas can be significant sources of nutrients when leaves and grass clippings are deposited on them. In addition, atmospheric deposition of nutrients onto impervious surfaces can generate significant amounts of pollution.

The following can be considered to be appropriate source control BMPs for nutrient control (see Chapter IV-4 for detailed guidance):

- BMP S1.90, Vegetation Management/Integrated Pest Management
- BMP S2.00, Maintenance of Storm Drainage Facilities
- BMP S2.20, Street Sweeping of impervious areas (e.g., curbs where accumulation of leaf litter occurs).

Additional maintenance guidance provided in Chapter IV-3 should also be considered and incorporated in this step.

*STEP 2C: Prepare Final Source Control BMP List*

Final selection of source control BMPs is made after consulting the detailed standards and specifications in relation to site specific conditions. For this the user is referred to Volume IV. A detailed description of each BMP will be found there that will enable final selections to be made.

#### **I-4.3.3 STEP 3: SELECT RUNOFF TREATMENT AND STREAMBANK EROSION CONTROL BMPS**

The goal of this step is to select BMPs that meet the runoff treatment and streambank erosion control requirements identified in Step 1D.

To avoid confusion, the selection of oil/water separators is made prior to selection of other BMPs. Note that a distinction is made between runoff treatment and streambank erosion control BMPs. It is important to understand the fundamental difference between these two functions when selecting BMPs. Some BMPs can combine both of these functions into the same facility. See the discussion in Section I-4.2.

*STEP 3A: Select Type of Oil/Water Separator, if required, as determined from Step 1A.*

Spill control (SC-type) separators will often be required in cases where storage of petroleum-based products occurs. API or CPS-type oil/water separators may be required where high traffic volumes or extensive use of petroleum-based products occur. A knowledge of the oil and grease characteristics (e.g., particle size, specific gravity) will be useful for selecting the correct type of separator. Consult Chapter III-7 for detailed design criteria. Sand filtration BMPs may also be used for treating oil in stormwater runoff on an interim basis (see Chapter III-3).



**STEP 3B: Determine Initial Order of Preference of Runoff Treatment BMPs from Table I-4.4**

Use Table I-4.4 to determine the initial order of preference for runoff treatment BMPs. The rationale for the initial order of preference is based primarily on the relative effectiveness of the various BMPs at removing pollutants. Note that a wider range of options exist if nutrient control is not required. Infiltration is the preferred practice for treatment, provided that proper soil conditions exist and ground water is adequately protected.

**Table I-4.4 Initial Order of Preference of Runoff Treatment BMPs\***

Rank	Nutrient Control Required	Nutrient Control Not Required
1	Infiltration (BMP RI.05, 10, 20, 30)	Infiltration (BMP RI.05, 10, 20, 30)
2	Constructed Wetland (BMP RD.09) or Wet Pond with marsh (BMP RD.06)	Constructed Wetland (BMP RD.09) or Wet Pond - with marsh (BMP RD.06) or Wet Pond - without marsh (BMP RD.05) or Biofiltration Swale (BMP RB.05) or Vegetative Filter Strip (BMP RB.10) or Sand Filtration (BMP RF.05 or RF.10)
3	(No other BMPs recommended)	Wet Vault/Tank (BMP RD.15)

\* Pretreatment BMPs are not included in this list.

Note: BMPs with the same rank number have an equal level of preference, e.g., if nutrient control is not required then any of the six types of BMPs listed are equally acceptable.

**STEP 3C: Determine Initial Order of Preference of Streambank Erosion Control BMPs**

Use Table I-4.5 to determine the initial order of preference for streambank erosion control BMPs. Two types of streambank erosion control BMPs are illustrated, i.e., those that detain and attenuate flows and those that are used to stabilize eroding streambanks. The rationale for the initial order of preference is, in both cases, to replicate the natural condition to the maximum extent practical. Recall the restrictions on the use of infiltration, i.e., proper soil conditions must exist and ground water quality must be protected.

**Table I-4.5 Initial Order of Preference of Streambank Erosion Control BMPs**

Rank	Flow Attenuation	Streamside Stabilization
1	Infiltration (see Table I-4.1)	Vegetative Streambank Stabilization (BMP RS.05) or Bioengineering Method (BMP RS.10)
2	Detention (see Table I-4.1)	Structural Stabilization (BMP RS.15)

*STEP 3D: Screen BMPs based on Comparative Stormwater Benefits and Restrictions*

Use Table I-4.6 to evaluate the comparative benefits and restrictions that may apply to the types of BMPs selected in steps 3B and 3C (initial order of preference). This table provides important information such as whether a BMP can achieve control of nutrients as well as conventional pollutants, whether a BMP requires or provides pretreatment, and if streambank erosion control can be provided. Some BMPs can achieve multiple purposes while others cannot.

Note in Table I-4.6 that similarly named *infiltration* BMPs may serve different purposes. Ones that are labeled "WQ" (acronym for "Water Quality") are primarily intended to provide **treatment** of runoff and may not be appropriate for fully infiltrating the large volumes of runoff required for streambank erosion control. Water Quality (WQ) BMPs will typically have soils of relatively low permeability that contain organic matter; examples are silty and sandy loams. It is extremely important that they be protected from sedimentation that could clog the soil pore spaces; thus pretreatment is always required for Water Quality infiltration BMPs.

*Infiltration* BMPs that are labeled "SBEC" (an acronym for Sreambank Erosion Control) are not suitable for runoff treatment and are to be used exclusively for providing streambank erosion control. These BMPs will typically utilize well drained soils that are low in organic material and are less prone to clog; examples are coarse sands and gravelly sands. Treatment of stormwater runoff must always precede discharge to SBEC infiltration BMPs.

A detailed description with design criteria for each runoff treatment and streambank erosion control BMP is provided in Volume III.

*STEP 3E: Screen Runoff Treatment and Streambank Erosion Control BMPs based on Other Physical Factors*

Two of the most important physical factors to consider are the total contributing catchment area and the types of soils on the site. Many BMPs can only be applied within relatively narrow ranges of catchment area and soil type, as shown in Tables I-4.7 and I-4.8. Note that in some situations a BMP may or may not be feasible and final selection should be based on a detailed examination of the site conditions and the standards and specifications.

Table I-4.9 presents a matrix that shows whether a BMP is also subject to other physical restrictions. Solid squares indicate that a factor is generally not a restriction while an unshaded square indicates that a restriction which may prohibit the use of a BMP. A partially shaded square indicates that a factor could restrict the use of a BMP, but careful site planning and BMP design may overcome the restriction.

As a general rule pond BMPs face fewer restrictions than do infiltration BMPs.

The nature of each of the physical factors outlined in the screens is described below.

**BMP Drainage Area (Table I-4.7)**

Pond BMPs generally require more drainage area than other BMPs. Infiltration trenches, vaults/tanks, and biofilters are more suitable for smaller areas. Wet pond-type BMPs located on small sites may lose their "permanent pool" during summer months but should retain the permanent pool during the winter months when the majority of rainfall occurs. Measures should be taken to ensure that the "shallow marsh" BMPs (BMP RD.06 and BMP RD.09) do not lose their vegetation during dry periods. See Chapter III-3 for further guidance.

TAI I-4.6  
 COMPARATIVE STORMWATER MANAGEMENT BENEFITS AND RESTRICTIONS  
 FOR RUNOFF TREATMENT AND STREAMBANK EROSION CONTROL BMPs

BMP ID	BMP Name	Treats Conventional Pollutants?	Provides Nutrient Control?	Pre-treatment Required?	Provides Pre-treatment?	Provides SBEC?	Notes
RI.05	WQ Infiltration Basin	Yes	Yes	Yes	No	Option	Proper soil conditions required
RI.06	SBEC Infiltration Basin	No	No	No	No	Yes	Use of excessively drained soils
RI.10	WQ Infiltration Trench	Yes	Yes	Yes	No	Option	Proper soil conditions required
RI.11	SBEC Infiltration Trench	No	No	No	No	Yes	Use of excessively drained soils
RI.15	Roof Downspout System	Yes	N/A	No	No	Option	For rooftop runoff only
RI.20	WQ Porous Pavement	Yes	Yes	Yes	No	Option	Proper soil conditions required
RI.21	SBEC Porous Pavement	No	No	No	No	Yes	Use of excessively drained soils
RI.30	WQ Concrete Grid/Modular Pavement	Yes	Yes	Yes	No	Option	Proper soil conditions required
RI.31	SBEC Concrete Grid/Modular Pavement	No	No	No	No	Yes	Use of excessively drained soils
RF.05	Sand Filtration Basin	Yes	No	Yes	Yes <sup>1</sup>	No	Can be used to treat oil
RF.10	Sand Filtration Trench	Yes	No	Yes	Yes <sup>1</sup>	No	Can be used to treat oil
RF.15E	Aquatard System	Yes	?	?	?	?	Experimental
RD.05	Wet Pond (Conventional Pollutants)	Yes	No	No <sup>2</sup>	No	Option	
RD.06	Wet Pond (Nutrient Control)	Yes	Yes	No	No	Option	
RD.09	Constructed Wetland	Yes	Yes	No <sup>2</sup>	No	Option	
RD.10	Presettling Basin	Limited <sup>3</sup>	No	No	Yes	No	
RD.11	Extended Detention Dry Pond	Limited <sup>3</sup>	No	No	Yes	Yes	
RD.15	Wet Vault/Tank	Yes	No	No	Limited <sup>4</sup>	Option	
RD.20	Extended Detention Dry Vault/Tank	No	No	No	No	Yes	
RB.05	Biofiltration Swale	Yes	No	No <sup>2</sup>	Yes	No	
RB.10	Vegetative Filter Strip	Yes	No	No <sup>2</sup>	Yes	No	
RO.05	Spill Control (SC) Oil/Water Separator	No <sup>5</sup>	No	No <sup>6</sup>	No	No	
RO.10	API Oil/Water Separator	No <sup>5</sup>	No	No <sup>6</sup>	No	No	
RO.15	Coalescing Plate Separator (CPS)	No <sup>5</sup>	No	No <sup>6</sup>	No	No	
RS.05	Vegetative Streambank Stabilization	No	No	No	No	Yes	
RS.10	Bioengineering Methods of Streambank Stabilization	No	No	No	No	Yes	
RS.15	Structural Streambank Stabilization	No	No	No	No	Yes	

WQ = "Water Quality" SBEC = "Streambank Erosion Control"

- 1 Can be used for pretreatment of oil to protect wet pond-type BMPs from siltation
- 2 Exception is when oil/water separators are required for specific land uses (see Volume IV)
- 3 Provides *pretreatment* only
- 4 Not an acceptable pretreatment BMP for water quality infiltration BMPs
- 5 Provides *oil treatment* only
- 6 Assumes low influent concentration of suspended solids.

It should be noted that the drainage area served does not have to be fixed. By creatively using local topography and drainage the catchment area can be varied. For example the drainage of a site could be divided to facilitate use of infiltration trenches. However, this technique may not be used to justify use of a vault or tank.

#### Soil Type (Table I-4.8)

The permeability of the soil underlying a BMP has a profound influence on its effectiveness. This is particularly true for infiltration BMPs, that are best suited in silty to loamy soils for runoff treatment and coarser soils for streambank erosion control. They cannot be used on sites that have final infiltration rates (f) of less than 0.5 inches per hour. Wet pond-type BMPs will need to be lined when located over permeable soils in order to maintain a permanent pool. Likewise, biofiltration-type BMPs may need to be lined so that runoff is not lost to infiltration before adequate treatment has taken place.

#### Other Physical Factors (Table I-4.9)

##### Slope

Steep slopes restrict the use of several BMPs. For example, biofiltration swales must be situated on sites with slopes of less than 5%. Infiltration BMPs are not suitable when the slope exceeds 15%.

##### High Water Table

The water table acts as an effective barrier to exfiltration and can sharply reduce the efficiency of an infiltration system. If the high water table extends to within three (3) feet of the bottom of an infiltration BMP, the site is seldom suitable.

##### Depth to Bedrock/Hardpan/Till

The downward exfiltration of stormwater is also impeded if a bedrock or till layer lies too close to the surface. If the impervious layer lies within two (2) feet below the bottom of the infiltration BMP the site is not suitable. Similarly, pond BMPs are often not feasible if bedrock lies within the area that must be excavated.

##### Proximity to Foundations and Wells

Since infiltration BMPs divert runoff back into the soil, some sites may experience problems with local seepage. This can be a real problem if the BMP is located too close to a building foundation. Another risk is ground water pollution, hence the requirement to site infiltration systems more than 100 feet away from drinking water wells.

##### Maximum Depth

Wet ponds are also subject to a maximum depth limit for the "permanent pool" volume. Deep ponds (greater than 6 feet) may stratify during summer and create low oxygen conditions near the bottom resulting in re-release of phosphorus and other pollutants back into the water.

##### High Sediment Input

Many BMPs are unable to handle the large loads of sediment that may occur during construction. Infiltration BMPs are particularly susceptible to rapid clogging and subsequent failure if significant sediment loads are allowed to enter the structure. Therefore infiltration BMPs must not be installed until all the land in the contributing drainage area is properly stabilized. Although sediment loads drop

sharply after construction is completed, gradual clogging of infiltration systems can still occur. Thus infiltration ponds and trenches require a pretreatment device to filter out sediment and other coarse material before they reach the facility (see Chapter III-3).

Pond BMPs can be used for sediment control during the construction phase with proper conversion, clean out and regrading. Even after construction sediment deposits will build up, and must be removed periodically. The cost and scope of sediment removal can be reduced by sediment forebays.

*STEP 3F: Prepare Modified BMP List*

The initial BMP selection may have to be modified after completing Steps 3A through 3E. Verify that the proposed BMPs will still meet the source control, runoff treatment, and streambank erosion control requirements established in Step 1. Modify the list as necessary.

*STEP 3G: Prepare Final BMPs*

Final selection of runoff control BMPs is made after consulting the detailed standards and specifications in relation to site specific conditions. For this the user is referred to Volume III. A detailed description of each BMP will be found here that will enable final selections to be made.

**I-4.3.4 STEP 4: COMPLETE STORMWATER SITE PLAN**

The purpose of this step is to complete development of the Stormwater Site Plan so that it can be submitted to the local government or Plan Approval Authority for approval. The user must first complete development of the Permanent Stormwater Quality Control Plan, including design and construction drawings.

*STEP 4A: Complete development of the Permanent Stormwater Quality Control Plan*

Compile the final list of source control, runoff treatment, and streambank erosion control BMPs and proceed to design them using the detailed guidance in Volumes III and IV.11 To complete the Permanent Stormwater Quality Plan both a report and a set of construction drawings must be completed. Refer to Chapter I-3 and the "Stormwater Program Guidance Manual for the Puget Sound Basin" for guidance on completing this plan (*Note: This guidance has not been completed at publication time. It is scheduled to be completed in 1992*).

*STEP 4B: Review other Stormwater Site Plan requirements*

The Permanent Stormwater Quality Control Plan is but one of several documents that are required for the Stormwater Site Plan. Review Chapter I-3 and the "Stormwater Program Guidance Manual for the Puget Sound Basin" for further details.

*STEP 4C: Finalize Stormwater Site Plan*

Incorporate all other documents and site plans required for the completion of the Stormwater Site Plan.

**I-4.3.5 STEP 5: SUBMIT FINAL STORMWATER SITE PLAN TO PLAN APPROVAL AUTHORITY**

The Plan Approval Authority may be the local government. Check with your local government to determine who within that government is the Plan Approval Authority.

I-4.4 REFERENCES

1. Schueler, Thomas R., Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Washington Council of Governments, July, 1987.
2. Resource Planning Associates, Water Quality Best Management Manual for Commercial and Industrial Land Uses, Prepared for the City of Seattle, 1989.

Table I-4.7  
Screening BMPs Based on Drainage Area

BMP Type	Recommended Drainage Area (acres)
Infiltration Basin	0 - 50
Infiltration Trench	0 - 50
Roof Downspout System	0.11 (5000 sq.ft.)
Porous Pavement	0 - 15
Concrete Grid/Modular Pavement	0 - 15
Sand Filtration Basin	0 - 50
Sand Filtration Trench	0 - 50
Wet Pond (Conventional Pollutants)	0 - 100*
Constructed Wetland/Wet Pond (Nutrient Control)	5 - 100*
Presettling Basin	0 - 100
Extended Detention Dry Pond	0 - 100
Vault/Tank (Wet or Dry)	0 - 5
Biofiltration Swale	0 - 10
Vegetative Filter Strip	0 - 10
Oil/Water Separator	0 - 5

\* These BMPs maintain a permanent pool that, ideally, should not go dry. To maintain a permanent pool will typically require a minimum drainage area. This is especially important for constructed wetlands and wet ponds that utilize a shallow marsh system (i.e., wet pond for nutrient control). Wet ponds that do not utilize a shallow marsh system may be allowed to periodically go dry but only during the summer dry season. In some cases a smaller drainage area than that shown above may be acceptable. See the criteria for individual BMPs in Chapter III-4.

Table I-4.8 Screening BMPs Based on Soil Type

Soil Type	WQ Infiltration	SBEC Infiltration	Wet Pond*	Dry Pond*	Biofiltration* (Swale or Filter Strip)
Coarse Sands or Cobbles		■			
Sand		■			
Loamy Sand	■	■			■
Sandy Loam	■				■
Loam	■				■
Silt Loam					■
Sandy Clay Loam					■
Clay Loam			■	■	■
Silty Clay Loam			■	■	■
Sandy Clay			■	■	■
Silty Clay			■	■	
Clay			■	■	

■ Indicates that use of BMP is appropriate for this soil type

\* Coarser soils may be used for these BMPs if a liner is installed to prevent infiltration.

WQ = "Water Quality" BMP (primarily designed for *runoff treatment*)

SBEC = "Streambank Erosion Control" (*runoff treatment* is not provided)

Note: Sand filtration BMPs are not listed in this table as their feasibility is not dependent on soil type.



Table I-4.9  
 Screening BMPs Based on Other Physical Factors

BMP Type	Slope	High Water Table	Depth to Bedrock	Proximity to Foundations	Maximum Depth	High Sediment Input
Infiltration Basin	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Infiltration Trench	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Roof Downspout System	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Porous Pavement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Concrete Grid/Modular Pavement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Sand Filtration Basin	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Sand Filtration Trench	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wet Pond/Constructed Wetland	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Presettling Basin	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Extended Detention Dry Pond	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Vault/Tank (Wet or Dry)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Biofiltration Swale	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Vegetative Filter Strip	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Oil/Water Separator	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

- Generally not a restriction
- Can be overcome with careful site design
- May preclude the use of a BMP

GLOSSARY AND NOTATION

Note: The following terms are provided for reference and use with this manual. They shall be superseded by any other definitions for these terms adopted by ordinance unless they are defined in a Washington State WAC or RCW or are used and defined as part of the Minimum Requirements for all new development and redevelopment.

AASHTO classification - The official classification of soil materials and soil aggregate mixtures for highway construction, used by the American Association of State Highway and Transportation Officials.

Absorption - The penetration of a substance into or through another, such as the dissolving of a soluble gas in a liquid.

Adjacent steep slope - A slope with a gradient of 15 percent or steeper within five hundred feet of the site.

Adsorption - The adhesion of a substance to the surface of a solid or liquid; often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to extract oil from waterways when oil spills occur. Heavy metals such as zinc and lead often adsorb onto sediment particles.

Aeration - The process of being supplied or impregnated with air. In waste treatment, the process used to foster biological and chemical purification. In soils, the process by which air in the soil is replenished by air from the atmosphere. In a well aerated soil, the soil air is similar in composition to the atmosphere above the soil. Poorly aerated soils usually contain a much higher percentage of carbon dioxide and a correspondingly lower percentage of oxygen.

Aerobic - Living or active only in the presence of free (dissolved or molecular) oxygen.

Aerobic bacteria - Bacteria that require the presence of free oxygen for their metabolic processes.

Aggressive plant species - Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to native species in this manual.

Algae - Primitive plants, many microscopic, containing chlorophyll and forming the base of the food chain in aquatic environments. Some species may create a nuisance when environmental conditions are suitable for prolific growth.

Algal bloom - Proliferation of living algae on the surface of lakes, streams or ponds; often stimulated by phosphate over-enrichment. Algal blooms reduce the oxygen available to other aquatic organisms.

American Public Works Association or APWA - the adopted edition of the Washington State Chapter of the American Public Works Association.

Anadromous - Fishes ascending rivers from the sea for breeding.

Anaerobic - Living or active in the absence of oxygen.

Anaerobic bacteria - Bacteria that do not require the presence of free or dissolved oxygen for metabolism.

Annual flood - The highest peak discharge on average which can be expected in any given year.

Antecedent moisture conditions - The degree of wetness of a watershed or within the soil at the beginning of a storm.

Anti-seep collar - A device constructed around a pipe or other conduit and placed through a dam, levee, or dike for the purpose of reducing seepage losses and piping failures.

Anti-vortex device - A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.

Applicant - The person who has applied for a development permit or approval.

Approved manual - means a stormwater management manual approved by Ecology.

Appurtenances - Machinery, appliances, or auxiliary structures attached to a main structure, but not considered an integral part thereof, for the purpose of enabling it to function.

Aquifer - A geologic stratum containing ground water that can be withdrawn and used for human purposes.

As-built drawings - Engineering plans which have been revised to reflect all changes to the plans which occurred during construction.

As-graded - the extent of surface conditions on completion of grading.

BSBL - See Building set back line.

Background - A description of pollutant levels arising from natural sources, and not because of man's immediate activities.

Backwater - Water upstream from an obstruction which is deeper than it would normally be without the obstruction.

Bankfull discharge - A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge conditions occurs on average every 1.5 to 2 years and controls the shape and form of natural channels.

Base flood - A flood having a one percent chance of being equaled or exceeded in any given year. This is also referred to as the 100-year flood.

Base flood elevation - The water surface elevation of the base flood. It shall be referenced to the National Geodetic Vertical Datum of 1929 (NGVD).

Baseline sample - A sample collected during dry-weather flow (i.e., it does not consist of runoff from a specific precipitation event).

Basin plan - A plan and all implementing regulations and procedures including but not limited to land use management adopted by ordinance for managing surface and storm water quality and quantity management facilities and features within individual subbasins.

Bearing capacity - The maximum load that a material can support before failing.

Bedrock - The more or less solid rock in place either on or beneath the surface of the earth. It may be soft, medium, or hard and have a smooth or irregular surface.

Bench - a relatively level step excavated into earth material on which fill is to be placed.

Berm - A constructed barrier of compacted earth, rock or gravel.

Best management practice (BMP) - Physical, structural, and/or managerial practices that, when used singly or in combination, prevent or reduce pollution of water, and have been approved by Ecology.

Biochemical oxygen demand (BOD) - An indirect measure of the concentration of biologically degradable materials present in organic wastes. The amount of free oxygen utilized by aerobic organisms when allowed to attack the organic material in an aerobically maintained environment at a specified temperature (20°C) for a specific time period (5 days), and thus stated as BOD<sub>5</sub>. It is expressed in milligrams of oxygen utilized per liter of liquid waste volume (mg/l) or in milligrams of oxygen per kilogram of waste solution (mg/kg = ppm = parts per million parts). Also called biological oxygen demand.

Biodegradable - Capable of being readily broken down by biological means, especially by bacterial action. Degradation can be rapid or may take many years depending upon such factors as available oxygen and moisture.

Bioengineering - Restoration or reinforcement of slopes and stream banks with living plant materials.

Biofilter - A designed, vegetated treatment facility where the more or less simultaneous processes of filtration, infiltration, adsorption and biological uptake of pollutants in stormwater takes place when runoff flows over and through. Vegetation growing in these facilities acts as both a physical filter which causes gravity settling of particulates by regulating velocity of flow, and also as a biological sink when direct uptake of dissolved pollutants occurs. The former mechanism is probably the most important in western Washington where the period of major runoff coincides with the period of lowest biological activity.

Biofiltration - The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials.

Biological control - A method of controlling pest organisms by means of introduced or naturally occurring predatory organisms, sterilization, the use of inhibiting hormones, or other means, rather than by mechanical or chemical means.

Biological magnification - The increasing concentration of a substance along succeeding steps in a food chain. Also called biomagnification.

Bollard - A post (may or may not be removable) used to prevent vehicular access.

Bond - A surety bond, cash deposit or escrow account, assignment of savings, irrevocable letter of credit or other means acceptable to or required by the manager to guarantee that work is completed in compliance with the project's drainage plan and in compliance with all local government requirements.

Borrow area - A source of earth fill material used in the construction of embankments or other earth fill structures.

Buffer - The zone contiguous with a sensitive area that is required for the continued maintenance, function, and structural stability of the sensitive area. The critical functions of a riparian buffer (those associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, overflow during high water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries

over time due to hydrologic or climatic effects. The critical functions of terrestrial buffers include protection of slope stability, attenuation of surface water flows from storm water runoff and precipitation, and erosion control.

Building setback line (BSBL) - A line measured parallel to a property, easement, drainage facility or buffer boundary, that delineates the area (defined by the distance of separation) where buildings, or other obstructions are prohibited (including decks, patios, outbuildings, or overhangs beyond 18 inches). Wooden or chain link fences and landscaping are allowable within a building setback line. In this manual the minimum building setback line shall be 5 feet.

CIP - See Capital Improvement Project.

Capital Improvement Project or Program (CIP) - A project prioritized and scheduled as a part of an overall construction program or, the actual construction program.

Catchbasin - A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Catchline - The point where a severe slope intercepts a different, more gentle slope.

Catchment - Surface drainage area.

Channel - A feature that conveys surface water and is open to the air.

Channel, constructed - Channels or ditches constructed (or reconstructed natural channels) to convey surface water.

Channel, natural - Streams, creeks, or swales that convey surface/ground water and have existed long enough to establish a stable route and/or biological community.

Channel stabilization - Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, and/or other measures.

Channel storage - Water temporarily stored in channels while enroute to an outlet.

Channelization - Alteration of a stream channel by widening, deepening, straightening, cleaning, or paving certain areas to change flow characteristics.

Check dam - Small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.

Chemical oxygen demand (COD) - A measure of the amount of oxygen required to oxidize organic and oxidizable inorganic compounds in water. The COD test, like the BOD test, is used to determine the degree of pollution in water.

Civil engineer - a professional engineer licensed in the State of Washington in Civil Engineering who is experienced and knowledgeable in the practice of soils engineering.

Civil engineering - the application of the knowledge of the forces of nature, principles of mechanics and the properties of materials to the evaluation, design and construction of civil works for the beneficial uses of mankind.

Clay lens - A naturally occurring, localized area of clay which acts as an impermeable layer to runoff infiltration.

Clearing - The destruction and removal of vegetation by manual, mechanical, or chemical methods.

Closed depression - An area which is lowlying and either has no, or such a limited, surface water outlet that during storm events the area acts as a retention basin.

Cohesion - The capacity of a soil to resist shearing stress, exclusive of functional resistance.

Coliform bacteria - Microorganisms common in the intestinal tracts of man and other warm-blooded animals; all the aerobic and facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. Used as an indicator of bacterial pollution.

Commercial agriculture - Those activities conducted on lands defined in RCW 84.34.020(2), and activities involved in the production of crops or livestock for wholesale trade. An activity ceases to be considered commercial agriculture when the area on which it is conducted is proposed for conversion to a nonagricultural use or has lain idle for more than five (5) years, unless the idle land is registered in a federal or state soils conservation program, or unless the activity is maintenance of irrigation ditches, laterals, canals, or drainage ditches related to an existing and ongoing agricultural activity.

Compaction - densification of a fill by mechanical means.

Compensatory storage - New excavated storage volume equivalent to the flood storage capacity eliminated by filling or grading within the flood fringe. Equivalent shall mean that the storage removed shall be replaced by equal volume between corresponding one foot contour intervals that are hydraulically connected to the floodway through their entire depth.

Compost - Organic residue or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus.

Composting - A controlled process of degrading organic matter by microorganisms. Present day composting is the aerobic, thermophilic decomposing of organic waste to relatively stable humus. Humus with no more than 25 percent dead or living organisms is stable enough not to reheat or cause odor or fly problems. It can undergo further, slower decay.

Comprehensive planning - Planning that takes into account all aspects of water, air, and land resources and their uses and limits.

Conservation district - A public organization created under state enabling law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries, usually a subdivision of state government with a local governing body and always with limited authority. Often called a soil conservation district or a soil and water conservation district.

Constructed wetland - those wetlands intentionally created on sites that are not wetlands for the primary purpose of wastewater or stormwater treatment and managed as such. Constructed wetlands are normally considered as part of the stormwater collection and treatment system.

Contour - An imaginary line on the surface of the earth connecting points of the same elevation.

Conveyance - A mechanism for transporting water from one point to another, including pipes, ditches, and channels.

Conveyance system - The drainage facilities, both natural and man-made, which collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.

Cover crop - A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

Created wetland - means those wetlands intentionally created from nonwetland sites to produce or replace natural wetland habitat (e.g., compensatory mitigation projects).

Critical Areas - at a minimum, areas which include wetlands, areas with a critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, geologically hazardous areas, including unstable slopes, and associated areas and ecosystems.

Critical depth - The depth which minimizes the specific energy of flow (E).

Critical Drainage Area - An area with such severe flooding, drainage and/or erosion/sedimentation conditions that the area has been formally adopted as a Critical Drainage Area by rule under the procedures specified in an ordinance.

Critical flow - Flow at the critical depth and velocity.

Critical reach - The point in a receiving stream below a discharge point at which the lowest dissolved oxygen level is reached and stream recovery begins.

Culvert - Pipe or concrete box structure which drains open channels, swales or ditches under a roadway or embankment. Typically with no catchbasins or manholes along its length.

Cut - Portion of land surface or area from which earth has been removed or will be removed by excavating; the depth below original ground surface to excavated surface. Cut-and-fill - Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

DNS - See Determination of nonsignificance.

Dead storage - The volume available in a depression in the ground below any conveyance system, or surface drainage pathway, or outlet invert elevation that could allow the discharge of surface and stormwater runoff.

Dedication of land - Refers to setting aside a portion of a property for a specific use or function.

Degradation - (Biological or chemical) The breakdown of complex organic or other chemical compounds into simpler substances, usually less harmful than the original compound, as with the degradation of a persistent pesticide. (Geological) Wearing down by erosion. (Water) The lowering of the water quality of a watercourse by an increase in the pollutant loading.

Degraded (disturbed) wetland (community) - A wetland (community) in which the vegetation, soils, and/or hydrology have been adversely altered, resulting in lost or reduced functions and values; generally, implies topographic isolation; hydrologic alterations such as hydroperiod alteration (increased or decreased quantity of water), diking, channelization, and/or outlet modification; soils alterations such as presence of fill, soil removal, and/or compaction; accumulation

of toxicants in the biotic or abiotic components of the wetland; and/or low plant species richness with dominance by invasive weedy species.

Denitrification - The biochemical reduction of nitrates or nitrites in the soil or organic deposits to ammonia or free nitrogen.

Depression storage - The amount of precipitation that is trapped in depressions on the surface of the ground.

Design engineer - The professional civil engineer licensed in the State of Washington who prepares the analysis, design, and engineering plans for an applicant's permit or approval submittal.

Design storm - A prescribed hyetograph and total precipitation amount (for a specific duration recurrence frequency) used to estimate runoff for a hypothetical storm of interest or concern for the purposes of analyzing existing drainage, designing new drainage facilities or assessing other impacts of a proposed project on the flow of surface water. (A hyetograph is a graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.)

Detention - the release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, the difference being held in temporary storage.

Detention facility - an above or below ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater.

Detention time - The theoretical time required to displace the contents of a stormwater treatment facility at a given rate of discharge (volume divided by rate of discharge).

Determination of Nonsignificance (DNS) - The written decision by the responsible official of the lead agency that a proposal is not likely to have a significant adverse environmental impact, and therefore an EIS is not required.

Development - For the purposes of this document any activity that requires a permit or approval, including but not limited to a building permit, grading permit, shoreline substantial development permit, conditional use permit, unclassified use permit, zoning variance or reclassification, planned unit development, subdivision, short subdivision, master plan development, building site plan, or right-of-way use permit. See also the definitions for new development, redevelopment and land disturbing activities.

Discharge - Outflow; the flow of a stream, canal, or aquifer. One may also speak of the discharge of a canal or stream into a lake, river, or ocean. (Hydraulics) Rate of flow, specifically fluid flow; a volume of fluid passing a point per unit of time, commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day.

Dispersed discharge - Release of surface and stormwater runoff from a drainage facility system such that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

Ditch - A long narrow excavation dug in the earth for drainage with its top width less than 10 feet at design flow.

Divide, Drainage - The boundary between one drainage basin and another.



Drain - A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or ground water.

(To) Drain - To provide channels, such as open ditches or closed drains, so that excess water can be removed by surface flow or by internal flow. To lose water (from the soil) by percolation.

Drainage - Refers to the collection, conveyance, containment, and/or discharge of surface and storm water runoff.

Drainage basin - A geographic and hydrologic subunit of a watershed.

Drainage channel - A drainage pathway with a well-defined bed and banks indicating frequent conveyance of surface and stormwater runoff.

Drainage course - A pathway for watershed drainage characterized by wet soil vegetation; often intermittent in flow.

Drainage easement - A legal encumbrance that is placed against a property's title to reserve specified privileges for the users and beneficiaries of the drainage facilities contained within the boundaries of the easement.

Drainage pathway - The route that surface and stormwater runoff, leaving any part of the site, follows downslope.

Drainage review - An evaluation by Plan Approving Authority staff of a proposed project's compliance with the drainage requirements in this manual or its technical equivalent.

Drainage, Soil - As a natural condition of the soil, soil drainage refers to the frequency and duration of periods when the soil is free of saturation; for example, in well-drained soils the water is removed readily but not rapidly; in poorly drained soils the root zone is waterlogged for long periods unless artificially drained, and the roots of ordinary crop plants cannot get enough oxygen; in excessively drained soils the water is removed so completely that most crop plants suffer from lack of water. Strictly speaking, excessively drained soils are a result of excessive runoff due to steep slopes or low available water-holding capacity due to small amounts of silt and clay in the soil material. The following classes are used to express soil drainage:

Well drained - Excess water drains away rapidly and no mottling occurs within 36 inches of the surface.

Moderately well drained - Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness. Mottling occurs between 18 and 36 inches.

Somewhat poorly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Mottling occurs between 8 and 18 inches.

Poorly drained - Water is removed so slowly that the soil is wet for a large part of the time. Mottling occurs between 0 and 8 inches.

Very poorly drained - Water is removed so slowly that the water table remains at or near the surface for the greater part of the time. There may also be periods of surface ponding. The soil has a black to gray surface layer with mottles up to the surface.

Drawdown - Lowering of the water surface (in open channel flow), water table or piezometric surface (in ground water flow) resulting from a withdrawal of water.

Drop-inlet spillway - Overall structure in which the water drops through a vertical riser connected to a discharge conduit.

Drop spillway - Overall structure in which the water drops over a vertical wall onto an apron at a lower elevation.

Drop structure - A structure for dropping water to a lower level and dissipating its surplus energy; a fall. A drop may be vertical or inclined.

Dry weather flow - The combination of sanitary sewage, and industrial and commercial wastes normally found in sanitary or storm sewers during the dry weather season of the year. Also that flow in streams during the dry season.

EIS - See Environmental Impact Statement.

ESC - Erosion and Sediment Control (Plan).

Earth material - any rock, natural soil or fill and/or any combination thereof.

Easement - The legal right to use a parcel of land for a particular purpose. It does not include fee ownership, but may restrict the owners use of the land.

Embankment - A structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.

Emergent plants - Aquatic plants that are rooted in the sediment but whose leaves are at or above the water surface. These wetland plants often have high habitat value for wildlife and waterfowl, and can aid in pollutant uptake.

Emergency spillway - A vegetated earth channel used to safely convey flood discharges in excess of the capacity of the principal spillway.

Energy dissipator - Any means by which the total energy of flowing water is reduced. In stormwater design, they are usually mechanisms that reduce velocity prior to, or at, discharge from an outfall in order to prevent erosion. They include rock splash pads, drop manholes, concrete stilling basins or baffles, and check dams.

Energy gradient - The slope of the specific energy line (i.e., the sum of the potential and velocity heads.)

Engineering geologist - a geologist experienced and knowledgeable in engineering geology.

Engineering geology - the application of geologic knowledge and principles in the investigation and evaluation of naturally occurring rock and soil for use in the design of civil works.

Engineering plan - A plan prepared and stamped by a professional civil engineer. An engineering plan contains a Technical Information Report and Site Improvement Plans which are described in detail in Chapter I-3.

Enhancement - To raise value, desirability, or attractiveness of an environment associated with surface water.

Environmental Impact Statement (EIS) - A document that discusses the likely significant adverse impacts of a proposal, ways to lessen the impacts, and alternatives to the proposal. They are required by the national and state environmental policy acts when projects are determined to have significant environmental impact.

**Erodible granular soils** - Soil materials that are easily eroded and transported by running water, typically fine or medium grained sand with minor gravel, silt, or clay content. Such soils are commonly described as Everett or Indianola series soil types in the SCS classification. Also included are any soils showing examples of existing severe stream channel incision as indicated by unvegetated streambanks standing over two feet high above the base of the channel.

**Erosion** - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Also, detachment and movement of soil or rock fragments by water, wind, ice, or gravity. The following terms are used to describe different types of water erosion:

**Accelerated erosion** - Erosion much more rapid than normal or geologic erosion, primarily as a result of the influence of the activities of man or, in some cases, of the animals or natural catastrophes that expose bare surfaces (e.g., fires).

**Geological erosion** - The normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc. Synonymous with natural erosion.

**Gully erosion** - The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, ranging from 1 to 2 feet to as much as 75 to 100 feet.

**Natural erosion** - Wearing away of the earth's surface by water, ice, or other natural agents under natural environmental conditions of climate, vegetation, etc., undisturbed by man. Synonymous with geological erosion.

**Normal erosion** - The gradual erosion of land used by man which does not greatly exceed natural erosion. See Natural erosion.

**Rill erosion** - An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils. See Rill.

**Sheet erosion** - The removal of a fairly uniform layer of soil from the land surface by runoff.

**Splash erosion** - The spattering of small soil particles caused by the impact of raindrops on wet soils. The loosened and spattered particles may or may not be subsequently removed by surface runoff.

**Erosion classes (soil survey)** - A grouping of erosion conditions based on the degree of erosion or on characteristic patterns. Applied to accelerated erosion, not to normal, natural, or geological erosion. Four erosion classes are recognized for water erosion and three for wind erosion.

**Erosion/sedimentation control** - Any temporary or permanent measures taken to reduce erosion; control siltation and sedimentation; and ensure that sediment-laden water does not leave the site.

**Erosion and sediment control facility** - A type of drainage facility designed to hold water for a period of time to allow sediment contained in the surface and stormwater runoff directed to the facility to settle out so as to improve the quality of the runoff.

**Escarpment** - A steep face or a ridge of high land.

Estuarine wetland - Generally, an eelgrass bed; salt marsh; or rocky, sandflat, or mudflat intertidal area where fresh and salt water mix. (Specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually semi-enclosed by land but with partially obstructed or sporadic access to the open ocean).

Estuary - An area where fresh water meets salt water, or where the tide meets the river current (e.g., bays, mouths of rivers, salt marshes and lagoons). Estuaries serve as nurseries and spawning and feeding grounds for large groups of marine life and provide shelter and food for birds and wildlife.

Eutrophication - Refers to the process where nutrient over-enrichment of water leads to excessive growth of aquatic plants, especially algae.

Evapotranspiration - The collective term for the processes of evaporation and plant transpiration by which water is returned to the atmosphere.

Excavation - the mechanical removal of earth material.

Exfiltration - The downward movement of runoff through the bottom of an infiltration BMP into the soil layer or the downward movement of water through soil.

Existing site conditions means - (a) For developed sites with stormwater facilities that have been constructed to meet the standards in the Minimum Requirements of this manual, existing site conditions shall mean the existing conditions on the site.

(b) For developed sites that do not have stormwater facilities that meet the Minimum Requirements, existing site conditions shall mean the conditions that existed prior to local government adoption of a stormwater management program. If in question, the existing site conditions shall be documented by aerial photograph records, or other appropriate means.

(c) For all sites in water quality sensitive areas as identified under Minimum Requirement #7, Water Quality Sensitive Areas, existing site conditions shall mean undisturbed forest, for the purpose of calculating runoff characteristics.

(d) For all undeveloped sites outside of water quality sensitive areas, existing site conditions shall mean the existing conditions on the site.

Experimental best management practice (BMP) - A BMP that has not been tested and evaluated by the Department of Ecology in collaboration with local governments and technical experts.

FIRM - See Flood Insurance Rate Map.

Fertilizer - Any material or mixture used to supply one or more of the essential plant nutrient elements.

Fill - a deposit of earth material placed by artificial means.

Filter fabric - A woven or nonwoven, water-permeable material generally made of synthetic products such as polypropylene and used in stormwater management and erosion and sediment control applications to trap sediment or prevent the clogging of aggregates by fine soil particles.

Filter fabric fence - A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The filter fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support.

**Filter strip** - A strip of vegetation used to retard or collect sediment for the protection of diversions, drainage basins, or other structures. Often used in conjunction with a level spreader to keep flow from becoming channelized in the filter strip.

**Flocculation** - The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules which eventually settle out of suspension. This process occurs naturally but can also be caused through the use of such chemicals as alum.

**Flood** - An overflow or inundation that comes from a river or any other source, including (but no limited to) streams, tides, wave action, storm drains or excess rainfall. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.

**Flood control** - Methods or facilities for reducing flood flows and the extent of flooding.

**Flood control project** - A structural system installed to protect land and improvements from floods by the construction of dikes, river embankments, channels, or dams.

**Flood frequency** - The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the "n-year flood" as being the flood that will, over a long period of time, be equaled or exceeded on the average once every "n" years.

**Flood fringe** - That portion of the floodplain outside of the floodway which is covered by floodwaters during the base flood; it is generally associated with standing water rather than rapidly flowing water.

**Flood Hazard Areas** - Those areas subject to inundation by the base flood. Includes, but is not limited to streams, lakes, wetlands, and closed depressions.

**Flood Insurance Rate Map (FIRM)** - The official map on which the Federal Insurance Administration has delineated many areas of flood hazard, floodway, and the risk premium zones.

**Flood Insurance Study** - The official report provided by the Federal Insurance Administration that includes flood profiles and the FIRM.

**Flood peak** - The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge.

**Floodplain** - The total area subject to inundation by the base flood including the flood fringe and floodway.

**Flood-proofing** - Adaptations that ensure a structure is substantially impermeable to the passage of water below the flood protection elevation that resists hydrostatic and hydrodynamic loads and effects of buoyancy.

**Flood protection elevation** - the base flood elevation or higher as defined by the local government.

**Flood protection facility** - Any levee, berm, wall, enclosure, raise bank, revetment, constructed bank stabilization or armoring, that is commonly recognized by the community as providing significant protection to a property from inundation by flood waters.

**Flood routing** - An analytical technique used to compute the effects of system storage dynamics on the shape and movement of flow represented by a hydrograph.

Flood stage - The stage at which overflow of the natural banks of a stream begins.

Floodway - The channel of the river or stream and those portions of the adjoining floodplains which are reasonably required to carry and discharge the base flood flow. The portions of the adjoining floodplains which are considered to be "reasonably required" is defined by flood hazard regulations.

Forebay - An easily maintained, extra storage area provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond or wetland BMP.

Forest practice - Any activity conducted on or directly pertaining to forest land and relating to growing, harvesting, or processing timber, including but not limited to:

- a. Road and trail construction.
- b. Harvesting, final and intermediate.
- c. Precommercial thinning.
- d. Reforestation.
- e. Fertilization.
- f. Prevention and suppression of diseases and insects.
- g. Salvage of trees.
- h. Brush control.

Forested communities (wetlands) - In general terms, communities (wetlands) characterized by woody vegetation that is greater than or equal to 6 meters in height; in this manual the term applies to such communities (wetlands) that represent a significant amount of tree cover consisting of species that offer wildlife habitat and other values and advance the performance of wetland functions overall.

Freeboard - The vertical distance between the design water surface elevation and the elevation of the barrier which contains the water.

Frequently flooded areas - the 100-year floodplain designations of the Federal Emergency Management Agency and the National Flood Insurance Program or as defined by the local government.

Frost-heave - The upward movement of soil surface due to the expansion of water stored between particles in the first few feet of the soil profile as it freezes. May cause surface fracturing of asphalt or concrete.

Frequency of storm (design storm frequency) - The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus a 10-year storm can be expected to occur on the average once every 10 years. Sewers designed to handle flows which occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

Functions - The ecological (physical, chemical, and biological) processes or attributes of a wetland without regard for their importance to society (see also values). Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, floodflow alteration, ground water recharge and discharge, water quality improvement, and soil stabilization.

Gabion - A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used as a protecting agent, revetment, etc., against erosion. Soft gabions, often used in streambank stabilization, are made of geotextiles filled with dirt, in between which cuttings are placed.

Gage or gauge - Device for registering precipitation, water level, discharge, velocity, pressure, temperature, etc. Also, a measure of the thickness of metal;

e.g., diameter of wire, wall thickness of steel pipe.

Gaging station - A selected section of a stream channel equipped with a gage, recorder, or other facilities for determining stream discharge.

Geologist - A person who has earned a degree in geology from an accredited college or university or who has equivalent educational training and has at least five years of experience as a practicing geologist or four years of experience and at least two years post-graduate study, research or teaching. The practical experience shall include at least three years work in applied geology and landslide evaluation, in close association with qualified practicing geologists or geotechnical professional/civil engineers.

Geologically hazardous areas - areas that because of their susceptibility to erosion, sliding, earthquake or other geological events, are not suited to the siting of commercial, residential or industrial development consistent with public health or safety concerns.

Geometrics - The mathematical relationships between points, lines, angles and surfaces used to measure and identify areas of land.

Geotechnical professional civil engineer - A practicing, geotechnical/civil engineer licensed as a professional Civil Engineer with the State of Washington who has at least four years of professional employment as a geotechnical engineer in responsible charge, including experience with landslide evaluation.

Grade - The slope of a road, channel, or natural ground. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction such as paving or the laying of a conduit.

(To) Grade - To finish the surface of a canal bed, roadbed, top of embankment or bottom of excavation.

Gradient terrace - an earth embankment or a ridge-and-channel constructed with suitable spacing and an acceptable grade to reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a stable nonerosive velocity.

Grassed waterway - A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate. See also biofilter.

Ground water - Water in a saturated zone or stratum beneath the land surface or a surface water body.

Ground water recharge - Inflow to a ground water reservoir.

Ground water table - The free surface of the ground water, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

(the) Guidance Manual - "The Stormwater Program Guidance Manual for the Puget Sound Basin"; a companion manual to this technical manual which contains program implementation guidance for local governments. Examples of the guidance contained are model ordinances, public education information, and guidance on setting up a stormwater utility.

Gully - A channel caused by the concentrated flow of surface and stormwater runoff over unprotected erodible land.

Habitat - The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be protected from harmful contaminants.

Hardpan - A cemented or compacted and often clay-like layer of soil that is impenetrable by roots.

Harmful pollutant - A substance that has adverse effects to an organism including immediate death, chronic poisoning, impaired reproduction, cancer or other effects.

Head (Hydraulics) - The height of water above any plain of reference. The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. Used in various compound terms such as pressure head, velocity head, and head loss.

Head loss - Energy loss due to friction, eddies, changes in velocity, or direction of flow.

Heavy metals - Metals of high specific gravity, present in municipal and industrial wastes, that pose long-term environmental hazards. Such metals include cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc.

Humus - Organic matter in or on a soil, composed of partly or fully decomposed bits of plant tissue or from animal manure.

Hydraulic gradient - Slope of the potential head relative to a fixed datum.

Hydrodynamics - means the dynamic energy, force, or motion of fluids as affected by the physical forces acting upon those fluids.

Hydrograph - A graph of runoff rate, inflow rate or discharge rate, past a specific point over time.

Hydrologic cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrologic Soil Groups - A soil characteristic classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one of four soil groups (A, B, C, or D) based upon infiltration rate and other properties.

Hydrology - The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Hydroperiod - a seasonal occurrence of flooding and/or soil saturation; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph - A graph of percentages of total precipitation for a series of time steps representing the total time in which precipitation occurs.

Illicit discharge - All non-stormwater discharges to stormwater drainage systems that cause or contribute to a violation of state water quality, sediment quality or ground water quality standards, including but not limited to sanitary sewer connections, industrial process water, interior floor drains, car washing and greywater systems.

Impact basin - A device used to dissipate the energy of flowing water. Generally constructed of concrete in the form of a partially depressed or partially submerged vessel, it may utilize baffles to dissipate velocities.



Impervious - A surface which cannot be easily penetrated. For instance, rain does not readily penetrate paved surfaces.

Impervious surface - means a hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces.

Impoundment - A natural or man-made containment for surface water.

Improvement - Streets (with or without curbs or gutters), sidewalks, crosswalks, parking lots, water mains, sanitary and storm sewers, drainage facilities, street trees and other appropriate items.

Infiltration - means the downward movement of water from the surface to the subsoil.

Infiltration facility (or system) - A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground, commonly referred to as a percolation, to dispose of surface and stormwater runoff.

Ingress/egress - The points of access to and from a property.

Inlet - A form of connection between surface of the ground and a drain or sewer for the admission of surface and stormwater runoff.

Insecticide - A substance, usually chemical, that is used to kill insects.

Interception (Hydraulics) - The process by which precipitation is caught and held by foliage, twigs, and branches of trees, shrubs, and other vegetation. Often used for "interception loss" or the amount of water evaporated from the precipitation intercepted.

Interflow - That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface for example, in a wetland, spring or seep.

Intermittent stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources. It is dry for a large part of the year, ordinarily more than three months.

Invasive weedy plant species - Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to non-native species in this manual.

Invert - The lowest point on the inside of a sewer or other conduit.

Invert elevation - The vertical elevation of a pipe or orifice in a pond which defines the water level.

Isopluvial map - A map with lines representing constant depth of total precipitation for a given return frequency.

Lag time - The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.

Lake - An area permanently inundated by water in excess of two meters deep and greater than 20 acres in size as measured at the ordinary high water marks.

Land disturbing activity - means any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to demolition, construction, clearing, grading, filling and excavation.

Landslide - Episodic downslope movement of a mass of soil or rock that includes but is not limited to rockfalls, slumps, mudflows, and earthflows. For the purpose of these rules, snow avalanches are considered to be a special case of landsliding.

Landslide Hazard Areas - Those areas subject to a severe risk of landslide.

Large Parcel Erosion and Sediment Control Plan" or "LPESC Plan" - a plan to implement BMPs to control pollution generated during land disturbing activity. Guidance for preparing a Large Parcel ESC Plan is contained in Chapter II-4. [Note: Ecology will be adding a sample Large Parcel ESC Plan to the Guidance Manual.]

Leachate - Liquid that has percolated through soil and contains substances in solution or suspension.

Leaching - Removal of the more soluble materials from the soil by percolating waters.

Legume - A member of the legume or pulse family, Leguminosae, one of the most important and widely distributed plant families. The fruit is a "legume" or pod. Includes many valuable food and forage species, such as peas, beans, clovers, alfalfas, sweet clovers, and vetches. Practically all legumes are nitrogen-fixing plants.

Level spreader - A temporary ESC device used to spread out stormwater runoff uniformly over the ground surface as sheet flow (i.e., not through channels). The purpose of level spreaders are to prevent concentrated, erosive flows from occurring, and to enhance infiltration.

Local government - Any county, city, or town having its own incorporated government for local affairs.

Low flow channel - An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and/or baseflow, directly to the outlet without detention.

Lowest floor - The lowest enclosed area (including basement) of a structure. An area used solely for parking of vehicles, building access, or storage, in an area other than a basement area, is not considered a building's lowest floor, provided that the enclosed area meets all of the structural requirements of the flood hazard standards.

MDNS - A Mitigated Determination of Nonsignificance (See DNS and Mitigation).

Manning's equation (Hydraulics) - An equation used to predict the velocity of water flow in an open channel or pipelines:

$$V = \frac{1.486R^{2/3}S^{1/2}}{n}$$

where:

- V is the mean velocity of flow in feet per second
- R is the hydraulic radius in feet
- S is the slope of the energy gradient or, for assumed uniform flow, the slope of the channel in feet per foot; and

n is Manning's roughness coefficient or retardance factor of the channel lining.

Mass wasting - The movement of large volumes of earth material downslope.

Master Drainage Plan - A comprehensive drainage control plan intended to prevent significant adverse impacts to the natural and manmade drainage system, both on and off-site.

Mean annual water level fluctuation - Derived as follows--

- (1) Measure the maximum water level (e.g., with a crest stage gage, Reinelt and Horner 1990) and the existing water level at the time of the site visit (e.g., with a staff gage) on at least eight occasions spread through a year.
- (2) Take the difference of the maximum and existing water level on each occasion and divide by the number of occasions.

Mean depth (Hydraulics) - Average depth; cross-sectional area of a stream or channel divided by its surface or top width.

Mean velocity - The average velocity of a stream flowing in a channel or conduit at a given cross-section or in a given reach. It is equal to the discharge divided by the cross-sectional area of the reach.

Measuring weir - A shaped notch through which water flows are measured. Common shapes are rectangular, trapezoidal, and triangular.

Mechanical analysis - The analytical procedure by which soil particles are separated to determine the particle size distribution.

Mechanical practices - Soil and water conservation practices that primarily change the surface of the land or that store, convey, regulate, or dispose of runoff water without excessive erosion.

Metals - Elements, such as mercury, lead, nickel, zinc and cadmium, that are of environmental concern because they do not degrade over time. Although many are necessary nutrients, they are sometimes magnified in the food chain, and they can be toxic to life in high enough concentrations. They are also referred to as heavy metals.

Mitigation - means, in the following order of preference:

- (a) Avoiding the impact altogether by not taking a certain action or part of an action;
- (b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;
- (c) Rectifying the impact by repairing, rehabilitating or restoring the affected environment;
- (d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
- (e) Compensation for the impact by replacing, enhancing, or providing substitute resources or environments.

Modification, Modified (wetland) - A wetland whose physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.

Monitor - To systematically and repeatedly measure something in order to track changes.

Monitoring - The collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

NGPE - See Native Growth Protection Easement.

NGVD - National Geodetic Vertical Datum (see Base flood elevation).

NPDES - The National Pollutant Discharge Elimination System as established by the Federal Clean Water Act.

National Pollutant Discharge Elimination System (NPDES) - The part of the federal Clean Water Act, which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits and, in Washington State, are administered by the Washington State Department of Ecology.

Native Growth Protection Easement (NGPE) - An easement granted for the protection of native vegetation within a sensitive area or its associated buffer. The NGPE shall be recorded on the appropriate documents of title and filed with the County Records Division.

Natural location - means the location of those channels, swales, and other non-manmade conveyance systems as defined by the first documented topographic contours existing for the subject property, either from maps or photographs, or such other means as appropriate.

New development - means the following activities: land disturbing activities, structural development, including construction, installation or expansion of a building or other structure; creation of impervious surfaces; Class IV - general forest practices that are conversions from timber land to other uses; and subdivision and short subdivision of land as defined in RCW 58.17.020. All other forest practices and commercial agriculture are not considered new development.

Nitrate ( $\text{NO}_3$ ) - A form of nitrogen which is an essential nutrient to plants. It can cause algal blooms in water if all other nutrients are present in sufficient quantities. It is a product of bacterial oxidation of other forms of nitrogen, from the atmosphere during electrical storms and from fertilizer manufacturing.

Nitrification - The biochemical oxidation process by which ammonia is changed first to nitrites and then to nitrates by bacterial action, consuming oxygen in the water.

Nitrogen, Available - Usually ammonium, nitrite, and nitrate ions, and certain simple amines available for plant growth. A small fraction of organic or total nitrogen in the soil is available at any time.

Nonpoint source pollution - Pollution that enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Normal depth - The depth of uniform flow. This is a unique depth of flow for any combination of channel characteristics and flow conditions. Normal depth is calculated using Manning's Equation.

**Nutrients** - Essential chemicals needed by plants or animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms. Some nutrients can be toxic at high concentrations.

**Off-site** - Any area lying upstream of the site that drains onto the site and any area lying downstream of the site to which the site drains.

**Off-system storage** - Facilities for holding or retaining excess flows over and above the carrying capacity of the stormwater conveyance system, in chambers, tanks, lagoons, ponds, or other basins that are not a part of the subsurface sewer system.

**On-site** - The entire property that includes the proposed development.

**Ordinary High Water Mark** - The term ordinary high water mark means the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area.

The ordinary high water mark will be found by examining the bed and banks of a stream and ascertaining where the presence and action of waters are so common and usual, and so long maintained in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation. In any area where the ordinary high water mark cannot be found, the line of mean high water shall substitute. In any area where neither can be found, the channel bank shall be substituted. In braided channels and alluvial fans, the ordinary high water mark or substitute shall be measured so as to include the entire stream feature.

**Orifice** - An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow, generally used for the purpose of measurement or control of water.

**Outlet** - Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

**Outlet channel** - A waterway constructed or altered primarily to carry water from man-made structures, such as terraces, tile lines, and diversions.

**Overflow** - A pipeline or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has allowed the portion of the flow which can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

**Overflow rate** - Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.

**Overtopping** - To flow over the limits of a containment or conveyance element.

**Peak discharge** - The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

**Peak-shaving** - Controlling post-development peak discharge rates to pre-development levels by providing temporary detention in a BMP.

**Percolation** - The movement of water through soil.

**Percolation rate** - The rate, usually expressed as a velocity, at which water moves through saturated granular material.

Permanent Stormwater Quality Control (PSQC) Plan - a plan which includes permanent BMPs for the control of pollution from stormwater runoff after construction and/or land disturbing activity has been completed. For small sites, this requirement is met by implementing a Small Parcel Erosion and Sediment Control Plan. Guidance on preparing a PSQC Plan is contained in Chapter I-3 and Chapter I-4. [Note: Ecology will add a sample Large Parcel ESC Plan to the Guidance Manual.]

Permeability rate - The rate at which water will move through a saturated soil. Permeability rates are classified as follows:

- a. Very slow - Less than 0.06 inches per hour.
- b. Slow - 0.06 to 0.20 inches per hour.
- c. Moderately slow - 0.20 to 0.63 inches per hour.
- d. Moderate - 0.63 to 2.0 inches per hour.
- e. Moderately rapid - 2.0 to 6.3 inches per hour.
- f. Rapid - 6.3 to 20.0 inches per hour.
- g. Very rapid - More than 20.0 inches per hour.

Permeable soils - Soil materials with a sufficiently rapid infiltration rate so as to greatly reduce or eliminate surface and stormwater runoff. These soils are generally classified as SCS hydrologic soil types A and B.

Person - Any individual, partnership, corporation, association, organization, cooperative, public or municipal corporation, agency of the state, or local government unit, however designated.

Perviousness - Related to the size and continuity of void spaces in soils; related to a soil's infiltration rate.

Pesticide - A general term used to describe any substance - usually chemical - used to destroy or control organisms; includes herbicides, insecticides, algicides, fungicides, and others. Many of these substances are manufactured and are not naturally found in the environment. Others, such as pyrethrum, are natural toxins which are extracted from plants and animals.

pH - A measure of the alkalinity or acidity of a substance which is conducted by measuring the concentration of hydrogen ions in the substance. A pH of 7.0 indicates neutral water. A 6.5 reading is slightly acid.

Physiographic - Characteristics of the natural physical environment (including hills).

Planned unit development (PUD) - A special classification authorized in some zoning ordinances, where a unit of land under control of a single developer may be used for a variety of uses and densities, subject to review and approval by the local governing body. The locations of the zones are usually decided on a case-by-case basis.

Plat - A map or representation of a subdivision showing the division of a tract or parcel of land into lots, blocks, streets, or other divisions and dedications.

Plunge pool - A device used to dissipate the energy of flowing water that may be constructed or made by the action of flowing. These facilities may be protected by various lining materials.

Point discharge - The release of collected and/or concentrated surface and storm water runoff from a pipe, culvert, or channel.

Pollution - Contamination or other alteration of the physical, chemical, or biological properties, of waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid,

gaseous, solid, radioactive or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental or injurious to the public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

Prediction - For the purposes of this document an expected outcome based on the results of hydrologic modelling and/or the judgment of a trained professional civil engineer or geologist.

Pretreatment - The removal of material such as gross solids, grit, grease, and scum from flows prior to physical, biological, or physical treatment processes to improve treatability. Pretreatment may include screening, grit removal, stormwater, and oil separators.

Priority peat systems - Unique, irreplaceable fens that can exhibit water pH in a wide range from highly acidic to alkaline, including fens typified by Sphagnum species, Ledum groenlandicum (Labrador tea), Drosera rotundifolia (sundew), and Vaccinium oxycoccos (bog cranberry); marl fens; estuarine peat deposits; and other moss peat systems with relatively diverse, undisturbed flora and fauna. Bog is the common name for peat systems having the Sphagnum association described, but this term applies strictly only to systems that receive water income from precipitation exclusively.

Professional civil engineer - A person registered with the State of Washington as a professional engineer in civil engineering.

Project - The proposed action of a permit application or an approval which requires a drainage review.

Puget Sound basin - Puget Sound south of Admiralty Inlet (including Hood Canal and Saratoga Passage); the waters north to the Canadian border, including portions of the Strait of Georgia; the Strait of Juan de Fuca south of the Canadian border; and all the lands draining into these waters as mapped in Water Resources Inventory Areas numbers 1 through 19, set forth in WAC 173-500-040.

R/D - See Retention/detention facility.

Rare, threatened, or endangered species - Plant or animal species that are regional relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats. Threatened and endangered species are officially listed by federal and state authorities, whereas rare species are unofficial species of concern that fit the above definitions.

Rational method - A means of computing storm drainage flow rates (Q) by use of the formula  $Q = CIA$ , where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area. This method is no longer used in the technical manual.

Reach - A length of channel with uniform characteristics.

Receiving waters - Bodies of water or surface water systems receiving water from upstream manmade (or natural) streams.

Recharge - The flow to ground water from the infiltration of surface and stormwater runoff.

Redevelopment - On an already developed site, the creation or addition of impervious surfaces, structural development including construction, installation or expansion of a building or other structure, and/or replacement of impervious surface that is

not part of a routine maintenance activity; and land disturbing activities associated with structural or impervious redevelopment.

Regional - An action (here, for stormwater management purposes) that involves more than one discrete property.

Regional detention facility - A stormwater quantity control structure designed to correct existing excess surface water runoff problems of a basin or subbasin. The area downstream has been previously identified as having existing or predicted significant and regional flooding and/or erosion problems.

This term is also used when a detention facility is used to detain stormwater runoff from a number of different businesses, developments or areas within a catchment. The use of regional detention facilities may be more efficient than on-site stormwater treatment although the preferred option is to include some on-site stormwater treatment through the use of grassy swales etc. even when regional detention facilities are used.

Release rate - The computed peak rate of surface and stormwater runoff for a particular design storm event and drainage area conditions.

Residential density - The number of persons per unit of residential land area. Net density includes only occupied land. Gross density includes unoccupied portions of residential areas, such as roads and open space.

Restoration - Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.

Retention - The process of collecting and holding surface and stormwater runoff with no surface outflow.

Retention/detention facility (R/D) - A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

Retrofitting - The renovation of an existing structure or facility to meet changed conditions or to improve performance.

Return interval - A statistical term for the average time of expected interval that an event of some kind will equal or exceed given conditions (e.g., a stormwater flow that occurs every 2 years).

Rhizome - A modified plant stem that grows horizontally underground.

Riffles - Fast sections of a stream where shallow water races over stones and gravel. Riffles usually support a wider variety of bottom organisms than other stream sections.

Rill - A small intermittent watercourse with steep sides, usually only a few inches deep. Often rills are caused by an increase in surface water flow when soil is cleared of vegetation.

Riprap - A facing layer or protective mound of stones placed to prevent erosion or sloughing of a structure or embankment due to flow of surface and stormwater runoff.

Riparian - Pertaining to the banks of streams, wetlands, lakes or tidewater.



Riser - A vertical pipe extending from the bottom of a pond BMP that is used to control the discharge rate from a BMP for a specified design storm.

Rodenticide - A substance used to destroy rodents.

Runoff - Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes and wetlands as well as shallow ground water.

SCS - Soil Conservation Service, U.S. Department of Agriculture.

SCS Method - A hydrologic analysis based on the Curve Number method (National Engineering Handbook - Section 4: Hydrology, August 1971).

SEPA - See State Environmental Policy Act.

Salmonid - A member of the fish family Salmonidae. Chinook, coho, chum, sockeye and pink salmon; cutthroat, brook, brown, rainbow and steelhead trout; Dolly Varden, kokanee and char are examples of salmonid species.

Saturation point - In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

Scour - Erosion of channel banks due to excessive velocity of the flow of surface and stormwater runoff.

Sediment - Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits, and is transported by, suspended in, or deposited by water.

Sedimentation - The depositing or formation of sediment.

Sensitive emergent vegetation communities - Assemblages of erect, rooted, herbaceous vegetation, excluding mosses and lichens, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as sundew and, as well as a number of species of *Carex* (sedges).

Sensitive life stages - Stages during which organisms have limited mobility or alternatives in securing the necessities of life, especially including reproduction, rearing, and migration periods.

Sensitive scrub-shrub vegetation communities - Assemblages of woody vegetation less than 6 meters in height, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as Labrador tea, bog laurel, and cranberry.

Settleable solids - Those suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.

Sheet erosion - The relatively uniform removal of soil from an area without the development of conspicuous water channels.

Sheetflow - Runoff which flows over the ground surface as a thin, even layer, not concentrated in a channel.

Shoreline development - The proposed project as regulated by the Shoreline Management Act. Usually the construction over water or within a shoreline zone (generally 200 feet landward of the water) of structures such as buildings, piers, bulkheads, and breakwaters, including environmental alterations such as dredging and

filling, or any project which interferes with public navigational rights on the surface waters.

Short circuiting - The passage of runoff through a BMP in less than the design treatment time.

Siltation - The process by which a river, lake, or other water body becomes clogged with sediment. Silt can clog gravel beds and prevent successful salmon spawning.

Site - The portion of a piece of property which is directly subject to development.

Slope - Degree of deviation of a surface from the horizontal; measured as a numerical ratio, percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 percent slope. Expressed in degrees, the slope is the angle from the horizontal plane, with a 90° slope being vertical (maximum) and 45° being a 1:1 or 100 percent slope.

Sloughing - The sliding of overlying material. It is the same effect as caving, but it usually occurs when the bank or an underlying stratum is saturated or scoured.

Small Parcel Erosion and Sediment Control Plan or "SPESC Plan" - a plan for small sites to implement temporary BMPs to control pollution generated during the construction phase only, primarily erosion and sediment. Guidance for preparing a Small Parcel ESC Plan is contained in Chapter I-3.

Soil - The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Soil group, hydrologic - A classification of soils by the Soil Conservation Service into four runoff potential groups. The groups range from A soils, which are very permeable and produce little or no runoff, to D soils, which are not very permeable and produce much more runoff.

Soil horizon - A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming factors.

Soil profile - A vertical section of the soil from the surface through all horizons, including C horizons.

Soil structure - The relation of particles or groups of particles which impart to the whole soil a characteristic manner of breaking; some types are crumb structure, block structure, platy structure, and columnar structure.

Soil permeability - The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil.

Soil stabilization - The use of measures such as rock lining, vegetation or other engineering structures to prevent the movement of soil when loads are applied to the soil.

Sorption - The physical or chemical binding of pollutants to sediment or organic particles.

Source control BMP - A BMP that is intended to prevent pollutants from entering stormwater. A few examples of source control BMPs are erosion control practices, maintenance of stormwater facilities, constructing roofs over storage and working areas, and directing wash water and similar discharges to the sanitary sewer or a dead end sump.

**Specific energy** - The total energy within any system with respect to the channel bottom, equal to the potential head plus velocity and pressure heads.

**Spillway** - A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

**State Environmental Policy Act (SEPA)** - The Washington State law intended to minimize environmental damage. SEPA requires that state agencies and local governments consider environmental factors when making decisions on activities, such as development proposals over a certain size and comprehensive plans. As part of this process, environmental documents are prepared and opportunities for public comment are provided.

**Steep slope** - Slopes of 40 percent gradient or steeper.

**Storm drains** - The enclosed conduits that transport surface and stormwater runoff toward points of discharge (sometimes called storm sewers).

**Storm drain system** - Refers to the system of gutters, pipes, streams, or ditches used to carry surface and stormwater from surrounding lands to streams, lakes, or Puget Sound.

**Storm frequency** - The time interval between major storms of predetermined intensity and volumes of runoff for which storm sewers and other structures are designed and constructed to handle hydraulically without surcharging and backflooding, e.g., a 2-year, 10-year or 100-year storm.

**Storm sewer** - A sewer that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a storm drain.

**Stormwater** - That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel, or a constructed infiltration facility.

**Stormwater drainage system** - constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat or filter stormwater.

**Stormwater facility** - A constructed component of a stormwater drainage system, designed or constructed to perform a particular function, or multiple functions. Stormwater facilities include, but are not limited to, pipes, swales, ditches, culverts, street gutters, detention basins, retention basins, constructed wetlands, infiltration devices, catchbasins, oil/water separators, sediment basins and modular pavement.

**Stormwater Management Manual for the Puget Sound Basin or "Manual"** - this manual as prepared by Ecology that contains BMPs to prevent, control or treat pollution in stormwater [or a technically equivalent Manual approved by Ecology].

**Stormwater Program** - Either the Basic Stormwater Program or the Comprehensive Stormwater Program as appropriate to the context of the reference. See the "Stormwater Program Guidance Manual for the Puget Sound Basin" for a complete description of the requirements of each program.

**Stormwater Site Plan** - a plan which includes an Erosion and Sediment Control (ESC) Plan and/or a Permanent Stormwater Quality Control Plan (PSQC). For small sites, this plan is the equivalent of a Small Parcel Erosion and Sediment Control Plan. Guidance on preparing a Stormwater Site Plan is contained in Chapter I-3.

Stream gaging - The quantitative determination of stream flow using gages, current meters, weirs, or other measuring instruments at selected locations. See Gaging station.

Streambanks - The usual boundaries, not the flood boundaries, of a stream channel. Right and left banks are named facing downstream.

Stream classification - The following stream classification which applies to all streams.

1. Type 1 streams are all streams inventoried as Shorelines of the State under Ch. 90.58 RCW.
2. Type 2 streams are all streams smaller than Type 1 streams that flow year around during years of normal rainfall, or are used by salmonids.
3. Type 3 streams are streams that are intermittent or ephemeral during years of normal rainfall and are not used by salmonids.

Streams - Those areas where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is indicated by hydraulically sorted sediments or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water year-round. This definition is not meant to include irrigation ditches, canals, storm water runoff devices or other entirely artificial watercourses unless they are used to convey Type 1 and 2 streams naturally occurring prior to construction. Those topographic features that resemble streams but have no defined channels (i.e. swales) shall be considered streams when hydrologic and hydraulic analyses done pursuant to a development proposal predict formation of a defined channel after development.

Structure - A catchbasin or manhole in reference to a storm drainage system.

Stub-out - A short length of pipe provided for future connection to a storm drainage system.

Subbasin - A drainage area which drains to a water course or waterbody named and noted on common maps and which is contained within a basin.

Subcatchment - A subdivision of a drainage basin (generally determined by topography and pipe network configuration).

Subcritical flow - Flow at depths greater than the critical depth.

Sub-division retention/detention facility - A retention/detention facility which is both (1) located within or associated with a short or formal plat sub-division containing only single family or duplex residential structures located on individual lots; and 2) which is required to handle excess runoff generated by development of an area of which two-thirds or more is designated for single family or duplex residential structures located on individual lots.

Subdrain - A pervious backfilled trench containing stone or a pipe for intercepting ground water or seepage.

Subgrade - A layer of stone or soil used as the underlying base for a BMP.

Subsoil - The B horizons of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil), in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as the "subsoil."

Substrate - The natural soil base underlying a BMP.

Supercritical flow - Flow at depths less than the critical depth.

Surcharge - The flow condition occurring in closed conduits when the hydraulic grade line is above the crown of the sewer.

Surface and stormwater - Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands as well as shallow ground water.

Surface and stormwater management system - Drainage facilities and any other natural features which collect, store, control, treat and/or convey surface and stormwater.

Suspended solids - Organic or inorganic particles that are suspended in and carried by the water. The term includes sand, mud, and clay particles (and associated pollutants) as well as solids in stormwater.

Swale - A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than one foot.

Terrace - An embankment or combination of an embankment and channel across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Tile, Drain - Pipe made of burned clay, concrete, or similar material, in short lengths, usually laid with open joints to collect and carry excess water from the soil.

Tile drainage - Land drainage by means of a series of tile lines laid at a specified depth and grade.

Time of concentration - The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.

Toe of slope - a point or line of slope in an excavation or cut where the lower surface changes to horizontal or meets the exiting ground slope.

Top of slope - a point or line on the upper surface of a slope where it changes to horizontal or meets the original surface.

Topography - General term to include characteristics of the ground surface such as plains, hills, mountains; degree of relief, steepness of slopes, and other physiographic features.

Total dissolved solids - The dissolved salt loading in surface and subsurface waters.

Total solids - The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when the moisture is evaporated and the remainder is dried at a specified temperature, usually 130°C.

Toxic - Poisonous, carcinogenic, or otherwise directly harmful to life.

Tract - A legally created parcel of property designated for special nonresidential and noncommercial uses.

Trash rack - A structural device used to prevent debris from entering a spillway or other hydraulic structure.

Travel time - The estimated time for surface water to flow between two points of interest.

Treatment BMP - A BMP that is intended to remove pollutants from stormwater. A few examples of treatment BMPs are detention ponds, oil/water separators, biofiltration swales and constructed wetlands.

Turbidity - Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid.

Underdrain - Plastic pipes with holes drilled through the top, installed on the bottom of an infiltration BMP which are used to collect and remove excess runoff.

Undisturbed buffer - A zone where development activity shall not occur, including logging, and/or the construction of utility trenches, roads, and/or surface and stormwater facilities.

Undisturbed low gradient uplands - Forested land, sufficiently large and flat to infiltrate surface and storm runoff without allowing the concentration of water on the surface of the ground.

Unstable slopes - those sloping areas of land which have in the past exhibited, are currently exhibiting, or will likely in the future exhibit, mass movement of earth.

Unusual biological community types - Assemblages of interacting organisms that are relatively uncommon regionally.

Urbanized area - Areas designated and identified by the U.S. Bureau of Census according to the following criteria: an incorporated place and densely settled surrounding area that together have a maximum population of 50,000.

USEPA - The United States Environmental Protection Agency.

Values - Wetland processes or attributes that are valuable or beneficial to society (also see Functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

Vegetation - all organic plant life growing on the surface of the earth.

Water body - Surface waters including rivers, streams, lakes, marine waters, estuaries, and wetlands.

Water quality - A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water quality BMP - A BMP specifically designed for pollutant removal.

Water quality design storm - The 6-month 24-hour design storm.

Water quality standards - Minimum requirements of purity of water for various uses; for example, water for agricultural use in irrigation systems should not exceed specific levels of sodium bicarbonate, pH, total dissolved salts, etc. In Washington, the Department of Ecology sets water quality standards.

Water quality swale - An open vegetated drainage channel intended to optimize water quality treatment of surface and stormwater runoff by following the specific design criteria described in the manual.

Watershed - a geographic region within which water drains into a particular river, stream, or body of water as identified and numbered by the State of Washington Water Resource Inventory Areas (WRIAs) as defined in Chapter 173-500 WAC.

Water table - The upper surface or top of the saturated portion of the soil or bedrock layer, indicates the uppermost extent of ground water.

Weir - Device for measuring or regulating the flow of water.

Weir notch - The opening in a weir for the passage of water.

Wetlands - Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. This includes wetlands created, restored or enhanced as part of a mitigation procedure. This does not include constructed wetlands or the following surface waters of the state intentionally constructed from sites that are not wetlands: Irrigation and drainage ditches, grass-lined swales, canals, agricultural detention facilities, farm ponds, and landscape amenities.

Wetland edge - Delineation of the wetland edge shall be based on the U.S. Army Corps of Engineers Wetlands Delineation Manual, Technical Report Y-87-1, U.S. Army Engineers Waterways Experiment Station, Vicksburg, Miss. (1987)

Wetponds and wetvaults - Drainage facilities for water quality treatment that contain permanent pools of water that are filled during the initial runoff from a storm event. They are designed to optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals absorb, and to allow biologic activity to occur that metabolizes nutrients and organic pollutants.

Zoning ordinance - An ordinance based on the police power of government to protect the public health, safety, and general welfare. It may regulate the type of use and intensity of development of land and structures to the extent necessary for a public purpose. Requirements may vary among various geographically defined areas called zones. Regulations generally cover such items as height and bulk of buildings, density of dwelling units, off-street parking, control of signs, and use of land for residential, commercial, industrial, or agricultural purposes. A zoning ordinance is one of the major methods for implementation of a comprehensive plan.

## NOTATION

This list of notations is provided only as a guide to some of the notations used in this report. The exact definition and units are listed when the symbol is used. Since the same symbol can be used for different design methods, the exact definition should be obtained directly from the appropriate section of the report.

A	=	drainage area ( $\text{mi}^2$ ), also full cross-sectional area of culvert barrel ( $\text{ft}^2$ )
$A_b$	=	top surface area of basin ( $\text{ft}^2$ ), also area of pond bottom ( $\text{ft}^2$ )
$A_d$	=	drainage area
$A_p$	=	surface area of porous asphalt pavement ( $\text{ft}^2$ )
$A_s$	=	surface area of swale ( $\text{ft}^2$ ), also average surface area for detention BMP
$A_t$	=	total area (acres)
C	=	estimated runoff coefficient
CN	=	SCS runoff curve number
$\Delta\text{CN}$	=	change in curve number
D	=	interior height of culvert barrel (ft)
$D_{50}$	=	median stone diameter (riprap)
d	=	average permanent pool depth of a detention BMP
$d_b$	=	basin depth (ft)
$d_c$	=	critical depth (ft)
$d_p$	=	depth of porous asphalt paving stone subbase (ft)
$d_s$	=	depth of swale check dam (ft)
dt	=	time interval in minutes
$d_x$	=	a mixture of riprap sizes where the percent of stone by weight is $<x$ (the specified diameter)
E	=	designated fraction of particulates to be removed by a BMP
f	=	final infiltration rate of soil (in/hr)
$f_d$	=	infiltration rate including a safety factor of two
g	=	acceleration due to gravity, $32.2 \text{ ft/sec}^2$
H	=	stage height (ft) or water depth above pond bottom, also $H = H_f + H_c + H_{cx}$ ; head on orifice
$H_c$	=	specific head at critical depth ( $d_c + V_c^2/2g$ ) (ft)



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$H_d$	=	design depth of pond
$H_c$	=	entrance head loss (ft) = $K_c(V^2/2g)$
$H_{ex}$	=	exit head loss (ft) = $V^2/2g$
$H_f$	=	Friction loss (ft) = $V^2n^2L/2.22R^{1.35}$ Note: if $(H_f + TW - LS) < D$ , adjust $H_f$ such that $(H_f + TW - LS) = D$ . This will keep the analysis simple and still yield reasonable results (erring on the conservative side)
HW	=	headwater depth above inlet invert (ft)
$h_b$	=	distance from the hydraulic grade line at the 2-year flow on the outflow pipe to the overflow elevation
I	=	inflow at time 1 and time 2
$I(t)$	=	instantaneous hydrograph, in cfs (SBUH hydrograph method)
i	=	hydraulic gradient (ft/ft)
$K_c$	=	entrance loss coefficient
k	=	time of concentration velocity factor (feet/second)
$k_c$	=	time of concentration velocity factor; channel flow
$k_s$	=	time of concentration velocity factor; shallow flow
L	=	distance of flow across a given segment, also length of culvert (ft), also width of emergency overflow weir
$MB_{el}$	=	mean tributary basin elevation above sea level (ft)
$M_s$	=	potential average snowmelt during storms (in)
m	=	number of flow segments
$N_s$	=	number of check dams along total length of swale
n	=	Manning's "n"
$n_s$	=	sheet flow; Manning's effective roughness coefficient
O	=	outflow at time 1 and time 2
P	=	rainfall depth (inches)
$P_R$	=	the total precipitation at a site for the 24-hour design storm event for the given return frequency (R)
Q	=	flow or discharge (cfs), also runoff depth from overlying area of dry well (ft), also orifice area
$Q_a$	=	after development depth of runoff (inches)
$Q_b$	=	before development depth of runoff (inches)
$Q_c$	=	depth of runoff from contributing area (ft)

$Q_d$	=	runoff depth in inches over a given area
$Q_o$	=	average release rate from detention BMP
$Q_s$	=	depth of runoff controlled by vegetated swale (inches)
$Q_t$	=	release rate for orifice
$Q_{total}$	=	total flow at maximum head
$Q(t)$	=	the routed flow of the runoff hydrograph (SBUH method)
$Q_{10\%}$	=	the flow that is not exceeded more than 10% of the time during the months of adult (salmonid) migration
$\Delta Q$	=	change in runoff depth (inches)
$\Delta q$	=	change in peak discharge (cfs)
$R$	=	hydraulic radius (ft) in Manning's equation
$R(t)$	=	the total runoff depth at time increment $dt$ , in inches; also known as precipitation excess
$S$	=	storage at time 1 and time 2, also culvert barrel slope (ft/ft)
$S(H)$	=	storage ( $ft^3$ ) at stage height (H)
$S_d$	=	the largest volume from an initial pond sizing
$s_f$	=	friction slope = $n^2V^2/2.21R^{4/3}$
$s_o$	=	slope of flow path (ft/ft), also bottom slope
$T$	=	width of swale or vegetated filter strip
$T_c$	=	time of concentration (hrs)
$T_i$	=	travel time of overland flow across separate flow path segments
$T_{1,2,n}$	=	the consecutive flow paths of different land cover categories having significant differences in flow path slope
$TW$	=	tailwater depth above invert of culvert outlet (ft) Note: if $TW < (D + d_c)/2$ , set $TW = (D + d_c)/2$ .
$t_d$	=	design detention time of a BMP
$\Delta t$	=	time interval; time 2 - time 1
$V$	=	average velocity across the land cover (ft/sec), also barrel velocity (fps), also mean velocity
$V_c$	=	flow velocity at critical depth (fps)
$V_{max}$	=	maximum allowed velocity of runoff in a biofilter
$V_{pp}$	=	permanent pool volume
$V_r$	=	void ratio

- $V_{sed}$  = settling velocity of the design soil particle
- $W_{50}$  = the median stone size (riprap)
- $w$  = settling velocity of target particle
- $y$  = depth of flow
- $Y_n$  = normal flow depth
- $Z$  = basin side slope ratio (h:v)
- $Z^1, Z^2$  = side slope ratio of swale cross section (h:v)
- $\alpha$  = energy coefficient which corrects for the non-uniform distribution of velocity over the channel cross-section

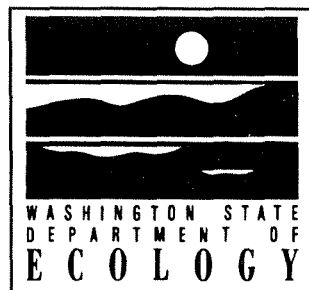


# **Stormwater Management Manual for the Puget Sound Basin**

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(The Technical Manual)

*Volume II - Erosion and Sediment  
Control*



VOLUME II - EROSION AND SEDIMENT CONTROL

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## FOREWORD

### Purpose of this Volume

This volume of the manual provides technical information to help in controlling erosion and sedimentation from new construction activities in the Puget Sound basin. Detailed standards and specifications for BMPs as well as background information on the erosion process and how it may be controlled are included. These BMPs are to be used to develop a detailed Erosion and Sediment Control Plan, as set out in Minimum Requirement #1 (see Chapter I-2). For a general overview of the entire stormwater program, please refer to Chapter I-1 in Volume I.

The target audience includes both officials in local governments who are responsible for administering ordinances pertaining to construction activities, and the development community. In a broader sense, this volume is intended for both engineers and planners because minimization of erosion requires good planning as well as good engineering and, most importantly, close collaboration between the two disciplines.

### Chapter Contents

Chapter II-1 provides a general overview of the erosion and sedimentation process and the basic principles by which it may be controlled.

Chapter II-2 explores the concept of BMPs. Seven major problem areas that are encountered during the construction process are discussed, and the various erosion and sedimentation control BMPs that can be applied to each of these areas are briefly described.

Chapter II-3 contains BMPs to deal with pollutants other than sediment. This chapter has been included because many pollutants are adsorbed by or otherwise associated with sediment. Many of these pollutants can be generated during the construction process as a result of the use of petroleum products, fertilizers, pesticides, and other construction chemicals. Some of these pollutants may be hazardous. This chapter outlines how the generation of these wastes can be minimized, and for those that are generated, how they should be handled and disposed of.

Information on NPDES stormwater construction permits and the preparation of an Erosion and Sediment Control (ESC) plan can be found in Chapter II-4.

Chapter II-5 presents the design standards for erosion and sediment control BMPs. BMPs are the means by which Minimum Requirement #1 can be satisfied. In some cases the standards and specifications of BMPs are more in the form of guidelines, such as seeding mixtures for cover practices. In most others the standards and specifications are the minimum technical requirements. Examples include the depth of sediment traps, length of construction entrances etc. Some of the BMPs are simple and easy to apply, such as mulching, but others such as sediment ponds require design by a professional engineer, using the standards set out in this manual. Best management practices for individual family lots and small sites may be found at the end of Chapter II-5.

### Acknowledgements

This volume of the manual was compiled by adapting existing manuals with advice from a technical advisory group comprised of people representing local agencies and other interested parties within the Puget Sound basin. The major sources of material include:

- (i) King County Surface Water Management Manual, January 1990.
- (ii) Michigan State Guidebook for Erosion and Sediment Control, 1975.
- (iii) Stormwater Management Manual (SNOMET/King Co. 208 Plan), prepared by URS, 1977.
- (iv) Construction and Erosion Control, King County Conservation District, December 1981.
- (v) Virginia Erosion and Sediment Control Handbook, Second Edition 1980.
- (vi) Erosion and Runoff Control, Clark County Conservation District, January, 1981.
- (vii) Construction Site Erosion and Sediment Control Inspector Training Manual, Center for Urban Water Resources Management, University of Washington, prepared by Loren Reinelt, October, 1991.

Information was also drawn from the Maryland Erosion and Sedimentation Control Manual (1983) and the Water Quality Manual of the Association of General Contractors of Washington.

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Peter B. Birch, Helen E. Pressley and Patrick D. Hartigan  
Compilers and Editors

CHAPTER II-1

THE EROSION AND SEDIMENTATION PROCESS

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CHAPTER II-1

THE EROSION AND SEDIMENTATION PROCESS

II-1.1 IMPACTS OF EROSION AND SEDIMENTATION

Erosion and sedimentation produced by land development damages the environment and is costly to society. Fisheries resources, recreational resources, and aesthetic qualities may be lost or severely degraded. Harbors, lakes, and rivers fill and must be dredged. Sediments become contaminated.

Contractors, consultants, regulators, and inspectors can significantly affect soil loss. When land is developed, erosion increases by 2-40,000 times (1,2). Such erosion is estimated to produce approximately 70 percent of all sediment produced in this country (7). However, using good erosion control practices can greatly reduce this. For example, a study in Lake Tahoe Basin compared practices at two similar construction sites (3). Without erosion control, estimated soil loss exceeded background levels by 100-1000 times. Using good erosion control practices, soil loss was only double background levels.

Everyone is affected by damages from increased erosion and sedimentation. There are a variety of ways.

- The soil loses nutrients as clays, silts, and fine organic matter wash away. Reestablishing vegetation is difficult. The contractor must either import costly topsoil or apply fertilizers.
- Sediment clogs culverts and storm sewers resulting in frequent and costly maintenance. Without maintenance culverts may wash out and storm sewers fail. Siltation also decreases flow capacities.
- Landslides cause damage on-site and off-site.
- Detention facilities fill rapidly with sediment increasing cleaning costs.
- Infiltration devices may become clogged. This has been cited as the major cause of their failure.
- As velocity decreases, streams deposit sediment requiring dredging of obstructed channels. Additionally, harbors must be dredged more often to keep them open for navigation.
- Lakes age more rapidly. As the sediment builds, shallow areas may become covered by waterlilies or weeds. Increased nutrients may cause algal blooms, which deplete oxygen and can lead to fish kills.
- We lose aesthetics. Many citizens value clean streams. An eroded, silt-clogged stream or lake is ugly.
- Turbidity (water cloudiness) and suspended sediment increases. This impairs the feeding ability of aquatic animals, clogs gill passages of fish, and reduces photosynthesis.
- Fish spawning is seriously impacted. Clean gravels provide a habitat for fish eggs and permit a free flow of well oxygenated water around the eggs and alevines (young with egg yolk still attached). Sediment-clogged gravel prevents successful spawning. Sedimentation following spawning can smother the eggs or alevines.

The costs associated with these damages vary. Some are easy to quantify, others more difficult. The loss of aesthetic values or of recreational values is hard to quantify. People prefer to canoe in clear streams. Others, who would prefer to water-ski close to home, are confronted with a lake clogged with sediment and weeds. The costs for restoration and management of a single lake can easily run into the millions of dollars.

Reductions in spawning habitat, and thus reduction in salmon and trout production, cause economic losses to sports fisheries and traditional Native American fisheries. When lost, natural production is replaced by hatchery production. The public incurs expenses for construction, operation, and maintenance of hatcheries, and loses the natural production which many people consider superior.

Most quantifiable are the maintenance costs of man-made structures and harbors. Increased maintenance is necessary for culverts, storm sewers, retention/detention facilities, dams, rivers, and harbors. Harbor maintenance, for example, is expensive. The Seattle District of the U.S. Army Corps of Engineers, which does about one-third of the maintenance dredging in Puget Sound, currently budgets about \$706,000 yearly for direct costs of dredging. This does not include administrative and other associated costs. Total yearly costs for dredging and administration for the Corps, the Ports and others runs into several million dollars. As city, county, state, and federal taxpayers, we all pay for these costs.

#### Impact Prevention

The problems listed above make it imperative to minimize erosion on construction sites. This is achieved through control of runoff. Knowledge of the erosion and sedimentation process is helpful in understanding the role of BMPs in runoff control.

### II-1.2 THE EROSION AND SEDIMENTATION PROCESS

Soil erosion is defined as the removal and loss of soil by the action of water, ice, gravity, or wind. This section deals principally with soil erosion caused by the force of falling and flowing water.

The erosion process includes the detachment and transport of soil particles. The force of raindrops falling on bare or sparsely vegetated soil detaches soil particles. Water running along the ground surface picks up these particles and carries them along. As runoff increases in velocity and concentration, it detaches more soil particles, cuts rills and gullies into the soil surface, and adds to its sediment load.

#### II-1.2.1 Types of Water Erosion

Types of erosion caused by falling and flowing water are illustrated in Figure II-1.1; they include raindrop, sheet, rill and gully, and stream and channel erosion.

1. Raindrop Erosion: Erosion resulting from the direct impact of falling drops of rain on soil particles. This impact dislodges soil particles so that they can then be easily transported by runoff.
2. Sheet Erosion: The removal of a layer of exposed surface soil by the action of raindrop splash and runoff. The water moves in broad sheets over the land and is not confined in small depressions.
3. Rill and Gully Erosion: As runoff flows it concentrates in rivulets, cutting grooves called rills into the soil surface. If the flow of water is sufficient, rills may develop into gullies.

4. Stream and Channel Erosion: Increased volume and velocity of runoff may cause erosion of the stream or channel banks and bottom.

#### II-1.2.2 Sedimentation

Sedimentation is defined as the settling out of soil particles transported by water (Figure II-1.2). Sedimentation occurs when the velocity of water in which soil particles are suspended is slowed for a sufficient time to allow particles to settle out. Heavier particles, such as sand and gravel, settle more rapidly than fine particles such as clay and silt.

### **II-1.3 FACTORS INFLUENCING EROSION**

The inherent erosion potential of any area is determined by four interrelated, principal factors: soil characteristics, vegetative cover, topography, and climate (Figure II-1.3).

#### II-1.3.1 Soil Characteristics and the Geology of the Puget Sound Basin

Soil properties which influence erosion by rainfall and runoff are those factors which affect the infiltration capacity of a soil and those which affect the resistance of the soil to detachment and being carried away by falling or flowing water. The vulnerability of a soil to erosion is called erodibility. Some key factors which control erodibility are:

- particle size and gradation
- organic content
- soil structure
- soil permeability

#### Particle Size

Soils that contain high proportions of silt and very fine sand are generally the most erodible and are easily detached and carried away. The erodibility of these soils is decreased as the percentage of clay or organic matter increases. Clay acts as a binder and tends to limit erodibility. Most soils with a high clay content are relatively resistant to detachment by rainfall and runoff. Once eroded, however, clays are easily transported and settle out slowly.

#### Organic Content

Organic matter creates a favorable soil structure, improving its stability and permeability. This increases infiltration capacity, delays the start of erosion, and reduces the amount of runoff.

#### Soil Structure

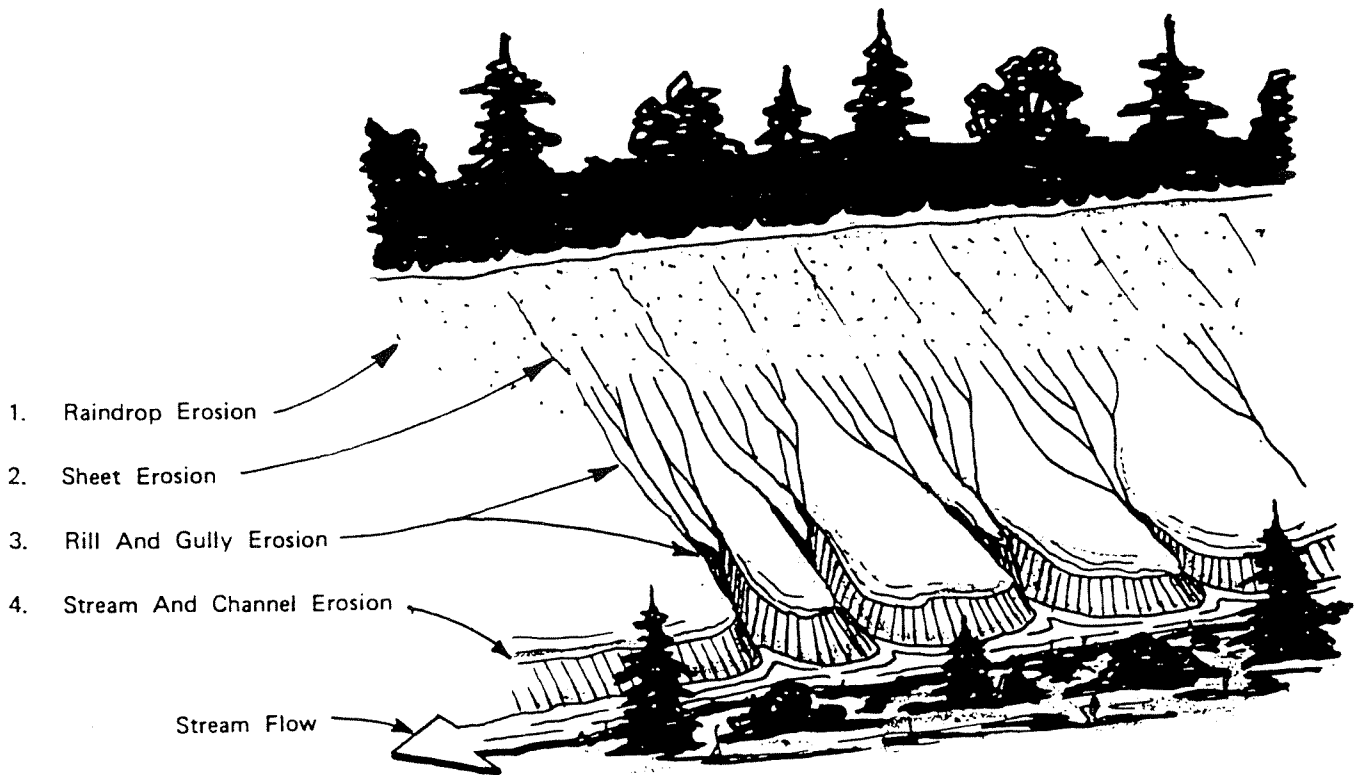
Organic matter, particle size and gradation affect soil structure (the arrangement, orientation, and organization of particles). Well-drained and well-graded gravels and gravel mixtures with little or no silt are the least erodible soils. Their high permeability and infiltration capacity helps prevent or delay runoff.

#### Soil Permeability

Soil permeability refers to the ease by which water passes through a given soil. Clay soils have high water holding capacity relative to sands and gravels, but poor infiltration characteristics. Although clay particles are harder to detach, they are more vulnerable to erosion because they tend to increase runoff.



Figure II-1.1 Types of Erosion



#### The Puget Lowland and Associated Watersheds

The landscape of Puget Sound is the product of a long history of mountain-building and subsidence, glaciation and volcanism, erosion and deposition. In addition, the makeup of surface soils is affected to varying degrees by landslide and slopewash activities. The fundamental geologic division in the Puget Sound region is between the Puget Lowland and the Cascade and Olympic mountain ranges. The terrain of the Puget Lowland is made up of a series of rolling plateaus (drift plains) cut by steep-sided valleys. The drift plains are built of unconsolidated sediment deposited during glacial and non-glacial periods during the past two million years. These deposits range from a thin veneer over bedrock hills to a depth of 3,600 feet in the deepest basin.

Two kinds of large valleys cross the lowlands. The longest and deepest of these (Hood Canal, Central Puget Sound, Lake Washington-Duwamish-Puyallup, Sammamish and Snoqualmie troughs) trend roughly north-south and were carved in their present form during the most recent glaciation. Their shapes reflect the direction of flow in ice streams and/or subglacial rivers in the bottom of the continental glaciers that filled the lowland. On the other hand, the canyons of the Nooksack, Skagit, Stillaguamish, Green, Puyallup, Nisqually and Olympic drainages were excavated by streams flowing off the retreating ice sheet and down the Cascade and Olympic mountains.

Although bedrock is not exposed extensively in the Puget Sound region, its underlying structure controls runoff and erosion. The properties of rocks, glacial

deposits and soils exposed at the ground surface determine their reactions to weathering and erosion, and their ability to absorb and transmit water.

### Glacial Deposits

Glacial deposits can be divided into two broad categories: till and outwash. The till, and underlying sediments, have undergone one or more glaciations. The weight of up to 4,000 feet of ice has compacted these deposits and can greatly affect their mechanical and hydraulic properties, particularly if the deposit is fresh and undisturbed. Till deposits contain large amounts of silt or clay, often intermixed with large cobbles, and have low percolation rates. Only a small fraction of infiltrated precipitation reaches the regional ground water table through the till. The rest moves laterally through the thin surface soil above the till deposit (generally as shallow subsurface flow), often reemerging at the base of hillslopes. Soils may become saturated during large storms and produce significant amounts of surface runoff. The peak runoff rate from till areas is therefore generally quite high. The lateral flow of subsurface water may also make some types of soil more vulnerable to sloughing.

In most of the drift plains, the outwash sediment deposited by streams that flowed off the front of the ice sheet are common. For the most part these sediments are coarse-grained, well-bedded, porous and loose. Some of these deposits are now terraces along modern stream valleys. Most outwash soils have high percolation rates, and rainfall in these areas is quickly absorbed. Creeks draining outwash deposits often intersect the ground water table and receive most of their flow from ground water discharge. Even for the largest storms, stream flow response is slow, with peak flow often lagging several days behind the rainfall that produced it. Erosion associated with outwash soils is much less than that associated with till. In contrast, erosion of fine-grained sandy outwash can be particularly severe.(8)

### II-1.3.2 Vegetative Cover

Vegetative cover (Figure II-1.4) plays an extremely important role in controlling erosion by:

- Shielding the soil surface from the impact of falling rain.
- Slowing the velocity of runoff, thereby permitting greater infiltration.
- Maintaining the soil's capacity to absorb water.
- Holding soil particles in place.

By limiting the removal of existing vegetation, and by decreasing duration of exposure, soil erosion can be significantly reduced. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential such as erodible soils, steep slopes, drainageways, and the banks of streams.

### II-1.3.3 Topography

The size and shape of a watershed influences the amount and rate of runoff. Several control measures, described in Chapters II-2 and II-5, deal with protecting vulnerable areas from high concentrations of runoff.

Slope length and steepness are key elements in determining the volume and velocity of runoff. As slope length and/or steepness increase, the rate of runoff increases and the potential for erosion is magnified.

Slope orientation is also a factor in determining erosion potential (Figure II-1.5). For example, a slope that faces south and contains droughty soils may have such poor growing conditions that vegetative cover will be difficult to reestablish.

#### II-1.3.4 Climate

The frequency, intensity, and duration of rainfall and temperature are fundamental factors in determining the amounts of runoff produced. As the volume and/or the velocity of runoff increase, the capacity of runoff to detach and transport soil particles increases.

Where storms are frequent, intense, or of long duration, erosion risks are high (Figure II-1.6). Seasonal changes in temperature, as well as variations in rainfall, help to define the high erosion risk period of the year. If precipitation falls as snow, no erosion will take place. In the spring, however, melting snow adds to the runoff, and erosion potential will be high. Because the ground is still partially frozen, its infiltration capacity is reduced.

The Puget Sound basin and adjacent areas vary significantly in storm intensity and duration from most of the rest of the country. This area is characterized in fall, winter and spring by storms that are mild in intensity and long-lasting in duration. Rainfall in the summer is sporadic and mild. Statistical analysis of the rainfall patterns in this area indicate that storms occur, on the average, every two days in the fall, winter and early spring, and every 7 days in the late spring and summer. These climatic differences are significant because storms in this area require the use of different management tools than do storms in other parts of the country.

#### **II-1.4 BASIC PRINCIPLES: A SUMMARY**

From this brief discussion of the erosion process and the factors that influence erosion, seven major principles of erosion and sedimentation control can be summarized.

1. Plan the development to fit the site.
2. Minimize the extent of the disturbed area and duration of exposure.
3. Stabilize and protect disturbed areas as soon as possible.
4. Keep runoff velocities low.
5. Protect disturbed areas from runoff.
6. Retain sediment within the corridor or site area.
7. Implement a thorough maintenance and follow-up program.

Each of these principles is discussed below in more detail.

1. Plan the Development to Fit the Particular Topography, Soils, Drainage Patterns, and Natural Vegetation of the Site.

Detailed designing should be employed to assure that roadways, buildings, and other permanent features of the development conform to the natural characteristics of the site. Large graded areas should be located on the most level portion of the site. Areas subject to flooding should be avoided and floodplains should be kept free from filling and other development. Areas with steep slopes, erodible soils and soils with severe limitations for the intended uses should not be utilized without overcoming the limitations

Figure II-1.2 Cross-Section of Flowing Waterway

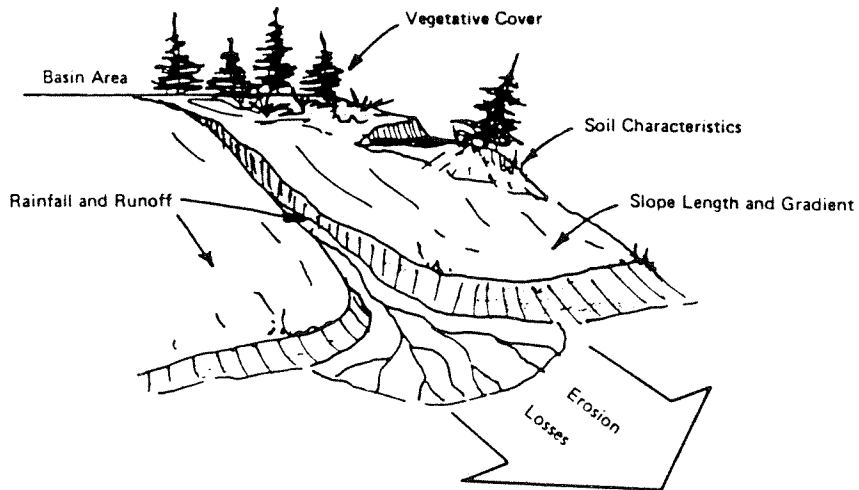
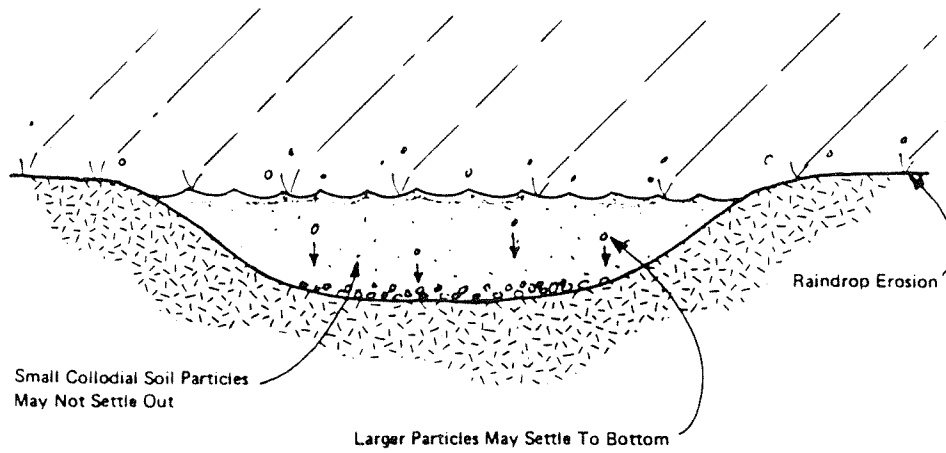
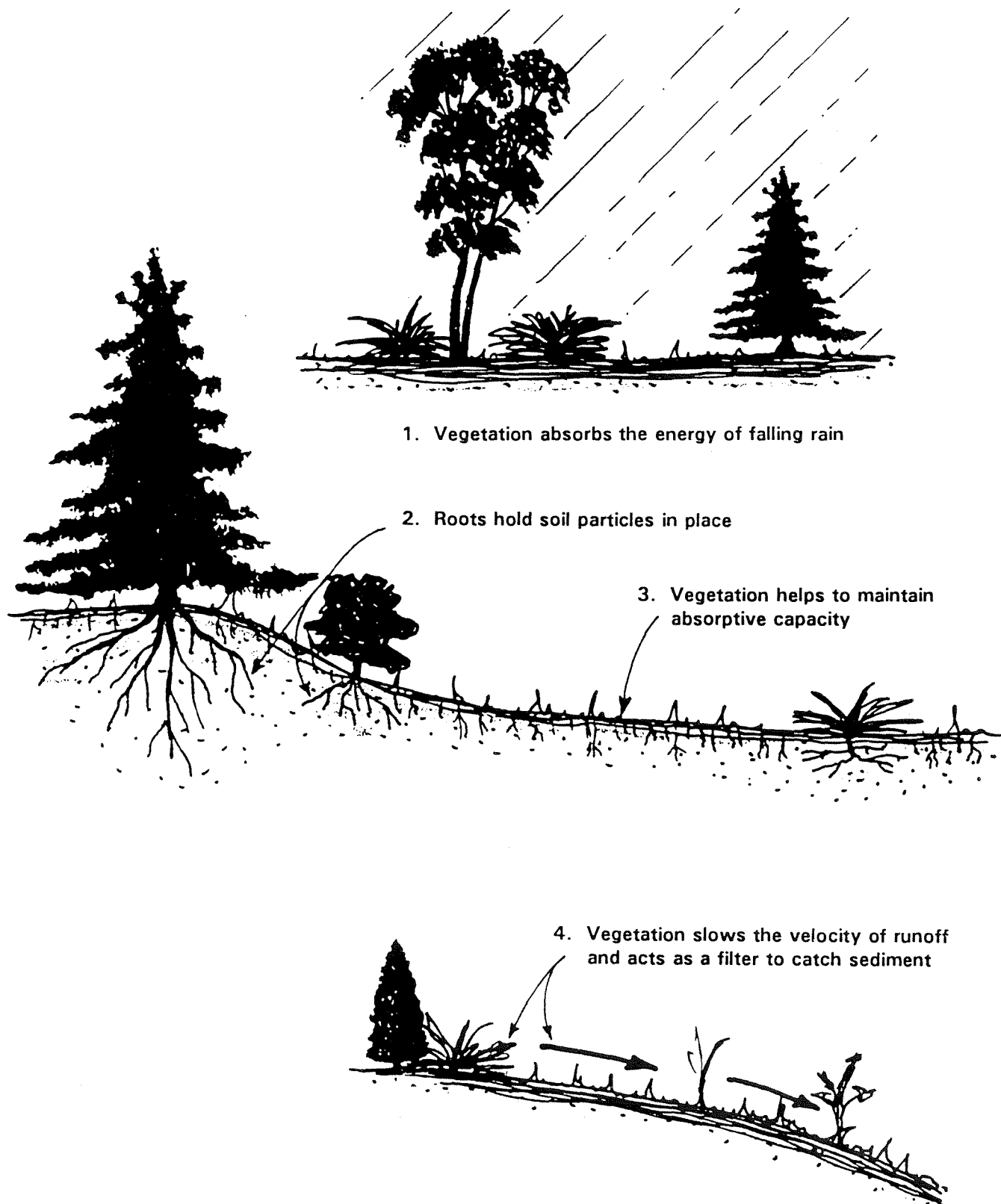


Figure II-1.3 Characteristics Which Affect Erosion Losses

Figure II-1.4 Effect of Vegetation on Stormwater Runoff



through sound engineering practices. For instance, long steep slopes can be broken by benching, terracing, or constructing diversion structures (see Chapter II-2.).

Erosion control, development, and maintenance costs can be minimized by selecting a site suitable by its nature for a specific proposed activity, rather than attempting to modify a site to conform to a proposed activity. This kind of planning can be more easily accomplished where there is a general land use plan based upon a comprehensive inventory of soils, water, and other related resources.

2. Minimize the Extent of the Area Exposed at One Time and the Duration of Exposure.

When earth changes are required and the natural vegetation is removed, keep the area and the duration of exposure to a minimum. Plan the phases or stages of development so that only the areas which are actively being developed are exposed. All other areas should have a good cover of temporary or permanent vegetation or mulch. Grading should be completed as soon as possible after it is begun. Then immediately after grading is complete, permanent vegetative cover should be established in the area. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated as the work progresses. This is known as staged seeding. Minimizing grading of large or critical areas during the period October-April reduces the risk of erosion.

3. Stabilize and Protect Disturbed Areas as Soon as Possible.

Two methods are available for stabilizing disturbed areas: mechanical (or structural) methods and vegetative methods. In some cases, these are combined in order to retard erosion. These control measures are discussed in Chapter II-2.

4. Keep Runoff Velocities Low.

The removal of existing vegetative cover and the resulting increase in impermeable surface area during development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control. Slope changes should be designed to keep slope length and gradient to a minimum. Short slopes, low gradients, and the preservation of natural vegetative cover can keep runoff velocities low. This will limit erosion hazards.

5. Protect Disturbed Areas from Stormwater Runoff.

Measures can be utilized to prevent off-site water from entering and running over the disturbed area. These protective measures are described in Chapter II-2.

6. Retain Sediment Within the Corridor or Site Area.

Sediment can be retained by two methods: (1) by filtering runoff as it flows and (2) by detaining sediment-laden runoff for a period of time so that soil particles settle out. The best way to control sediment, however, is to prevent erosion in the first place.

7. Implement a Thorough Maintenance and Follow-Up Program.

This last principle is vital to the success of the six other principles. A site cannot be effectively controlled without thorough, periodic checking of

Figure II-1.5 Slope Orientation Affects Erodibility

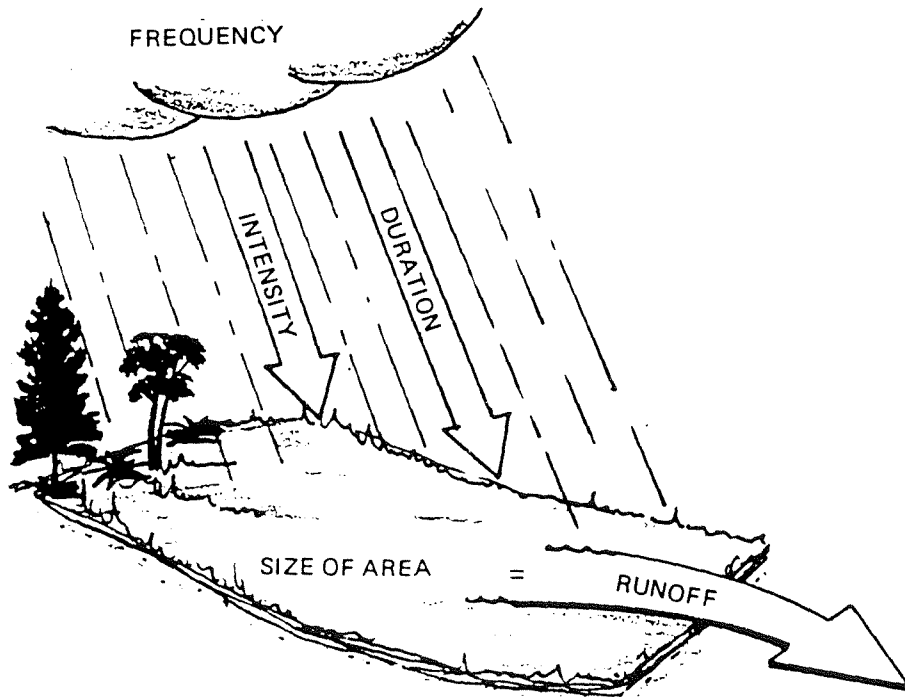
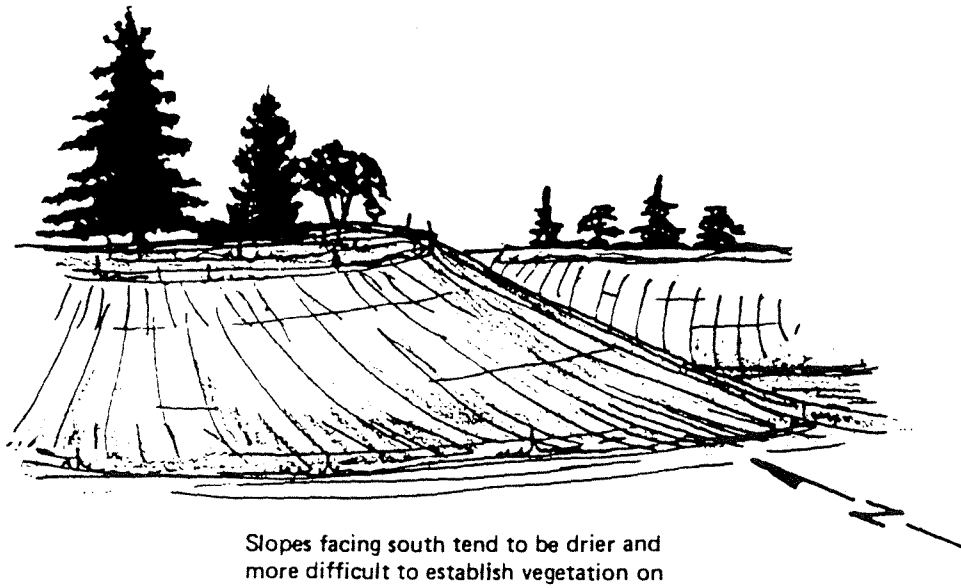


Figure II-1.6 Rainfall Characteristics Help to Determine Amounts of Runoff

the erosion and sediment control practices. These practices must be maintained just as construction equipment must be maintained and materials checked and inventoried. An example of applying this principle would be to start a routine "end of day check" to make sure that all control practices are working properly.

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## CHAPTER II-2

### BEST MANAGEMENT PRACTICES FOR PROBLEM AREAS ON CONSTRUCTION SITES

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## CHAPTER II-2

## BEST MANAGEMENT PRACTICES FOR PROBLEM AREAS ON CONSTRUCTION SITES

## II-2.1 BEST MANAGEMENT PRACTICES

Understanding the basic processes of erosion and sedimentation and the basic principles of control provides the foundation for developing and implementing a successful erosion and sedimentation control plan. This chapter will outline the types of erosion and sediment control measures (Best Management Practices) that can be applied before, during and after the development process. Best Management Practices (BMPs) are defined as physical, structural, and/or managerial practices, that when used singly or in combination, prevent or reduce pollution of water and have been approved by Ecology.

The purpose of this chapter is to provide guidelines and background information that will assist in choosing the most suitable BMPs to control erosion and sediment from construction sites. This is done by describing the major problem areas and the appropriate BMPs that could be implemented to manage the problem. Complete standards and specifications for each BMP are provided in Chapter II-5.

Best Management Practices are those practices that are currently believed to provide the most effective, practicable means of preventing or reducing pollution generated by non-point sources. They are used to implement the general principles presented in the previous chapter. Most importantly, they change with time, as we discover or become aware of other practices that better accomplish their purposes.

Most of the BMPs presented in this manual either minimize erosion or control sedimentation. In any construction project, it is most important to do everything feasible to prevent erosion first. Stabilizing slopes, creating natural vegetation buffers, diverting runoff from exposed areas, controlling the volume & velocity of runoff and conveying that runoff away from the development area all serve to decrease erosion. Silt fences, sediment traps and diversions all trap sediment before it leaves the site. Sedimentation control should only deal with the sediment produced from unavoidable erosion.

Best Management Practices fall into a number of categories. Frequently they are split into cover BMPs, including grasses, mulches or other materials used to stabilize soil surfaces, or structural BMPs including check dams, sediment ponds (basins)<sup>1</sup>, diversions and other structural techniques. Most sites require the use of several types of BMPs to adequately control erosion and sedimentation, so vegetative BMPs and structural BMPs are often used together to address a single problem. BMPs may be temporary or permanent. Soil that is exposed for a lengthy time is a large contributor to erosion and it should be stabilized as soon as possible. Thus, a temporary control measure (vegetative or structural), may be used because more grading will be needed later in the project or because putting in a permanent control is not immediately feasible. Measures left in place for a year or less are generally considered temporary (Figure II-2.1). In some cases temporary BMPs can be planned into a development in such a way that they may become permanent as completion of various phases of the development occurs. For example, sediment ponds can, with modification, function as permanent detention ponds (Figure II-2.2).

#### Monitoring and Maintenance

No matter whether BMPs are temporary or permanent, structural or vegetative, monitoring and maintenance of BMPs is vital. The importance of maintenance has been supported by a survey of BMPs by the King County Conservation District (1).

---

<sup>1</sup> The terms sediment pond and sediment basin are used interchangeably.

Table II-2.1 Categories, Examples and Effectiveness of BMPs  
(adapted from Reinelt, 1991)

Site Design and Construction Management:

- Preserving Natural Vegetation\*
- Buffer Zones\*
- Gradient Terraces\*
- Dust Control

Site and Drainage Way Stabilization

- Stabilized Construction Entrance\*
- Riprap
- Construction Road Stabilization
- Vegetative Streambank Stabilization
- Bioengineering Protection of Very Steep Slopes
- Bioengineering Methods of Streambank Protection
- Structural Streambank Protection

Flow Diversion

- Interceptor Dike and Swale\*
- Level Spreader
- Pipe Slope Drains
- Subsurface Drains

Overland Flow Management

- Biofilters (see Chapter III-6)
- Temporary Seeding of Stripped Areas\*\*
- Permanent Seeding\*\*
- Mulching and Matting\*\*
- Plastic Covering
- Sodding\*\*
- Topsoiling
- Inlet Protection
- Outlet Protection
- Check Dams\*\*
- Surface Roughening

Sediment Trapping

- Filter Fence\*\*
- Brush Barrier
- Straw Bale Barrier\*\*\*
- Gravel Filter Berm
- Sediment Trap\*\*\*
- Sediment Pond\*\*

Effectiveness Ratings (from the King County Conservation District)

- Most Effective \*
- Moderately Effective \*\*
- Least Effective \*\*\*

Note: Effectiveness ratings are not available for all BMPs listed.

Preliminary results indicate that the major reason for BMP failure is poor maintenance. BMPs should be inspected regularly, particularly before, during, and after a major storm. Specific maintenance requirements of individual BMPs are dealt with in Chapter II-5.

#### II-2.1.1 Problem Areas

The remainder of this chapter will examine particular problem areas of the construction site (such as slopes or surface drainageways) and will describe which BMPs best alleviate problems associated with each area. The areas are:

1. Slopes
2. Streams and Waterways
3. Surface Drainageways
4. Enclosed Drainage Inlets and Outfalls
5. Large, Flat Surface Areas
6. Borrow Areas
7. Adjacent Properties

A listing of the BMPs and the problem area, or areas, they are appropriate for, is presented as a uniform coding system in Table II-2.2 at the end of this chapter. This has been introduced to promote uniformity in the specification and presentation of BMPs on Erosion and Sedimentation Control (ESC) plans. Each BMP has been assigned a specific number, code and symbol.

Assigned numbers should be used to identify BMPs in the narrative or other written portions of the plan, while the practice symbol should be used to identify practices on the map or site plan. The BMP can be further defined to indicate whether it is proposed as a temporary or permanent measure by using the notation "t" or "p". For example SOP = permanent sodding; STt = temporary sediment trap. The practice symbols are based upon similar systems used in other states such as Virginia and Maryland. We hope that the system will become widely used so that ESC plans will become more uniform and understandable throughout the Puget Sound basin.

Note: The American Society of Agricultural Engineers (ASAE) is proposing to standardize mapping symbols for erosion and sediment control structures and practices. These symbols differ somewhat from those now in this manual, as they are based on another resource. Since those symbols are still in the discussion stage, we have chosen to continue to use the practice symbols found in the Virginia manual.

#### **II-2.2 SLOPES**

Slopes greatly increase the potential for erosion. As slope length and steepness increase, runoff velocity increases. This increases the capacity of water to detach and transport soil particles. Steeper slopes usually have faster runoff velocities, less infiltration and more erosion than less steep slopes.

Modifying a slope by clearing existing vegetative cover also increases its vulnerability to erosion. Vegetation slows down runoff velocity and root systems hold soil particles in place. Vegetation maintains the soil's capacity to absorb precipitation. The following conditions indicate a need for special care when modifying or creating a slope:

1. Extensive length.<sup>2</sup>
2. Moderate to extreme steepness. (greater than about 7%)
3. High soil erodibility.
4. Difficulty of reestablishing vegetative cover.

Vegetative stabilization, diversion measures, slope drains and slope stabilization measures may counteract problems created by modifying slopes.

II-2.2.1 Vegetative Stabilization Techniques (BMPs E1.10, E1.15, E1.30, E1.35, E1.40)

**Vegetative Buffer Strips**

Maintaining a natural vegetative buffer or filter strip at the base of a slope retains sediment on site and is the preferred method for control of erosion. If the natural vegetative cover is left, other cover techniques such as mulch or plastic covering will not have to be used. Undisturbed vegetation is by far the best method to maintain unstable slopes. If the natural vegetative covering must be disturbed, methods such as placing sod strips at intervals along the face of the slope also help (Figure II-2.8). These measures help slow runoff, trap sediment, and reduce the volume of runoff.

Grass or grass and legumes are the most commonly used plant material for stabilizing slopes. Plants are usually established in one of three ways (Figure II-2.9):

1. Hydro-seeding: A mixture of seeds, fertilizer, and water is sprayed on the slope. A mulch and a mulch tacking agent can also be applied. This method is effective on large areas.
2. Standard seeding: Seed is drilled or broadcast either mechanically or by hand. A cultipacker or similar tool is used after seeding to make the seedbed firm and to provide seed covering. The proper timing of seeding, mulching, and watering is important for areas seeded in this manner.
3. Sodding: Sod strips are laid across the slope and in this way instant cover is provided. Sod should be placed on a prepared bed and pegged on steep slopes. Watering is important. This method is effective and is often used on steep slopes.

II-2.2.2 Diversion Measures Used to Control Erosion (BMP E2.55)

A dike, ditch or a combination dike/ditch can divert runoff from the face of an exposed slope. For short slopes, placing these diversion measures at the top works well. For longer slopes, placing the dikes or ditches across the slope at intervals effectively reduces slope length. Temporary diversions must remain in place until slopes have been permanently restabilized.

Diversion ditches can be bare channels, vegetatively stabilized channels, or channels lined with a hard surface material (Figure II-2.3). To determine what size and design is appropriate for each situation consider the following:

1. The amount of runoff to be diverted.
2. The velocity of runoff in the diversion.

---

<sup>2</sup> As a general rule there will be a potential hazard if slope lengths exceed the following: 0-7% - 300 feet; 7-15% - 150 feet; >15% - 75 feet.

3. The erodibility of the soils on the slope.
4. The erodibility of the soils within the channel.

When properly constructed, diversions minimize runoff over disturbed slopes. They may also collect runoff and divert it to a sediment trap or pond.

Since diversions concentrate the volume of surface runoff, they increase its erosive force. The contractor should release runoff onto a stabilized area to reduce erosion potential. Gradually reducing the slope of the diversion channel is sometimes adequate. The contractor may also use level spreaders, or stormwater conveyance channels such as grassed waterways (Figure II-2.4).

II-2.2.3 Slope Drains (BMPs E2.25, E2.70)

Where disposing of runoff laterally is unsatisfactory, the contractor may drain it over the slope face. Slope drains can run down the surface of the slope as sectional downdrains, paved chutes, or pipes placed beneath the ground surface (Figure II-2.5).

On-surface sectional downdrains are usually pipes made of corrugated metal, bituminous fiber, or other material; these slope drains are temporary. Paved chutes covered with a surface of concrete or bituminous material are usually permanent. Subsurface pipes are also permanent.

The contractor should protect against erosion at the inlet; otherwise undercutting at the lip of the drain and piping under the drain frequently occur. Compacting the soil carefully at the mouth of the slope drain and anchoring it adequately can prevent this undercutting. Also, any areas cleared to construct the drain should be revegetated and stabilized.

Figure II-2.1 Temporary Control Measures Used During Construction

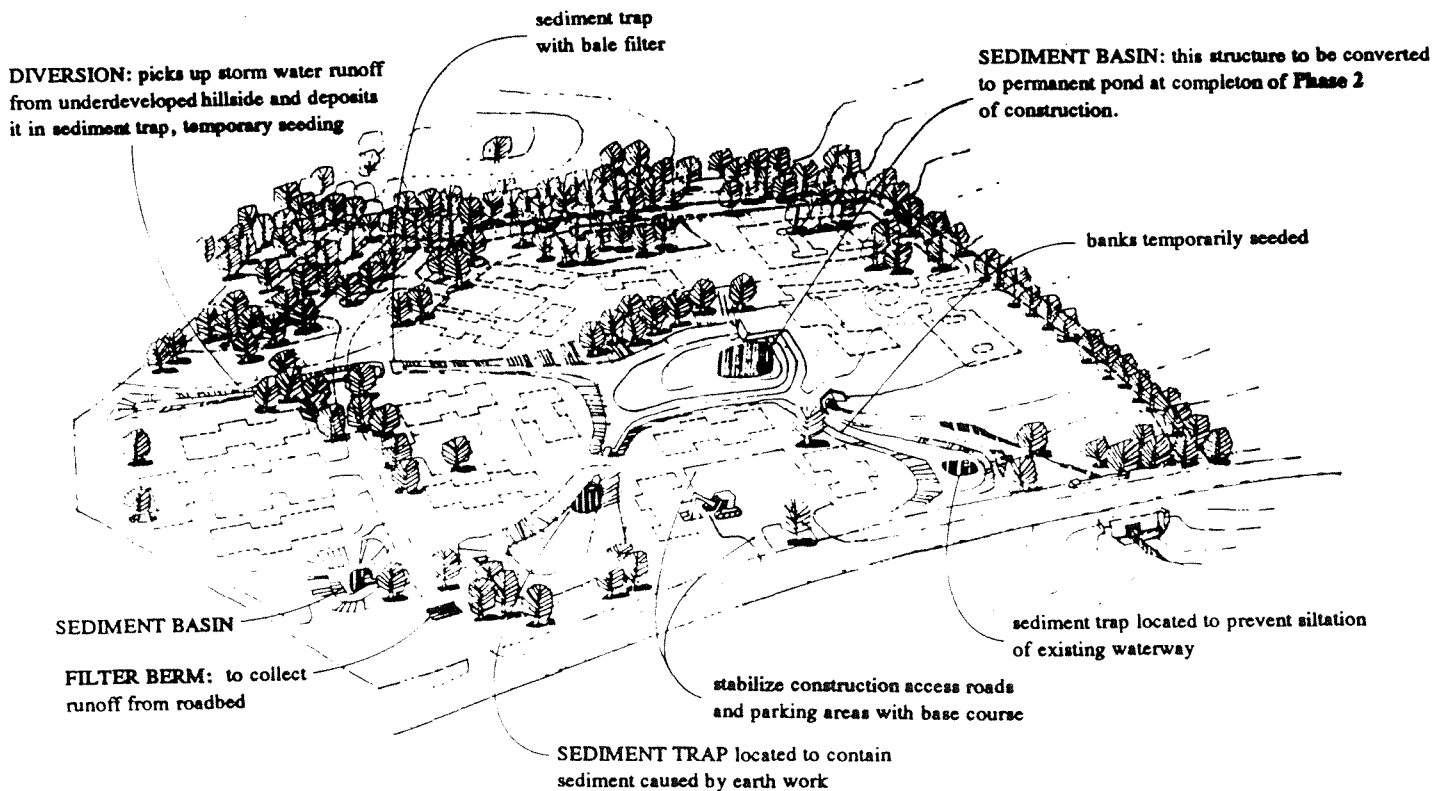
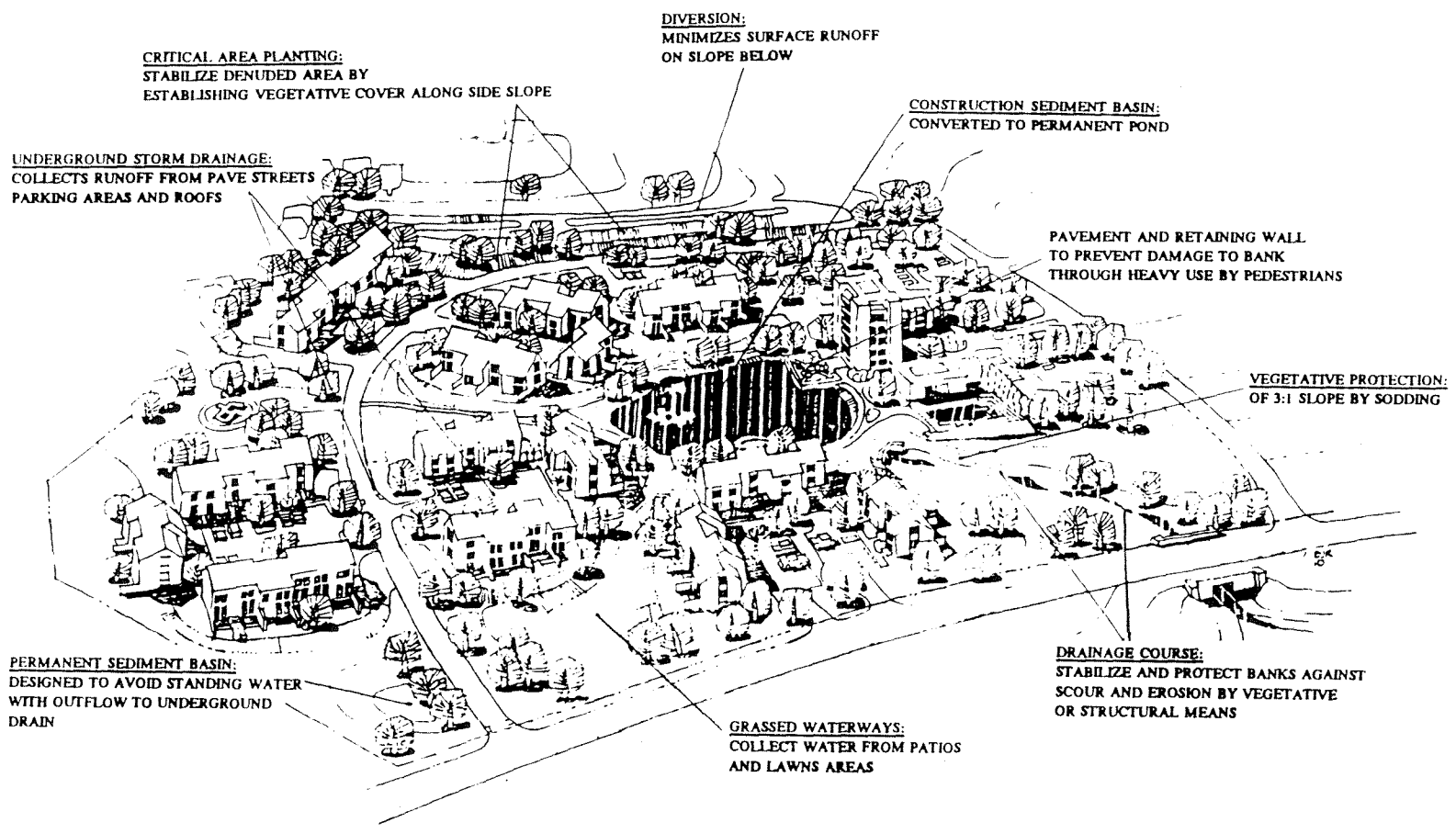


Figure II-2.2 Many Temporary Measures can be Made Permanent





At the slope drain outlet, energy dissipators (such as riprap) are frequently necessary. Not using a dissipator can result in serious erosion problems at the outflow end of the drain. The dissipator slows the velocity of the runoff to a nonerosive level. Riprap is one effective energy dissipator.

#### II-2.2.4 Structural Slope Stabilization Measures (BMPs E2.35, E2.40, E2.45)

The most effective way to decrease erosion is to avoid modifying slopes. The angle of repose naturally achieved is the most stable for that soil type and situation. However, during construction it is often necessary to modify existing slopes or to create non-natural slopes. Cut and fill slopes are a good example.

One way to stabilize slopes is to reduce their steepness. To choose an appropriate slope ratio we consider the soil's stability, drainage characteristics, and erodibility. The type of vegetative cover and the type of maintenance are also important.

To reduce extreme slope a developer may use retaining walls (Figure II-2.6). Retaining walls are often used when a slope is too steep to establish and maintain vegetation. They obviate disturbance of the upper parts of natural slopes when lower parts are disturbed. Thus, trees or other naturally stable vegetation can be maintained. The cost of building retaining walls is significant but many areas are difficult or impossible to stabilize otherwise. Another way to protect slopes against erosion is to reduce length by using diversions or benches, as previously mentioned.

When slopes are disturbed, leaving them rough reduces velocity and increases infiltration rates. Rough slopes hold water, seed, and mulch better than smooth slopes. (2) Slope surfaces can be roughened by running wheeled construction equipment across the slope, or tracked equipment up and down the slope face. The grooves created by the construction equipment should run across the slope horizontally, and not up and down the slope. Slopes can also be scarified to produce the desired surface roughness (Figure II-2.7).

A suitable soil, good seedbed preparation, and adequate lime and fertilizer are required for all of these methods. However, special precautions need to be taken to avoid nutrients (especially phosphorus) from fertilizers being washed into waterways.

If final grading is delayed more than a few days, the contractor should stabilize exposed slopes immediately after completing rough grading. For short periods of protection either temporary mulching or temporary seeding and mulching together should be used.

When slopes are cut to final grade, permanent vegetative stabilization measures are implemented. Selecting appropriate plant materials depends on:

1. Soil and climate conditions.
2. Duration, quantity, and velocity of runoff.
3. Time required to establish cover.
4. Maintenance requirements.
5. Site use.

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Figure II-2.3 Diversion Control Measures

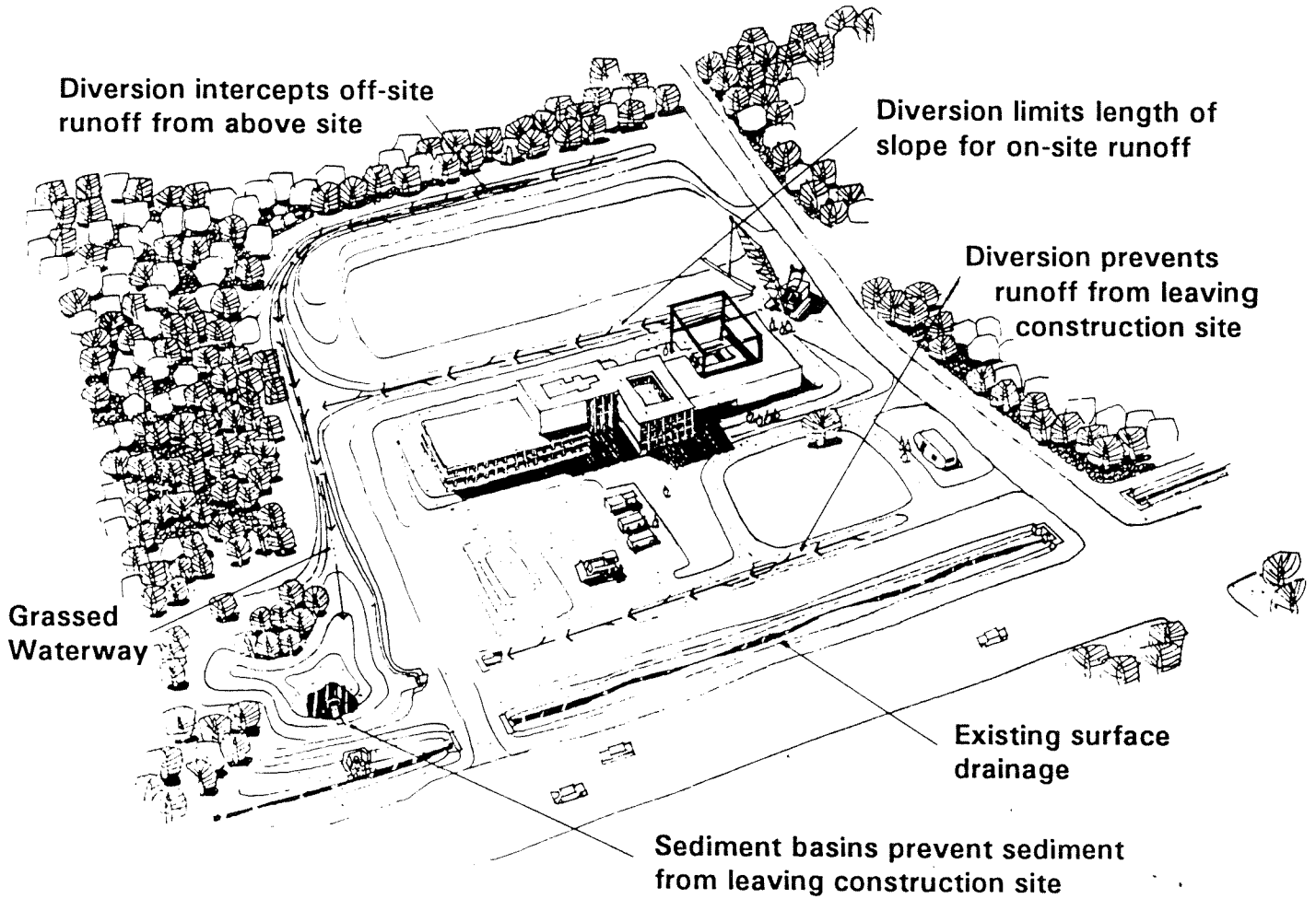
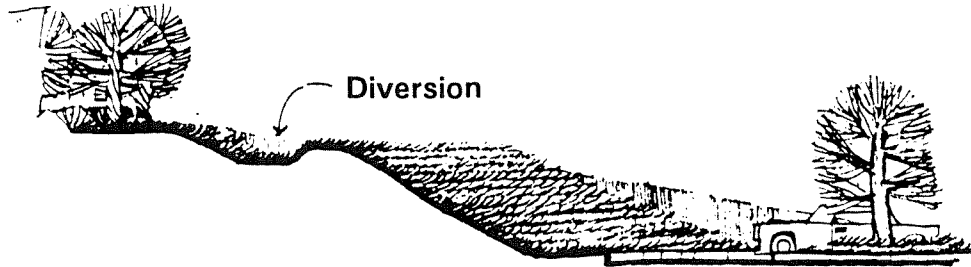
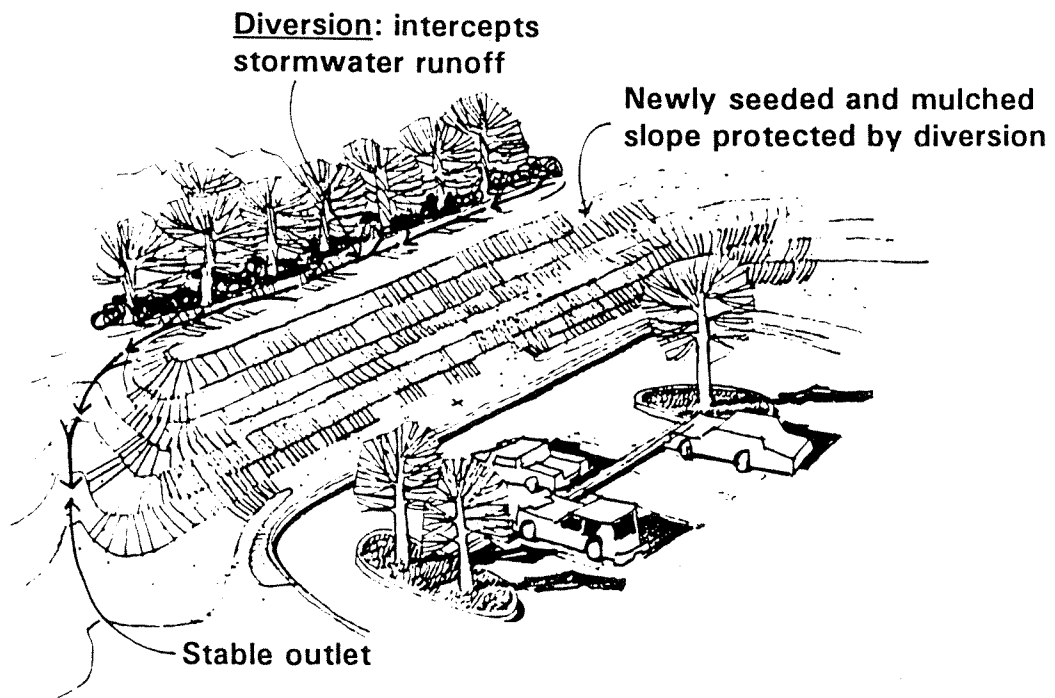


Figure II-2.4 Diversion Control Measures

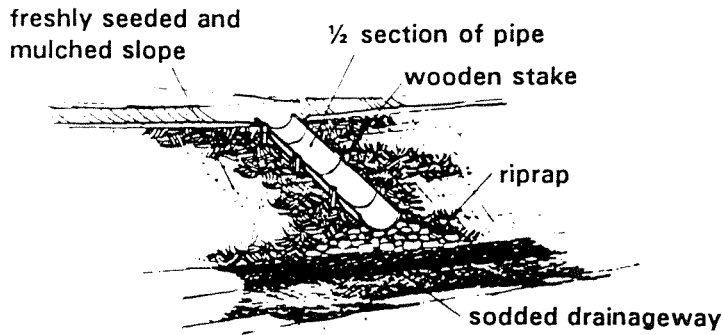


SECTION OF DIVERSION AT TOP OF SLOPE

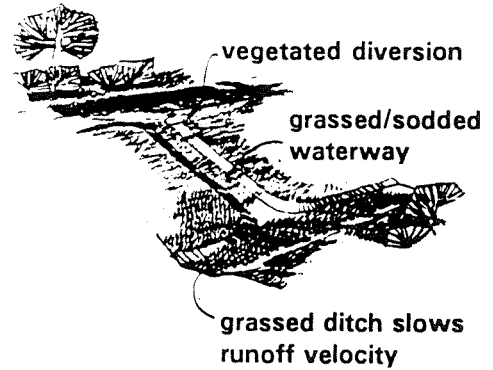


**DIVERSION OF CONTROL MEASURES CAN INTERCEPT  
STORMWATER RUNOFF BEFORE IT REACHES SLOPES**

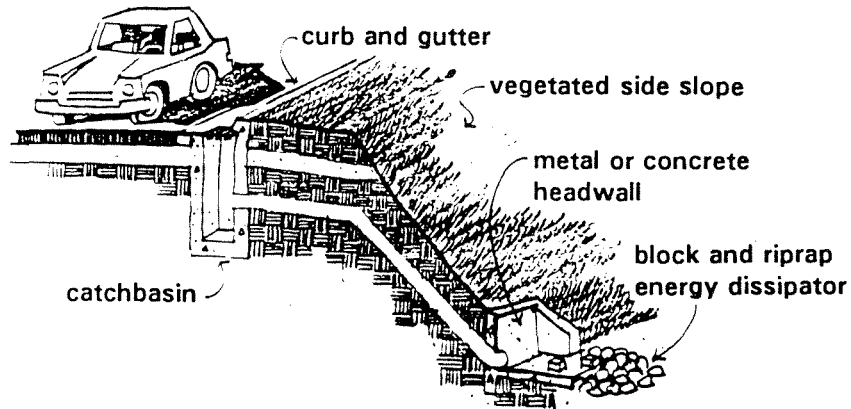
Figure II-2.5 Slope Drains



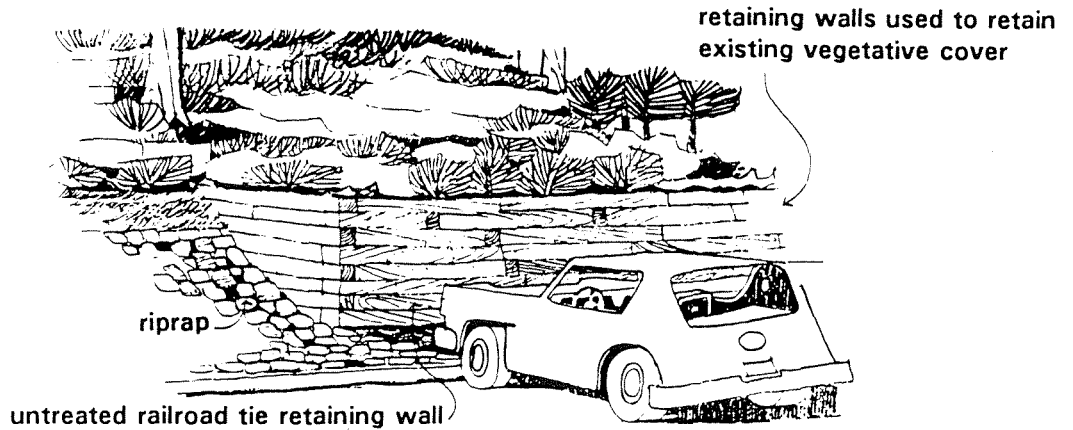
SECTIONAL DOWNDRAIN



CHUTE SLOPE DRAIN



DOWNSPOUT SLOPE DRAIN



RETAINING WALLS USED TO RETAIN EXISTING VEGETATIVE COVER

Figure II-2.6 Use of Retaining Walls

Establishing grass successfully requires that contractors:

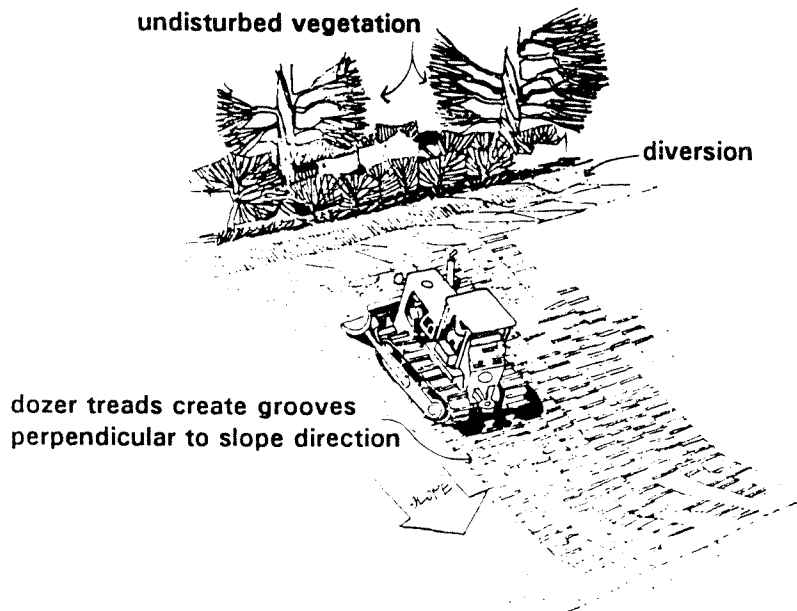
1. Select proper seeding mixture for the site.
2. Observe seeding dates.
3. Cover area to be seeded with topsoil.
4. Prepare seedbed and plant properly.
5. Apply the correct amount of fertilizer for the specific seed or plant type.
6. Protect slope from wind and water erosion during establishment.
7. Ensure that adequate water is available during establishment and in dry periods, if necessary (by natural or other means).

Clear plastic covering provides immediate protection to slopes that cannot be prepared and seeded during the seeding period and/or during initial establishment of seeded areas. However, plastic covering also increases the quantity and velocity of runoff, requiring safe disposal of it onto stabilized areas. Additionally, plastic becomes a disposal problem once it is removed from the slopes it is protecting. Generally, mulches are a better solution for covering exposed areas.

#### Mulches

Mulching after permanent seeding as well as before seeding protects exposed areas for short periods. Mulches decrease the impact of falling rain, slow runoff velocity and increase the capacity of the soil to absorb water. Mulches hold seeds in place, preserve soil moisture, and insulate germinating seeds from the extremes of heat and cold. Many mulches are available: these include straw and woodchips.

Figure II-2.7 Slope Roughening



**Unvegetated Slopes Should Be Temporarily Scarified To Minimize Runoff Velocities**

Most mulches must be anchored. Another alternative is to disc the mulch just enough to anchor it. While tacking agents can be used, they are only effective under the right conditions and cannot be used to try and solve problems with unsuitable soils or excessively steep slopes.

#### Special Problems

On fill slopes, compaction can be a major factor in erosion control. In addition to other compaction controls required by the nature of the project, the minimum criterion recommended for successful erosion control on fill slopes is to meet or exceed the standards described in WSDOT Standard Specifications Section 2-03.3(14)C "Compacting Earth Embankments." (3) Running heavy equipment over the fill usually compacts it adequately. Formal testing may not be required. On cut slopes, ground water seepage can cause erosion problems. Seepage causes piping and soil slippage. (4)

Slope is an important factor in the success of vegetative restabilization measures. On steep slopes (2:1 or steeper; 2 feet horizontal distance to 1 foot vertical rise) normal tillage equipment cannot be used to prepare a seedbed. Stormwater runoff will result in the loss of seeds, fertilizer, and soil. Sod can be used to stabilize steep slopes instead of seeding where grades are more than 2:1. Sod on steeper slopes must be anchored with pegs.

Sandy soils present a special problem for establishing vegetation, especially in areas where the sand is deep and droughty. American beach grass is one solution to this problem. This plant is established by hand planting live plants.

Steeply sloped areas such as lake shores and road banks involve three special considerations:

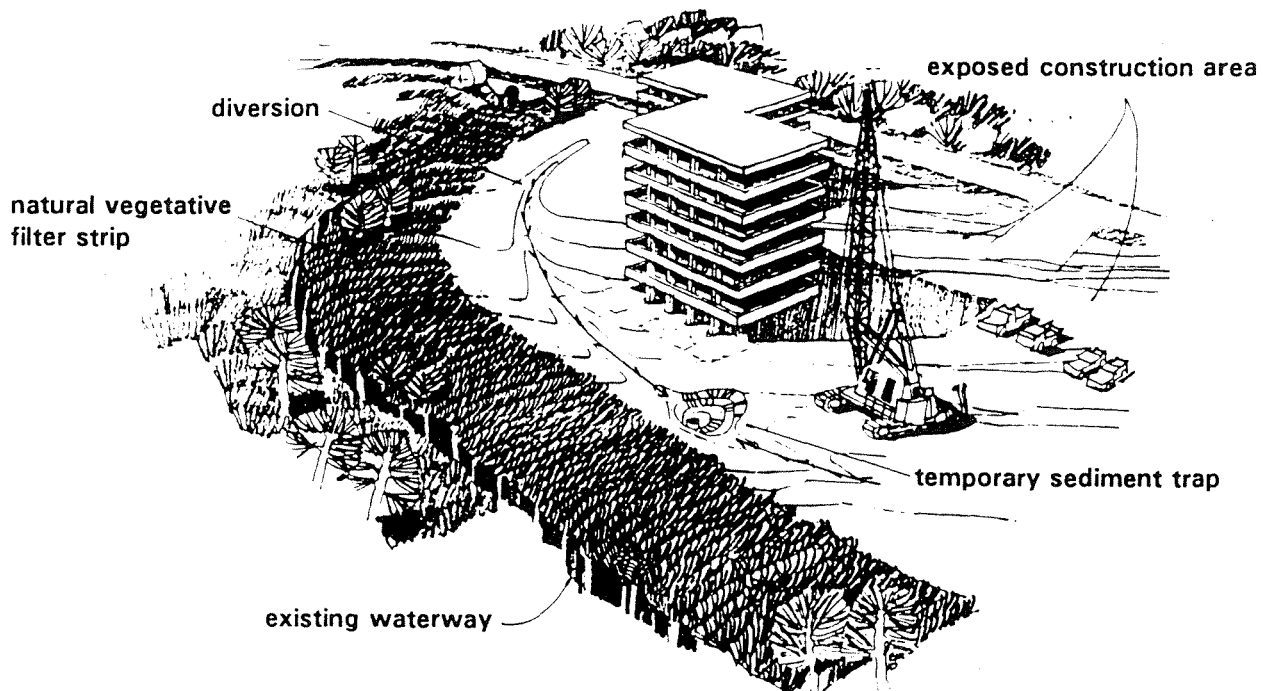
1. To ensure probability of successful stabilization, banks should consist of slopes that are 2:1 or flatter.
2. The toe of the slope must be protected from undercutting or other erosive forces by mechanical means where necessary.
3. Water seepage coming out on the face of the slope should be intercepted by a properly designed drainage system (Figure II-2.10).

#### II-2.2.5 Summary

This section reviewed a range of choices available for erosion control on slopes. These measures may protect other areas exposed during development. A summary follows:

1. **Diversion measures:** Diversions can intercept stormwater runoff before it reaches disturbed slopes or other exposed areas. They can also collect runoff and convey it to a sediment basin or other suitable location.
2. **Vegetative buffer strips:** Natural vegetative filters retain sediment on-site. The contractor can significantly reduce erosion on slopes through proper application of these control measures.
3. **Slope stabilization control measures:** Slopes can be stabilized both mechanically and vegetatively. A slope exposed for longer than a few days should be stabilized by using temporary mulching and seeding. Retaining walls reduce slope and stabilization problems.

Figure II-2.8 Natural Vegetative Filter Strips



**NATURAL VEGETATIVE FILTER STRIPS HELP TO MINIMIZE SEDIMENTATION**

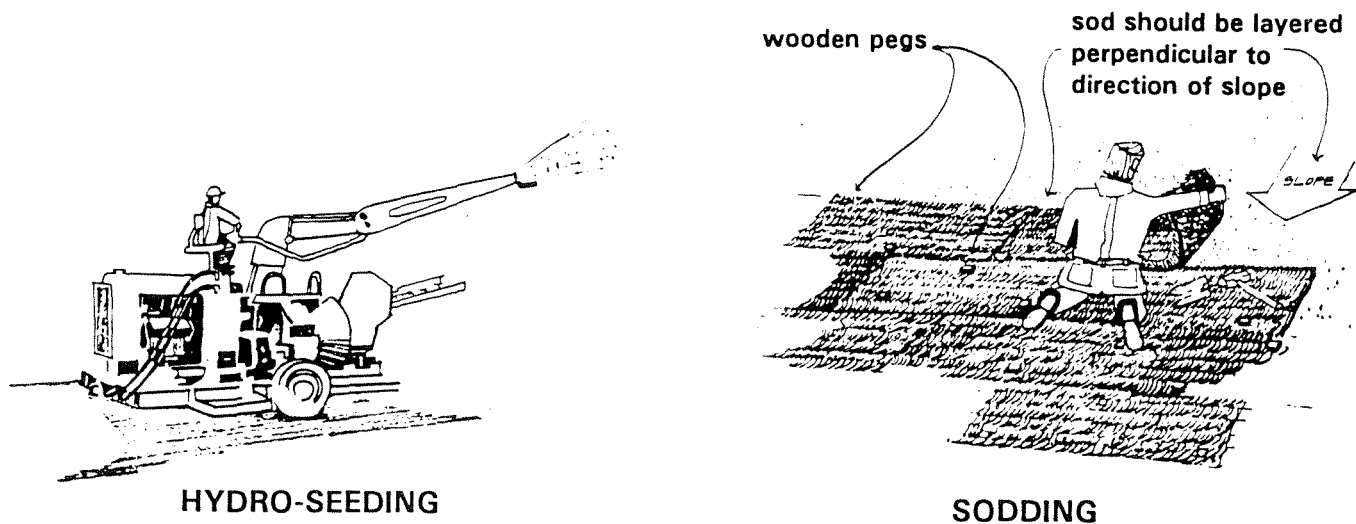


Figure II-2.9 Seeding Methods



### II-2.3 STREAMS AND WATERWAYS

Protecting streams and waterways on and near sites undergoing development and protecting areas downstream from development involves three goals:

1. The increased sediment loads carried by surface runoff from areas under construction must not be allowed to enter streams.
2. Stream banks must be protected from erosion hazards caused by increases in runoff volume and velocity.
3. The rates of release of increased volumes of runoff into streams and waterways and the velocity of flow in stream channels must be controlled.

There are several characteristics that serve to identify streams that are particularly vulnerable to erosion. Streams which have a small channel capacity and steep banks are very susceptible to erosion. Streams which flow through areas of erodible soil and streams with sharp meanders or bends in the channel alignment are also prone to erosion (4). Before development begins, nearby streams should be analyzed to identify potential problem areas.

#### II-2.3.1 Streambank Stabilization Measures (BMPs E2.75-2.90)

The maintenance of existing vegetation on stream banks is a fundamental principle of erosion and sedimentation control. Streambank vegetation serves to stabilize the soil, slow runoff and dissipate its erosive energy, and to filter sediment from runoff. To prevent the destruction of streambank vegetation, stream crossing and construction traffic along the banks must be controlled. Culverts or temporary bridges for vehicle crossings should be constructed only where necessary (Figure II-2.11).

**(Note: federal, state and local permits may all be required before streambank (or near streambank) work can commence - see Chapter I-3.**

#### Vegetative Measures

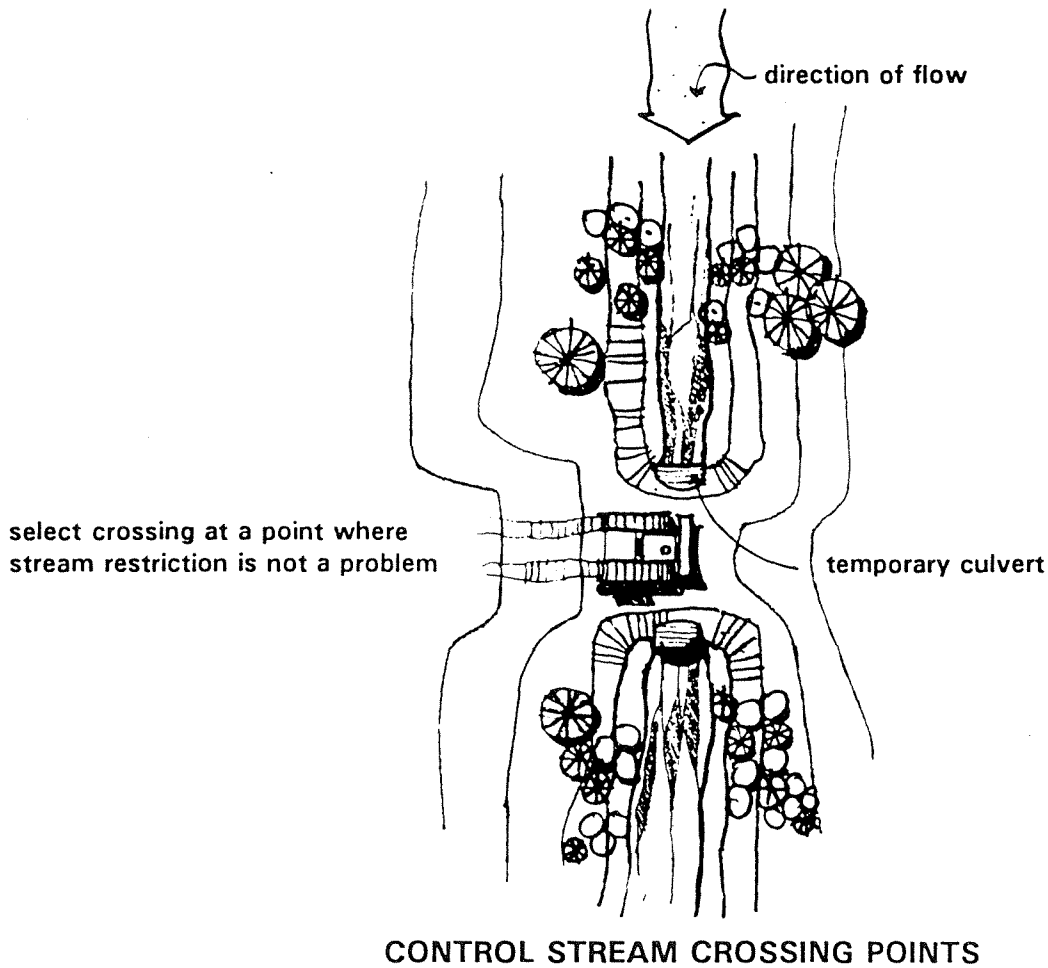
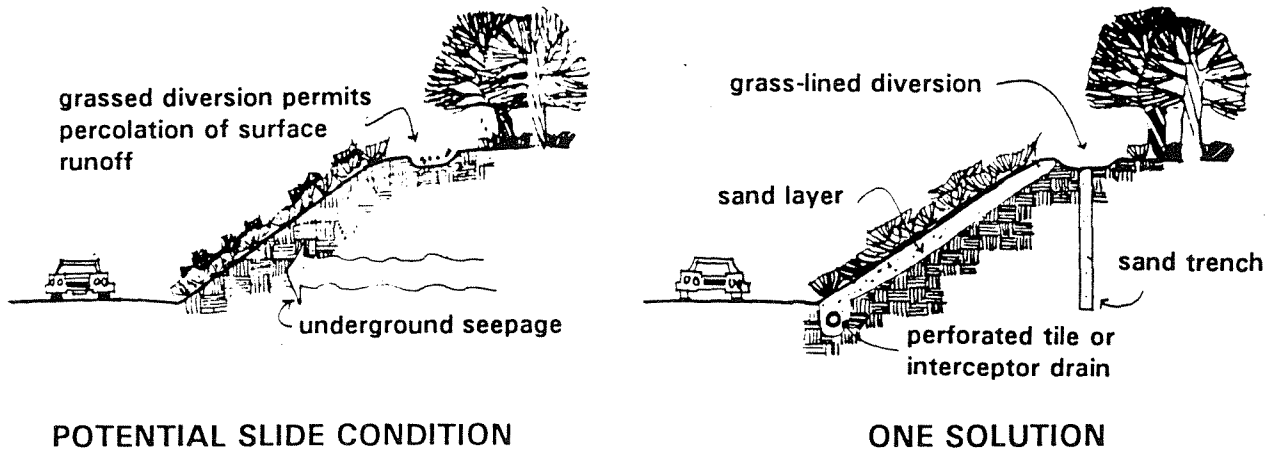
Where stream banks must be disturbed or where existing cover is inadequate, grass or grass-legume mixtures may be established. Immediately after grading on stream banks has been completed, vegetative restabilization measures must be initiated. Willows and other natural vegetation, as well as grass and legumes, are recommended for the protection of stream banks. Woody vegetation is used where ice damage may occur.(6)

#### Structural Measures

Stream banks can be protected from erosion by structural as well as vegetative measures. Where vegetation will not provide sufficient protection, banks can be protected with revetments and deflectors, as well as other mechanical measures. However, willows and other vegetation can also be used in conjunction with structural measures. This is a biomechanical approach. Biomechanical and vegetative methods are always preferred over purely structural measures, which only should be used when absolutely necessary.

Revetments, which cover the banks, are commonly used where sharp bends or constrictions in the stream channel (such as culverts, bridges, or grade control structures) occur. Riprap, gabions, sacked concrete, and concrete or asphalt paving are commonly used as revetment materials. Deflectors consist of jetties or pilings that angle outward from the bank in a downstream direction and deflect currents away from vulnerable bank areas (Figure II-2.12).

Figure II-2.10 Slope Drain



CONTROL STREAM CROSSING POINTS

Figure II-2.11 Stream Crossing

II-2.3.2 Sediment Control Measures (BMPs E2.60, E3.10 through 3.40)

The first essential step in preventing sediment from entering streams and waterways is to control erosion on construction sites. A second necessary step in sediment control is to trap sediment that is transported by runoff before it reaches streams and waterways or leaves the construction site.

To trap sediment, the runoff must be detained for a sufficient period of time (up to 40 hours or longer) to allow the suspended soil particles to settle out. The amount of sediment which is deposited will depend on the speed at which runoff flows through the sediment trap, the length of time that runoff is detained, and the size and weight of the soil particles which are in suspension (6).

Several techniques are available for controlling the amount of sediment which reaches streams and waterways. Vegetative filter strips (preferably strips left in their natural state) between streams and development areas serve to slow runoff and filter out sediment. Check dams can also be constructed in drainageways. Check dams placed at regular intervals within a drainage channel are a temporary sediment control measure that is easy and economical to construct (Figure II-2.13). Barriers are constructed of bags filled with peagravel or crushed rock and stacked in an interlocking manner which is designed to trap sediment and reduce the velocity of flow. Bags filled with peagravel tend to filter the water. They do not totally block the flow like sandfilled bags.

Piping, or undercutting, can be reduced by setting the bags at least 6 inches into the bottom of the drainageway and compacting excavated soil along the upstream side (Figure II-2.14).

Streams may also be protected from increased sediment loads by trapping runoff in sediment basins or ponds before it is released into stream channels. In addition to trapping sediment, these basins are designed to release runoff at nonerosive rates. Such sediment basins can be constructed by excavating a pit or by construction of an impoundment (Figure II-2.15).

Sediment basins often consist of an earthen dam, mechanical spillway (including a perforated riser pipe), and an emergency spillway. The construction of sediment basins should be completed before clearing and grading begin. They are generally located at or near the low point of the site. Points of discharge from sediment basins must be stabilized. In many developments these temporary sediment basins may be converted into permanent retention/detention basins (Figure II-2.16).

II-2.3.3 Summary

The two categories of BMPs used to protect streams and waterways from erosion and sedimentation are:

1. **Streambank stabilization BMPs:** Streambanks can be stabilized by using vegetative or mechanical control techniques. Deciding which method is appropriate includes factors such as the volume and velocity of water in the stream, the gradient and shape of the stream, and maintenance of control measures.
2. **Sedimentation control BMPs:** It is necessary to prevent sediment from entering streams and waterways and this can be done by using vegetative filters and sediment traps or basins and check dams. Sediment traps and basins can be either temporary or permanent. Sediment traps are usually temporary and are removed and filled in after construction. Permanent sediment ponds may become a part of the final development in the form of ponds or small lakes. These ponds can be attractive after development is completed.

## II-2.4 SURFACE DRAINAGEWAYS

Surface runoff, and runoff intercepted by erosion control measures such as diversions, must be collected by drainageways and let out in stabilized areas, storm sewers, or sediment basins. The design of these drainageways ensures that runoff is transported without risk of erosion or flooding. Unless surface drainageways are adequately designed, constructed, and maintained, they can become a major source of sediment pollution.

Development should be planned to maintain and utilize the naturally stabilized drainageways that exist on a site. Increases in runoff volume and velocity because of changes in soil and surface conditions during and after construction must be anticipated and controlled to the maximum extent possible. Where the capacity of the natural site drainage channels is exceeded, additional capacity, stabilizing vegetation, and/or structural measures may be needed.

Allowable design velocities vary with soil conditions, the character of the channel lining, and anticipated runoff volume. Formulas and techniques for determining runoff flows, channel cross sections, slopes, stabilizing covers, and design velocity are discussed in Volume III, Chapter III-2 instead of this volume to avoid duplication in BMPs.

### II-2.4.1 Grade Control Structures

To reduce the velocity of runoff in drainageways, a variety of grade control structures can be used. These structures can be either temporary or permanent depending on the long-range requirements for the site. Pipe drops and drop spillways can be used.

### II-2.4.2 Summary

Erosion and sedimentation from surface runoff can be minimized through the use of the following:

1. Grassed waterways: These channels may be stabilized through seeding and mulching or with sod, and are the preferred form of conveyance.
2. Lined channels: Lined channels should be used where water velocities are high, but are an undesirable alternative to grassed waterways.
3. Grade control structures: In some cases, grade control structures are necessary to reduce runoff velocity to non-erosive levels. Care should be taken to ensure the protection of channel sides and bottoms.

## II-2.5 ENCLOSED DRAINAGE: INLET AND OUTFALL CONTROL

The capacity of vegetated drainage channels may be exceeded by the increases in runoff caused by construction activities. As a result, vegetatively-lined channels may scour and erode. Enclosed storm sewers can safely convey runoff of high concentrations and velocities; they can also serve to decrease the velocity of runoff and release it at preferred rates of flow. The following factors should be considered in determining when to use a storm sewer:

1. Whether or not existing enclosed storm sewers are available within reasonable proximity to the site or if there is a natural outlet available.
2. What the actual size of paved areas is and what the ratio of paved areas is to vegetated areas.

The installation of storm sewers, grassy swales, and other runoff control systems before major building construction begins can aid in controlling site runoff and in avoiding erosion hazards. Volume III contains BMPs for runoff quality and quantity control.

Diversions and surface drainageways are needed to intercept runoff and to convey runoff to storm sewers.

#### II-2.5.1 Drain Inlet Sediment Filters (BMPs E3.30, E3.35)

The capacity of the storm sewer system itself can be severely impaired by sediment deposits within the system. Sediment should be prevented from entering the enclosed storm sewer by the use of small sediment traps or sumps and filters at system inlets. Filters made of crushed rock, gravel, or sod, can be placed at inlets where sediment traps cannot be constructed (Figures II-2.17 and II-2.18). It is essential to regularly check and clean out these sediment traps and filters to insure that they function properly.

#### II-2.5.2 Enclosed Drains and Sediment Basins (BMP E3.40)

Where enclosed drainage systems do not tie into existing storm drainage mains, consideration must be given to the location and design of the enclosed drainage system outlet. These outlets must be resistant to erosion. The rate of release must be controlled and the energy of flow must be dissipated. It is essential that sediment be removed from runoff before it is released from the site or corridor. Sediment basins are frequently used at storm sewer outlets during construction.

#### II-2.5.3 Summary

Enclosed storm sewer systems can safely convey high velocities and large volumes of runoff as well as aid in preventing erosion during and after construction. Sediment must be prevented from entering the storm sewer system and it must be removed from runoff. The following BMPs achieve these purposes:

1. Drain inlet sediment filters prevent sediment from entering the storm sewer system.
2. Enclosed drains and sediment basins must be carefully located and designed to:
  - a. Trap sediment that may be in storm water before it is released off the site or downstream.
  - b. Control the volume and velocity of runoff.

The use of temporary control measures can reduce the accumulation of sediment in an enclosed drainage system.

### **II-2.6 LARGE, FLAT SURFACE AREAS**

#### II-2.6.1 Exposed Surfaces (BMPs E1.10, E1.15, E2.10, E2.15, E3.10, E3.40)

Although erosion rates on steep exposed slopes are higher than on flat or gently sloping areas, all areas of exposed soil are vulnerable to erosion. If erosion control is ignored on large areas of nearly flat or gently sloping land, it will be possible for significant amounts of soil to be eroded. Clearing, grading, and vegetative restabilization in these areas can be timed so that the extent of exposed area and the duration of exposure is minimized. These areas require prompt

Figure II-2.12 Riprap Revetment Can Help to Minimize Erosion

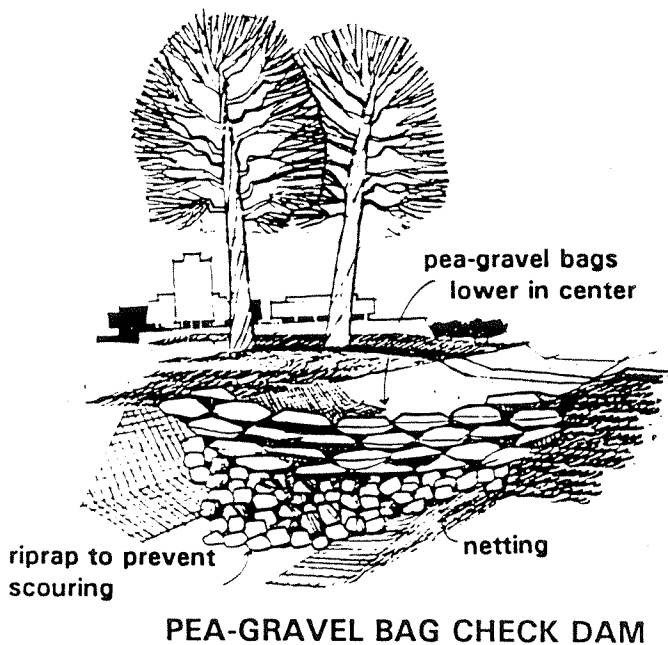


Figure II-2.13 Check Dam

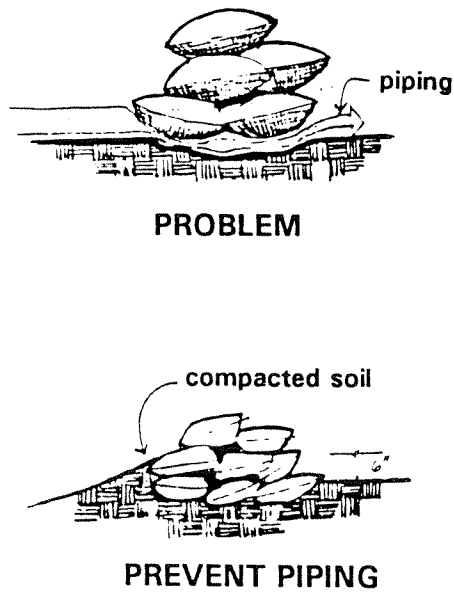
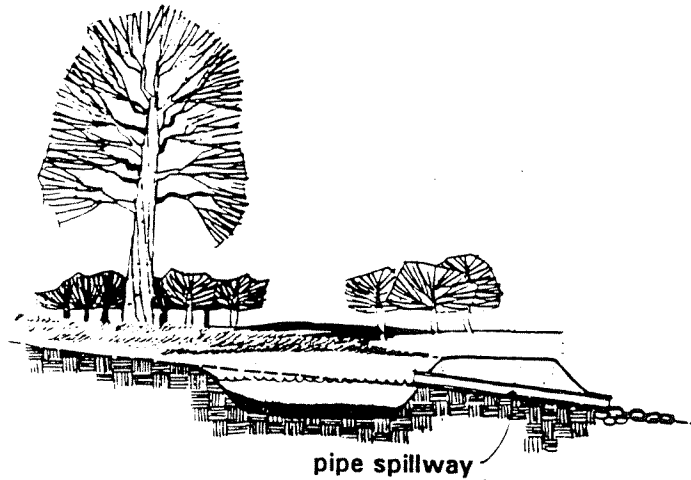
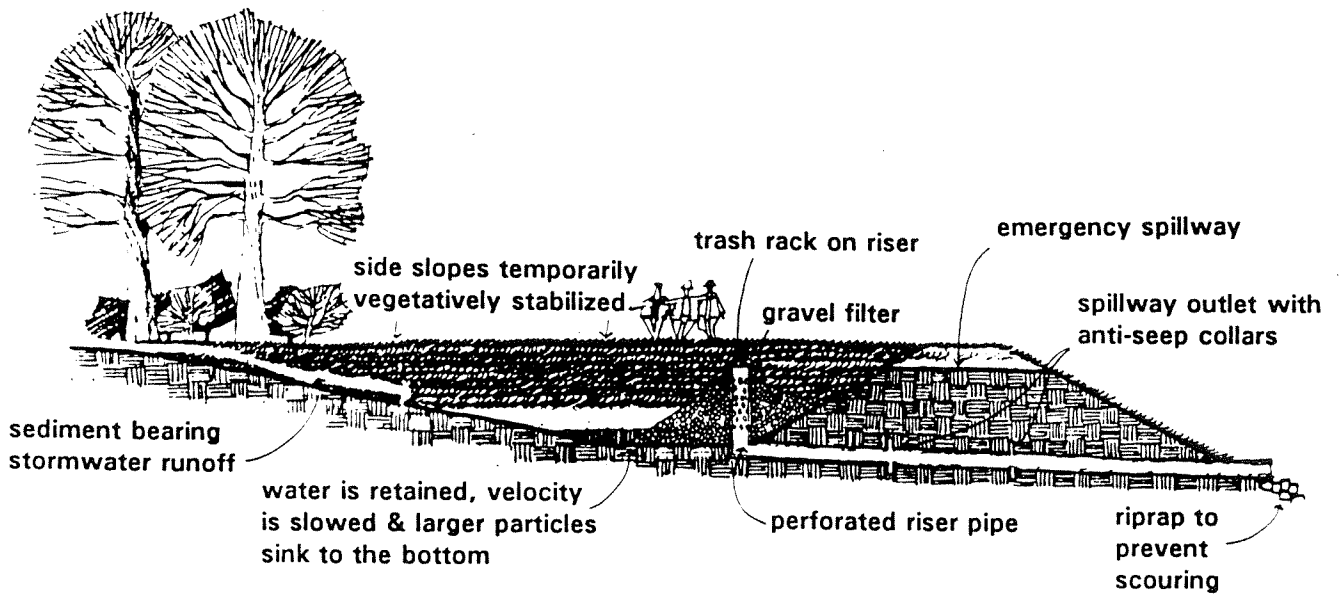


Figure II-2.14 Proper Construction of Check Dam

Figure II-2.15  
Profile Through Typical Embankment Sediment Basin

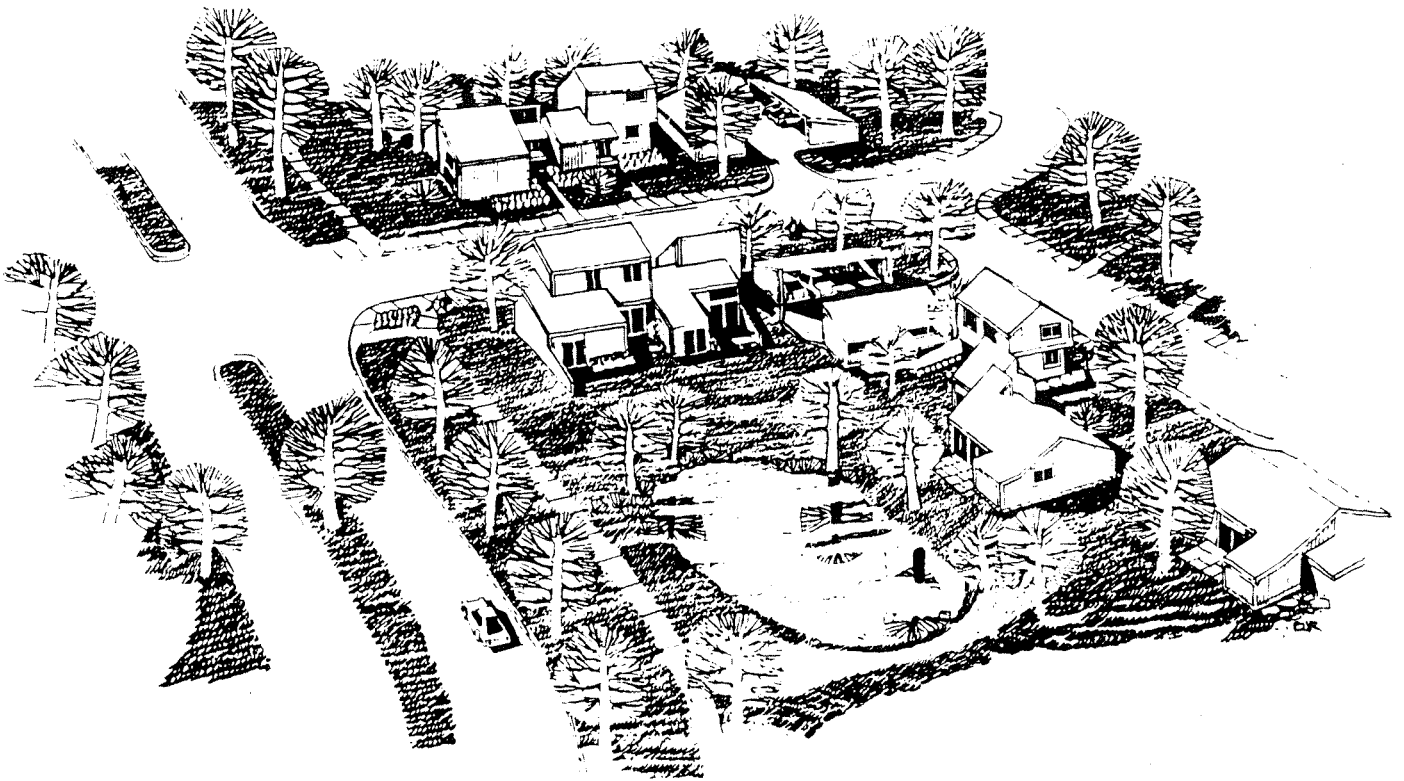


PROFILE THROUGH AN EXCAVATED SEDIMENT BASIN



PROFILE THROUGH TYPICAL EMBANKMENT SEDIMENT BASIN

Figure II-2.16 Detention Basin



**PERMANENT RETENTION BASINS CAN BE INTEGRATED INTO A DEVELOPMENT**



vegetative restabilization. Temporary seeding or mulching is required where large areas will not be permanently stabilized within recommended time limits. Diversions, sediment barriers, or traps constructed on the lower side of large disturbed areas should be used to intercept and collect sediment.

Rights-of-way and parking areas that are being prepared for paving must be protected from rainfall and runoff. Diversions should be constructed to protect these areas from runoff before clearing and grading begin.

Areas that are being prepared for paving should be properly compacted because compaction makes the exposed surface area less vulnerable to erosion. Cleared rights-of-way may be covered with crushed aggregate to reduce erosion. Where rights-of-way will not be used for construction traffic, they can be seeded with a temporary cover.

Gravel or stone filter berms should be used at intervals along the gradient right-of-way to intercept runoff and direct it to stabilized areas, drainageways, or enclosed drainage system inlets. Filter berms also serve to slow and filter runoff and collect sediment. These berms can be crossed by construction equipment.

#### II-2.6.2 Paved Surfaces (BMP E3.25)

An increase in paved or compacted surface area on a site greatly increases the rate of site runoff. For example, a 20 percent increase in paved area can cause runoff to more than double during a heavy rainfall (8). In addition, the velocity of runoff moving across a paved surface is higher than the velocity of runoff moving across an area of exposed earth or vegetation. Pavement provides very little resistance to flow and does not allow any infiltration. Runoff draining from a paved surface area is also often highly concentrated.

The concentration of runoff leaving paved areas is highly erosive. After construction is complete, the paved roadway itself can serve as a drainageway with curbs and gutters conducting runoff to enclosed drainage system inlets. Where it is not economically feasible to install curbs and gutters, paved surfaces should be designed so that runoff will travel the shortest possible distance across the paved areas. This will prevent large accumulations of runoff from leaving paved areas at high velocities in any one area.

Well-stabilized drainageways will be necessary to receive and convey the increased volumes and velocities of runoff from paved surfaces. Where concentrated flows of runoff leave paved surface areas, outlet points must be especially well stabilized.

#### II-2.6.3 Summary

The amount of erosion on flat and gently sloping surface areas can be significant. Erosion on these areas can be minimized by:

1. Scheduling development in phases: The extent of the exposed area and the duration of exposure should be kept to a minimum.
2. Vegetative restabilization: Prompt surface stabilization with either temporary or permanent vegetative cover minimizes erosion.
3. Sediment traps: These measures trap soil eroded from exposed surface areas before it is carried off the site or into waterways.

Areas being prepared for paving should be protected from erosion by the use of:

1. Gravel or stone filter berms: Filter berms slow and filter runoff and divert runoff from the exposed right-of-way.

2. **Compaction:** Compaction reduces the vulnerability of the exposed right-of-way to erosion, but increases the velocity and amount of runoff.
3. **Aggregate cover:** Aggregate cover stabilizes the soil surface while allowing the movement of construction equipment on the right-of-way.

By implementing the control measures listed above, soil erosion on exposed surface areas and areas adjacent to paved surfaces can be minimized.

#### II-2.7 BORROW AND STOCKPILE AREAS (BMPs E1.10, E1.20, E1.35, E1.50, E2.35, E2.55)

Borrow areas, especially those that are located off the development site, cannot be ignored in erosion and sedimentation control planning. Borrow areas, as well as stockpile and spoil areas, must be stabilized.

Borrow and stockpile areas present the same set of problems for the control of erosion and sedimentation as exposed cut and fill slopes. All areas are erodible. Runoff should be diverted from the face of the slopes which are exposed in the excavation process. The runoff must then be conveyed in stabilized channels to stable disposal points.

The BMPs used to control erosion on slopes, such as the top of dikes, diversions, slope drains, etc., should also be used in borrow areas. Only those sections of the borrow area which are currently needed to supply fill should be stripped. Immediately after the required fill has been taken, the exposed area should be stabilized. If practical, each phase of the borrow operation should be:

1. graded
2. covered with topsoil
3. seeded with permanent vegetation and mulched

If final grading is delayed for more than a few days, temporary seeding should be used. By properly timing the disturbance of the natural cover in the borrow area in carefully planned phases, the area of exposed soil and the duration of exposure are reduced and, therefore, erosion losses are reduced.

The topsoil from borrow areas is stripped and stockpiled for later redistribution on the disturbed area. These stockpiles should be located on the uphill side of the excavated area wherever possible so that they can act as diversions. Stockpiles should be shaped and seeded with temporary cover. They can also be covered with plastic and circled at the bottom with a ditch to catch the runoff.

Where borrow areas are off the development site, a separate system for trapping sediment from the borrow area is needed. After the excavation is complete, borrow areas must be restored. Regrading to ensure proper drainage and to blend the borrow area with the surrounding topography is required. Stockpiled topsoil is then redistributed and permanent vegetative cover established.

#### II-2.8 ADJACENT PROPERTIES

The protection of adjacent properties and waterways from accelerated erosion and sedimentation is an important concern. Relevant BMPs for protecting adjacent properties have already been discussed under the previous problem areas. The following list illustrates some of the BMPs which can be used:

1. Sediment traps
2. Diversions

Figure II-2.17 Inlet Sediment Trap

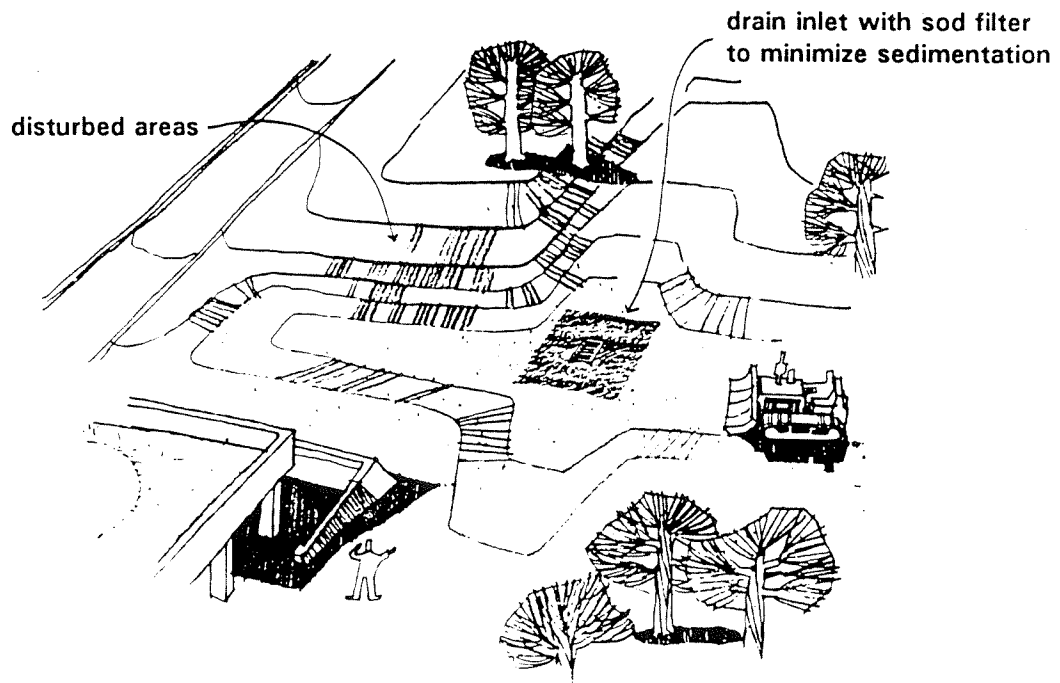
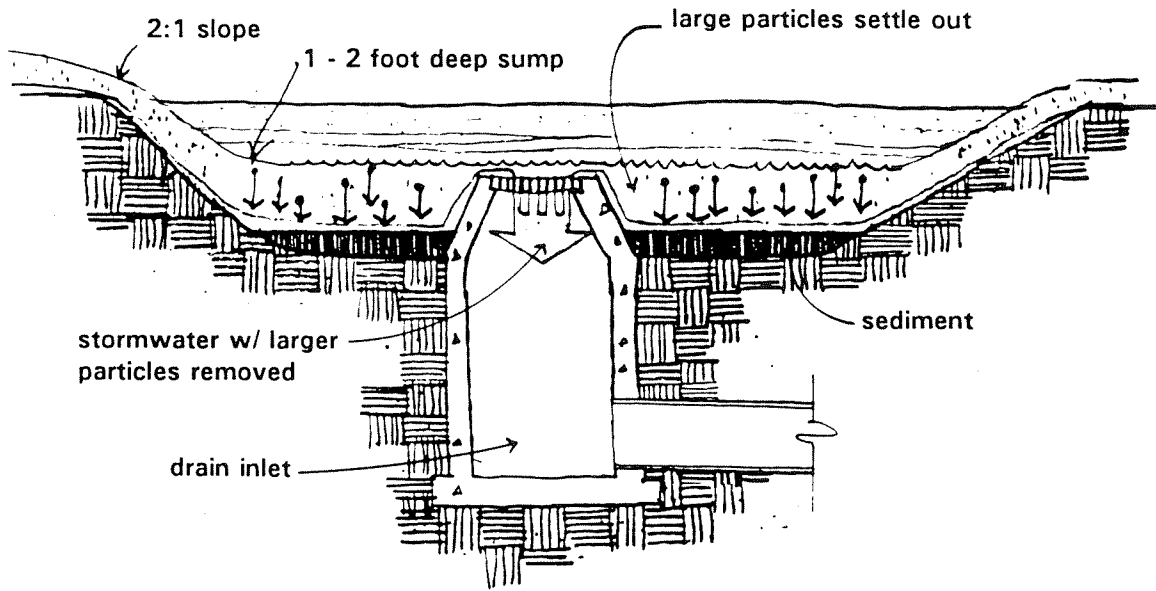


Figure II-2.18 Sod Filter for Drain Inlet

3. Grass waterways
4. Rock and washed gravel check dams
5. Vegetative filter strips
6. Filter fences



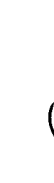








A more complete list of applicable BMPs is shown in The Unified Coding System in Table II-2.2.

Table II-2.1 Unified Coding System for Erosion and Sedimentation Control BMPs and Their Applicability to Control Various Problem Areas

BMPs	Code	Symbol	Problem Areas						
			Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
<b><u>I. Cover Practices</u></b>									
E1.10 Temporary Seeding	TS		X		X		X	X	X
E1.15 Mulching & Matting	MU		X				X	X	
E1.20 Clear Plastic Covering	CPC		X					X	
E1.25 Preserving Natural Vegetation	VEG		X	X					
E1.30 Buffer Zones	BZ		X	X					X
E1.35 Permanent Seeding & Planting	PS		X				X		
E1.40 Sodding	SO		X		X		X	X	X
E1.45 Topsoiling	TO		X				X	X	

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BMPs	Code	Symbol	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
<b>II. Erosion Control</b>									
E2.10 Stabilized Construction Entrance & Tire Wash	CE						X		
E2.15 Construction Road Stabilization	CRS		X						
E2.20 Dust Control	DC						X	X	X
E2.25 Pipe Slope Drains	PSD		X						
E2.30 Subsurface Drains	SD		X						
E2.35 Surface Roughening	SR		X				X		
E2.40 Gradient Terraces	GT		X					X	
E2.45 Bioengineered Protection of Very Steep Slopes	SSP		X					X	
E2.50 Level Spreader	LS				X				
E2.55 Interceptor Dike & Swale	IDS		X					X	X
E2.60 Check Dams	CD				X				X
E2.70 Outlet Protection	OP			X	X				

BMPs	Code	Symbol	Slope Protection	Waterway Protection	Surface Protection	Enclosed Drainage	Large Flat Areas	Borrow Areas	Adjacent Properties
<b>II. Erosion Control, con't.</b>									
E2.75 Riprap	RR		X	X	X				
E2.80 Vegetative Streambank Stabilization	VSS			X					
E2.85 Bioengineering Methods of Streambank Stabilization	BSS			X					
E2.90 Structural Streambank Protection	SSS			X					
<b>III. Sediment Detention</b>									
E3.10 Filter Fence	FF			X		X			X
E3.15 Straw Bale Barrier	STB			X		X			X
E3.20 Brush Barrier	BB		X	X					X
E3.25 Gravel Filter Berm	GFB		X	X			X		X
E3.30 Storm Drain Inlet Protection	IP		X			X			X
E3.35 Sediment Trap (or Sump)	ST			X	X				X
E3.40 Sediment Pond (or Basin)	SB			X	X	X			X

II-2.9 REFERENCES

- (1) Tiffany, Chris, Gary Minton and Rachel Friedman-Thomas, Erosion and Sediment Control: An Evaluation of Best Management Practices on Construction Sites in King County, Washington, King County Conservation District, Draft, April, 1990.
- (2) Maryland Dept. of Water Resources, C. Becker, T.R. Mills and Hittman Associates, Inc., Guidelines for Erosion and Sediment Control Planning and Implementation, U.S. EPA, Washington D.C., 1972, p. 31.
- (3) Washington State Dept. of Transportation, Standard Specifications for Road, Bridge and Municipal Construction, 1988.
- (4) U.S. Dept. of Agriculture Soil Conservation Service and Milwaukee Co. Soil and Water Conservation District, Minimizing Erosion in Urbanizing Areas: Guidelines, Standards and Specifications, U.S.D.A. Soil Conservation Service, Madison, WI., 1973, p. 33.
- (5) Maryland Dept. of Water Resources, C. Becker, T.R. Mills and Hittman Associates, Inc., Guidelines for Erosion and Sediment Control Planning and Implementation, U.S. EPA, Washington D.C., 1972, p. 15.
- (6) Michigan Soil Conservation Service, Streambank Protection by Vegetative Measures, Soil Conservation Service, Lansing MI., 1971, p. 580B-2.
- (7) Hittman Associates, Inc., Workbook: Control of Sediment Generated on Construction Sites, Columbia, MD., 1973, p. 2.
- (8) Hittman Associates, Inc., Workbook: Control of Runoff During Construction, Columbia, MD., 1973, p.1.
- (9) Reinelt, Loren E., Construction Site Erosion and Sediment Control Inspector Training Manual, University of Washington, November, 1991.



CHAPTER II-3

GUIDELINES FOR CONTROLLING POLLUTANTS OTHER THAN SEDIMENT  
ON CONSTRUCTION SITES

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## CHAPTER II-3

GUIDELINES FOR CONTROLLING POLLUTANTS OTHER THAN SEDIMENT  
ON CONSTRUCTION SITES

## II-3.1 INTRODUCTION

Potential pollutants other than sediment associated with construction activity, include numerous hazardous wastes as well as other solid and liquid wastes. Hazardous wastes include pesticides (insecticides, fungicides, herbicides, rodenticides etc.), petrochemicals (oils, gasoline, asphalt degreaser etc.) and other construction chemicals such as concrete products, sealer, paints, and wash water associated with these products. Other wastes include paper, wood, garbage, sanitary wastes, and fertilizer.

Practices must be used that prevent these potential pollutants from leaving the construction site. Good erosion and sediment control, coupled with stormwater management, will deter the movement of large amounts of sediment off the site. [It must be recognized, however, that pollutants carried in solution in runoff water, or fixed with sediment crystalline structures (e.g., crystalline clays), will be carried through the erosion and sediment control defenses.] Pollutants such as oils, waxes, and water-insoluble pesticides, form surface films on water and on solid particles, and also, oil films serve as a medium for concentrating water-soluble insecticides. Other than by use of very costly water-treatment facilities, or long runoff water detention periods, these pollutants become nearly impossible to control once present in the runoff.

The most economical and effective controls for pollutants other than sediment generated on construction sites, are the exercise of good "housekeeping" practices, and an awareness by construction workers, planners, engineers, and developers of the need and purpose of compliance with federal, state, and local regulations. For example, most pesticides can kill forms of life other than their pest targets. Certain insecticides can persist for months or years in soil and water, and many toxic chemicals can be passed along plant and animal food chains. Similarly, high levels of nutrients (principally phosphorus and nitrogen) from fertilizers used to revegetate exposed subsoils in graded areas may enter waterways and ponds, and increase the growth of algae at the surface to such an extent that light penetration in the water column is decreased. The end result is over-enrichment (or eutrophication). In confined water bodies, over-enrichment can lead to complete deoxygenation of the water and consequent death of fish and other organisms.

Ways must be found to protect ponds, wetlands, lakes, streams, and coastal and estuarine water bodies from damage by sediment and other pollutants generated during construction activities.

The variety of pollutants and the severity of the damage they cause depend upon a number of factors. The most significant of these include:

1. The nature of the construction activity.
2. The physical characteristics of the construction site, including such factors as weather, time of year for construction, topography, soil condition, drainage systems, etc.
3. The proximity, quantity, and quality of the receiving waters (i.e., the amount and purity of the water receiving the contaminated runoff).

It is reasonable to expect, for example, that potential pollution resulting from fertilizers used during revegetation would be more severe on a highway or housing

development than for a shopping center development. This is because highways and housing developments usually have far greater landscaping requirements than shopping centers which are composed mostly of rooftops and pavement.

The physical characteristics of the construction site have a major bearing on the potential severity of pollution from construction activities. As in the case of sediment, the vast majority of all pollutants are carried into the receiving waters via runoff. The amount of runoff coming from a construction site is dependent upon hydrologic factors. These include the amount, intensity, and frequency of rainfall; the infiltration rate of the soil; surface roughness; and the length and steepness of the ground slope. Large areas denuded or stripped of vegetation, long slopes, steep slopes, tight soils, and high intensity rainfall are all factors conducive to heavy runoff.

Another physical factor influencing the severity of pollution is the proximity of the pollutant, or potential pollutant, to the receiving water. For example, fertilizers applied to a streambank are more apt to cause water pollution than fertilizers applied to a slope well upland of the waterway.

The following information deals with the nature and control of various construction-related pollutants, other than sediment.

### II-3.2 BMP C1.10 PESTICIDE CONTROL

Although the word "pesticide" has come to mean only those chemicals which attack insect populations, here the word is used to include herbicides and rodenticides as well as chemicals commonly known as pesticides. Insecticides, rodenticides, and herbicides have historically been used on construction sites to increase health and safety, maintain a pleasant environment, and reduce maintenance and fire hazards. Often, rodents are attracted to construction sites and rodenticides are used.

Pesticides shall only be used in conjunction with Integrated Pest Management (IPM). IPM utilizes a needs assessment which determines which method to use and the necessity of controlling a pest population. Pesticides should be the tool of last resort; methods which are the least disruptive to the environment and to human health should be used first (1). IPM as a BMP is further discussed in Volume IV, Chapter IV-4, BMP S1.90.

If pesticides must be used, clearance for use of any of these chemicals is often required by restrictive federal and state regulations. All pesticides should be stored and applied in accordance with regulations of the State Department of Agriculture, WAC 16-228-185. EPA has produced a pamphlet "Suspended, Canceled and Restricted Pesticides" (Jan. 1985), which includes information on many pesticides. As it is more than five years old, it is wise to check with EPA's Region 10 Pesticides Branch, Seattle, if any questions regarding the use of pesticides arise. An awareness of the need to adhere to recommended dosages, type of application equipment, time of application, cleaning of application equipment, and safe disposal of these chemicals, will go far in limiting the pollution of waterways. Application rates should conform to registered label direction. Many of these compounds are considered "Dangerous Wastes" and must be disposed of properly. Disposal of excess pesticides and pesticide-related wastes should conform to registered label directions for the disposal and storage of pesticides and pesticide containers set forth in applicable federal, state and local regulations. General disposal procedures are:

- Dispose of through a licensed waste management firm or treatment, storage and disposal company (TSD).
- Use up, or give away to garden center, landscape service, etc.

- Triple rinse containers before disposal, reuse rinse waters as product.

"Hazardous Waste Pesticides - Determining if Your Pesticide is a Hazardous Waste," booklet #89-14 provides guidance and is available from Ecology's Publications Office. For more information call Hazards Line (587-3292) or Hazardous Substance Information Hotline (1-800-633-7585).

Pesticide storage areas on the construction site should be protected from the elements, from vandals, and from the curious. Warning signals should be placed in areas recently sprayed or treated with the most dangerous pesticides. Persons involved in the mixing and application of these chemicals, to be in compliance with the law, must wear suitable protective clothing.

Other practices include:

- Set aside a locked, weather-resistant storage area.
- Lids should be tightly closed.
- Keep in a cool, dry place. Many pesticides rapidly lose their effectiveness if stored in areas exposed to heat.
- In case of a leak, put original container into a larger container and label it properly.
- Check containers periodically for leaks or deterioration.
- Keep a list of products in storage.
- Use plastic sheeting to line the area.
- The applicator must follow the notification requirements of the WDSA. Neighbors on properties adjacent to the one being sprayed should also be notified prior to spraying.
- All storage sheds, dumpsters or other storage facilities should be regularly monitored for leaks and repaired as necessary. Remind workers during subcontractor or safety meetings about proper storage and handling of materials.

### II-3.3 BMP C1.20 HANDLING OF PETROLEUM PRODUCTS

Petroleum products are widely used during construction activities. They are used as fuels and lubricants for vehicular operations, power tools, and general equipment maintenance. These pollutants include oils, fuels such as gasoline, diesel oil, kerosene, lubricating oils, and grease. Asphalt paving can be a pollutant source as it continues to release various oils for a considerable length of time. Most of these pollutants adhere to soil particles and other surfaces easily.

One of the best modes of control is to retain sediments containing oil on the construction site. Soil erosion and sediment control practices can effectively accomplish this. Improved maintenance and safe storage facilities will reduce their chances of contaminating construction sites. One of the greatest concerns confronting uses of these petroleum products is the method for waste disposal. Oil and oily wastes such as crankcase oil, cans, rags, and paper dropped in oils and lubricants, can be best disposed of in proper receptacles or recycled (call 1-800-RECYCLE). Waste oil for recycling should not be mixed with degreasers, solvents, antifreeze, or brake fluid. The dumping of these wastes in sewers and other drainage channels is illegal and could result in fines or job shutdown. A further

source of these pollutants is leaky vehicles. Proper maintenance of equipment and installation of proper stream crossings will further reduce pollution of water by these sources. Stream crossings should be minimized through proper planning of access roads.

Guidelines for storing petroleum products are as follows:

- Store products in weather-resistant sheds where possible.
- Create shelter around area with cover and wind protection.
- Line the storage area with double layer of plastic sheeting or similar material.
- Create impervious berm around the perimeter.
- Capacity of bermed area should be 110 percent of largest container.
- All products should be clearly labeled.
- Keep tanks off the ground.
- Keep lids securely fastened.
- Contact local fire marshall for more information.
- Post information for procedures in case of spills. Persons trained in handling spills should be on-site or on call at all times.
- Materials for cleaning up spills should be kept on-site and easily available. Spills should be cleaned up immediately and the contaminated material properly disposed of.
- Specify a staging area for all vehicle maintenance activities. This area should be located away from all drainage courses.
- All storage sheds, dumpsters or other storage facilities should be regularly monitored for leaks and repaired as necessary. Remind workers during subcontractor or safety meetings about proper storage and handling of materials.

#### II-3.4 BMP C1.30 NUTRIENT APPLICATION AND CONTROL

Inorganic nutrient pollution is most often caused by fertilizers used in revegetating graded areas. The use of proper soil-stabilization measures, sediment control, and stormwater detention structures can be effective means of keeping these materials out of waterways. Only small amounts of inorganic nutrients are beneficial to the productivity of waterways, while excess amounts result in over-enrichment (eutrophication).

Nutrient pollution can be minimized by working fertilizers and liming materials into the soil to depths of 4 to 6 inches, and by proper timing of the application. Hydro-seeding operations, in which seed, fertilizers and lime are applied to the ground surface in a one-step operation, are more conducive to nutrient pollution than are conventional seedbed-preparation operations, where the fertilizers and lime are tilled into the soil. In the case of surface dressings, control can be achieved by applying the required quantity of fertilizer in more than one operation. For example, an area requiring an application of 500 lbs. per acre of fertilizer could be dressed with about 125 lbs. per acre at four separate times over the growing season.

Use of fertilizers containing little or no phosphorus may be required by local authorities if the development is near sensitive water bodies. In any event great care should be taken to use only the minimum amount of phosphorus needed, as determined by soil tests, or advice from the local Conservation District or Soil Conservation Service.

Near sensitive surface waters, the addition of lime can affect the pH (or acidity) of runoff and receiving waters. Importation of topsoil is better than heavily liming and fertilizing exposed subsoil.

#### **II-3.5 BMP C1.40 SOLID WASTE HANDLING AND DISPOSAL**

Solid waste is one of the major pollutants caused by construction. Solid waste is generated from trees and shrubs removed during land clearing for construction of streets and parking facilities, and during the installation of structures. Other wastes include wood and paper from packaging and building materials, scrap metals, sanitary wastes, rubber, plastic and glass pieces, masonry products, and others. Food containers such as beverage cans, coffee cups, lunch-wrapping paper and plastic, cigarette packages, leftover food, and aluminum foil contribute a substantial amount of solid waste to the construction site.

The major control mechanism for these pollutants is to provide adequate disposal facilities. Collected solid waste should be removed and disposed of at authorized disposal areas. Frequent garbage removal helps maintain construction sites in a clean and attractive manner. Waste containers should be labelled and located in a covered area. Lids should be kept closed at all times. Any useful materials should be salvaged and recycled. For instance, masonry waste can be used for filling borrow pits; trees and brush from land-clearing operations can be converted into woodchips through mechanical chippers and then used as mulch in graded areas. Sanitary facilities must be convenient and well maintained to avoid indiscriminate soiling of adjacent areas. Selective (rather than wholesale) removal of trees is helpful in conservation of soil and reduction of wood wastes. Indiscriminate removal of trees and other beneficial vegetation should be avoided.

Soil erosion and sediment control structures capture much of the solid waste from construction sites. Constant removal of litter from these structures will reduce the amount of solid waste despoiling the landscape. The extension of local and state anti-litter ordinances to cover construction sites is also a viable control mechanism. Adherence to these regulations by construction personnel reduces unnecessary littering through carelessness and negligence.

#### **II-3.6 BMP C1.50 USE OF CHEMICALS DURING CONSTRUCTION**

Many types of chemicals may be used during construction activities. These chemical pollutants include paints, acids for cleaning masonry surfaces, cleaning solvents, asphalt products, soil additives used for stabilization and other purposes, concrete-curing compounds, and many others. These materials are carried by sediment and runoff from construction sites.

A large percentage of these pollutants can be effectively controlled through implementation of source control soil erosion and sedimentation control practices. By using only the recommended amounts of these materials and applying them in a proper manner, pollution can be further reduced. As in the case of other pollutants, good housekeeping is the most important means of controlling pollution.

The correct method of disposal of wastes varies with the material. Wash-up waters from water-based paints may go into a sanitary sewer, but wastes from oil-based paints, cleaning solvents, thinners, and mineral spirits must be disposed of through

a licensed waste management firm or TSD. Disposal of concrete products, additives, and curing compounds depends on the product. Information is available from the local health department or the Hazardous Substance Information Hotline (1-800-633-7585).

### II-3.7 OTHER POLLUTANTS

Other pollutants include concrete wash water from concrete mixers, acid and alkaline solutions from exposed soil or rock units high in acid, and alkaline-forming natural elements.

The control of these pollutants involves good site planning and pre-construction geological surveys. Neutralization of these pollutants often provides the best treatment. Sealing of fractures in the bedrock with grout and bentonite will reduce the amount of acid or alkaline seepage from excavations. Adequate treatment and disposal of concrete further reduces pollution.

### II-3.8 GENERAL GUIDELINES

General guidelines for managing or minimizing any of the above hazardous wastes are as follows:

#### II-3.8.1 BMP C1.60 Managing Hazardous Products

- Buy and use only what is needed. Leftovers need to be stored, re-used, given away, recycled or disposed of safely.
- Read labels and follow directions on the label. Hazardous products may be labeled:
 

Danger	Poisonous	Volatile
Combustible	Caustic	Explosive
Warning	Corrosive	Flammable
Caution		
- Try to keep products in original containers and always keep them well-labeled. If the product must be transferred to smaller containers, use the proper size funnel and avoid spills. Label all containers.
- Labels can fall off with weathering. To prevent, cover with transparent tape. To relabel, use a metal tag attached to the container or use a stencil and spray paint.
- Do not mix chemical substances unless recommended by the manufacturer.
- Use in well-ventilated areas. Protect skin, eyes, nose, and mouth when necessary by wearing gloves, respirator, or other protective clothing.
- Keep corrosive liquids away from flammable liquids.
- Look for nontoxic or less toxic options (check with the State Department of Ecology Office of Waste Reduction at 1-800-822-9933).
- Use all of the product before disposing of the container.
- There are private firms that specialize in the cleanup of spills.

II-3.8.2 BMP C1.70 Equipment Washing

Thinners or solvents should not be discharged into the sanitary or storm sewer systems when cleaning large machine parts where discharge of water is required. Use alternative methods for cleaning larger equipment parts such as high pressure, high temperature water washes, or steam cleaning.

Equipment washing detergents can be used and wash water discharged into the sanitary system if grit is removed from the solution first. The water discharged into the sewer must not exceed the discharge limits set by the Sewer Authority.

Small parts can be cleaned with degreasing solvents which are reused after filtering or recycled. These solvents should not be discharged into any sewer. Further information is available from the Department of Ecology.

II-3.8.3 BMP C1.80 Spill Control Planning and Cleanup

Construction site supervisors shall adopt a spill control plan and identify persons responsible for implementing the plan if a spill of a dangerous or hazardous waste should occur. Any spill that occurs, regardless of the size and/or type of spill, should be reported to the following agencies:

- If the spill of a hazardous substance could reach surface waters, the following agencies must be notified (there are fines for failing to notify):

National Response Center            1-800-424-8802 (24-hour)

- Locally, notify the regional Department of Ecology offices:

Northwest Region - Redmond 649-7000 (24-hour)  
Southwest Region - Olympia 753-2353 (24-hour)

- Within the City of Bellevue

Storm & Surface Water Utility 455-7846 (24-hour)

- For spills within salt water

U.S. Coast Guard 286-5440

**There are fines for failing to notify the appropriate authority when a spill occurs.**

Some of the important components of a spill control plan are:

- Establish who to notify in the event of a spill, particularly if it is hazardous.
- Provide specific clean-up instructions for different products handled on site.
- Assign a person to be in charge of clean-up assistance.
- Prepare spill containment and clean-up lists that are easy to find and use.
- Post a summary of the clean-up plan at appropriate locations.
- If a spill occurs, demobilize it as quickly as possible.



- If there is a change that the spill could enter a storm drain or sewer, plug the inlet and turn off or divert any incoming water.
- Cover the spill with absorbent material such as kitty litter or sawdust. Do not use straw. Dispose of the used absorbent per Ecology or manufacturer's instructions. If the spill is flammable, dispose of as directed by the local fire marshal.
- Keep the area well ventilated.

#### II-3.8.4 BMP C1.90 Treatment and Disposal of Contaminated Soils

Contaminated ground water or soil may be encountered during earthwork activities or by the spill or leak of a hazardous product. The contaminant may be known or unknown. Sampling and laboratory tests may be required to determine whether a landfill can accept the contaminated soil. In some cases it is possible to reduce the hazardous potential of the soil by aerating it, for example. Local health departments can supply the necessary procedures. Private firms can also be consulted for disposal.

The Model Toxics Control Act, Ch. 70.105 RCW, requires that Ecology's Toxic Cleanup Program be notified if contaminated soil or ground water is encountered during a project.

#### II-3.8.5 BMP C 2.00 Concrete Trucks/Spray Washing of Exposed Aggregate Driveways and Walkways

The washout from a concrete truck should be disposed of into:

- A designated area which will later be backfilled: a slurry pit.
- An area where the concrete wash can harden, be broken up, and then put in the dumpster.
- A location which is not subject to surface water runoff, and more than 50 feet away from a storm drain, open ditch, or receiving water.

#### Never Dump Into:

- Sanitary sewer
- Storm drain
- Soil or pavement which carries stormwater runoff.

When spray washing driveways or walkways to expose the aggregate, all wash water should be diverted or sprayed to the sides, not down the driveway. If water must run down the driveway towards the street or sidewalk, it should be diverted at the bottom to a sump or sediment trap.

#### II-3.8.6 BMP C2.10 Use of Sandblasting Grits

If used to clean old buildings where lead, cadmium, or chrome-based paints were applied, the sandblasting grits are a hazardous waste. They cannot be washed into any sewer system. Contact a licensed waste management firm or TSD facility.

#### II-3.8.7 BMP C2.20 Disposal of Asbestos and PCBs

Use and disposal of these potential pollutants are regulated by both state and federal agencies. For further information, contact:

For Asbestos:

Puget Sound Air Pollution Control Agency: 296-7330  
U.S. EPA: 442-7369

For Wastes Containing PCBs:

Washington Department of Ecology, Hazardous Waste Section: 449-6687  
U.S. EPA: 442-7369

#### II-3.9 REFERENCES

- (1) Washington Toxics Coalition, letter dated January 31, 1990.
- (2) Reinelt, Loren, Construction Site Erosion and Sediment Control Inspector Training Manual, Center for Urban Water Resources Management, University of Washington, October, 1991.

CHAPTER II-4

NPDES STORMWATER PERMIT REQUIREMENTS AND THE  
DEVELOPMENT OF LARGE PARCEL EROSION AND SEDIMENT CONTROL PLANS

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CHAPTER II-4

NPDES STORMWATER PERMIT REQUIREMENTS

AND THE DEVELOPMENT OF LARGE PARCEL EROSION AND SEDIMENT CONTROL PLANS

INTRODUCTION

Two different types of requirements commonly must be satisfied for construction sites. Those sites larger than 5 acres must comply with the requirements that will be contained in the baseline General NPDES Stormwater Permit (now under development). All new development and redevelopment sites larger than 1 acre must comply with Erosion and Sediment Control Requirements 1 through 14 (see Chapter I-2). This compliance is demonstrated through the submittal of an Erosion and Sediment Control (ESC) Plan.

II-4.1 NPDES STORMWATER PERMITS

EPA's National Pollutant Discharge Elimination System Permit (NPDES) regulations for stormwater (40 CFR Parts 122, 123 and 124) became effective on November 16, 1990. Washington is a NPDES delegated state which requires Ecology to administer NPDES permits. Cities and counties with a population of 100,000 and greater that have separate storm sewer systems, most industries that discharge stormwater associated with industrial activities or storage of raw materials, and construction sites 5 acres in area and greater are required to apply for NPDES permits. Stormwater from industrial uses that does not come in contact with industrial activities or storage of raw materials or products, such as runoff from roofs and parking lots, generally does not require a NPDES permit.

The purpose of the new stormwater NPDES regulations is to:

- Prohibit non-stormwater discharges into storm sewers
- Reduce discharge of stormwater-borne pollutants to the maximum extent practicable
- Establish a permit system for stormwater discharges

The Stormwater Management Program that Ecology and the Puget Sound Water Quality Authority are preparing for the Puget Sound Basin will be as consistent as possible with NPDES requirements. The thrust of the Stormwater Program is to direct the 111 cities and counties in the Basin to adopt and implement programs to prevent water pollution and enhance water quality for themselves and privately owned facilities in their jurisdiction. NPDES is a statewide permit program that Ecology will administer directly to cities, counties and regulated industrial facilities including construction sites.

Construction activity including clearing, grading and excavation activities that result in the disturbance of five acres or more will require a permit. Parcels less than five acres in area that are part of a common plan of development or sale totaling five acres or more will also be required to obtain a permit. Ecology anticipates that at the point that a permit program is developed, that construction sites will be covered as part of the baseline general permit to be published in final form in August, 1992. Once the permit is finalized, the contractor will be required to send to Ecology a Notice of Intent to begin construction 30 days before construction is to begin. At this time, details are not finalized.

Applications for coverage under the baseline permit should be submitted after Ecology adopts the permit (targeted for August, 1992), but before the current federal deadline of October 1, 1992. Applications will consist of filing a NOTICE

**OF INTENT (NOI).** Ecology has not yet decided on the information requirements for a **NOTICE OF INTENT.** Proposed requirements for a Notice of Intent will be discussed at public workshops and hearings.

At this time there will be no charges associated with the filing of the NOI. Ecology charges a fee for permits as allowed under State regulation, Chapter 173-224 WAC. That regulation does not identify a fee for facilities which will be covered under the baseline permit for storm water. Ecology plans to seek an increased legislative appropriation for the next biennium (July 1, 1993-June 30, 1995) to administer storm water permits. Fees would be set by amending the fee rule. There will be opportunities for public comment on the fee proposals. Subject to the appropriation and adoption of the amended fee regulation, fees for storm water permits would become effective after July 1, 1993.

**PROPOSED ECOLOGY INDUSTRIAL/CONSTRUCTION PERMIT DEADLINES**

May, 1992	Ecology holds public workshops, hearing on baseline permit.
August, 1992	Projected adoption of Ecology's baseline permit (including construction activities). The permit is effective 30 days later.
After 10/31/92	<b>New</b> industries must submit a NOTICE OF INTENT (to Ecology), and develop a pollution prevention plan (to be retained by the industry), before commencement of construction of a storm water discharge. EPA has proposed that these be completed at least 30 days prior to commencement.

**ECOLOGY CONTACTS**

Industrial permits

- Stan Ciuba (206) 438-7042
- Ed O'Brien (206) 438-7037

Municipal permits

- Gary Kruger (206) 438-7529

**II-4.2 INTRODUCTION TO LARGE PARCEL EROSION AND SEDIMENT CONTROL PLANS**

This section is designed to provide an overview of the important components and process for developing, reviewing and implementing Large Parcel Erosion and Sediment Control (ESC) plans for construction sites. A separate example LPESC plan will be provided in the Stormwater Program Guidance Manual for the Puget Sound Basin currently being developed as a companion document to this manual. Small Parcel ESC requirements can be found in Chapters I-3 and II-5.

Section II-4.3 contains basic information which all site planners and plan reviewers should become familiar with. It describes criteria for plan format and content, ideas for improved planning effectiveness and sources of technical assistance.

Section II-4.4 outlines and describes a recommended step-by-step procedure for developing an erosion and sediment control plan from data collection to finished product. This procedure is written in general terms to be applicable to all types of projects.

Site planners, as well as local plan approving authorities, are urged to become familiar with the contents of this chapter so that plans will

eventually become more standardized and thus more meaningful throughout the Puget Sound basin.

## II-4.3 GENERAL GUIDELINES

### II-4.3.1 What is a Large Parcel Erosion and Sediment Control Plan?

A Large Parcel ESC plan is a document which describes the potential for erosion and sedimentation problems on a construction project over 1 acre in size and explains and illustrates the measures which are to be taken to control those problems. The plan has a written portion known as a narrative and an illustrative portion known as a map or site plan.

The LPESC plan should be an independent entity. While it is a good idea to include erosion and sediment control standards and specifications in contract documents, the erosion and sediment control plan itself should be a separate document which can stand alone.

A LPESC plan is required for all new development and redevelopment where greater than 1 acre of land disturbing activities occur. See Chapter I-2 for more specific information on which type of planning is appropriate.

### II-4.3.2 What is an "Adequate" Plan?

An erosion and sediment control plan must contain sufficient information to satisfy the Plan Approval Authority of the local government that the problems of erosion and sedimentation have been adequately addressed for a proposed project. The length and complexity of the plan should be commensurate with the size of the project, the severity of site conditions, and the potential for off-site damage.

In general, plans for constructing a few homes in a small subdivision do not need to be as complex as a plan for a large shopping center development or a large subdivision. Also, plans for projects undertaken on flat terrain will generally be less complicated than plans for projects constructed on steep slopes where the erosion potential is higher. The greatest level of planning and detail should be evident on plans for projects which are large in size, directly adjacent to flowing streams, other sensitive areas, or high value properties where damage may be particularly costly or detrimental to the environment.

The primary requirements that determine the adequacy of a plan are the Erosion and Sediment Control standards found in Minimum Requirement #1, described in Chapter I-2. Each of these Erosion and Sediment Control Requirements applicable to a project should be satisfied in the LPESC Plan unless a specific variance is granted by the Plan Approval Authority. The design and implementation of the LPESC plan should specifically fulfill all the Erosion and Sediment Control Requirements contained within Minimum Requirement #1 unless an exemption has been granted by the local government. As a guide to format, the site planners and plan reviewers should use the checklist contained in Section II-4.4.6. The step-by-step procedure outlined in this section is recommended for the development of all plans.

### II-4.3.3 A Narrative is Important

The narrative is a written statement which explains and justifies the erosion and sediment control decisions made for a particular project. The narrative is especially important to the Plan Approval Authority because it contains concise information concerning existing site conditions, construction schedules, and other pertinent items which are not contained in a typical site plan.

The narrative is also important to the construction superintendent and inspector who are responsible to see that the plan is implemented properly. It provides them with a single report which describes where and when the various erosion and sediment control BMPs should be installed.

#### II-4.3.4 BMP Standards and Specifications

Chapters II-3 and II-5 of this volume of the manual contain standards and specifications for BMPs. These standards apply within the Puget Sound drainage basin except where an adopted and implemented basin plan is in place (see Minimum Requirement #9 in Chapter I-2). Wherever any of these BMPs are to be employed on a site, the specific title and number of the BMP should be clearly referenced in the narrative and marked on the plan. By referencing this manual properly, (or, the locally adopted technical equivalent of this manual) the site planner can reduce the need for detailed drawings and lengthy descriptions of the practices in the plan.

Modifications to standard practices or new innovative conservation practices may also be employed, but such practices (Experimental BMPs) must be thoroughly described and detailed to the satisfaction of Ecology and the Plan Approval Authority of the local government before they may be used (see Section I-2.17).

#### II-4.3.5 General Principles in Selecting BMPs for a Large Parcel Erosion and Sediment Control Plan

- Prevention of pollutant release is superior to pollutant capture later. Select source control BMPs as a first step.
- Selection of BMPs must depend on site characteristics and the construction plan.
- The proper first step is a site drainage analysis. Determine where runoff will enter, cross and exit the site.
- Flowing water has a tendency to concentrate in channels instead of flowing as sheet flow.
- Determine whether subsurface water is a factor.
- Divert runoff from exposed areas wherever possible.
- Existing vegetation is the most effective erosion control.
- Limit and phase clearing.
- Use materials found on the site wherever possible.
- Incorporate natural drainage features whenever possible, using adequate buffers and protecting areas where flow enters the drainage system.
- Keep structures simple.
- Minimize slope length and steepness.
- Keep runoff velocities low.
- Reduce the tracking of sediment off-site.
- Select and install controls that can be maintained.
- Select appropriate BMPs from Chapter II-3 for the control of pollutants not associated with sediment.

#### II-4.3.6 Standard Practice Coding System

Site planners are urged to use the standard numbering and coding system for BMPs contained in this manual. Table II-2.2 in Chapter II-2 lists each practice with its

designated number, symbol, and code. Use of this coding system will result in increased uniformity of plans and increase their readability to plan reviewers, job superintendents, and inspectors Puget Sound-wide. Since the BMPs in Chapter II-3 are not site-specific, they have not been given codes or symbols.

#### II-4.3.7 Comprehensive Site Planning

Erosion and sediment control planning should be an integral part of the site planning process, not just an afterthought. The potential for soil erosion should be a significant consideration when deciding upon the layout of buildings, parking lots, roads, and other facilities. Adverse environmental impacts and costly erosion and sediment control measures can be minimized if the site design can be adapted to existing site conditions and good conservation principles are used. Additionally, if thought is given to the design of temporary erosion control devices, they may be able to be converted into permanent facilities as well.

#### II-4.3.8 Who is Responsible for Preparing a Plan?

The owner or lessee of the land being developed has the responsibility for plan preparation and submission. The owner or lessee may designate someone (i.e., an engineer, architect, contractor, etc.) to prepare the plan, but he/she retains the ultimate responsibility. It is important for the developer to comply with the requirements of the local government and Minimum Requirement #1 contained in Chapter I-2 of this manual.

#### II-4.3.9 Technical Assistance

Possible sources of erosion and sediment control planning assistance within the state include:

1. Conservation Districts: These districts have elected representatives (directors) from each locality. One of the primary functions of these districts is to provide assistance to landowners for soil conservation planning and implementation. The USDA-Soil Conservation Service provides conservation districts with technical assistance. Requests for assistance in preparing erosion and sediment control plans for a construction site can be made through a district.
2. USDA-Soil Conservation Service: The Soil Conservation Service (SCS) provides technical assistance or conservation planning and implementation to landowners throughout the country through local conservation districts. In addition, the SCS is involved in soil surveys within the state. Requests can be made through a Soil Conservation Service field office for a soil survey on a specific site. These requests will be acted upon according to local priorities.

#### **II-4.4 STEP-BY-STEP PROCEDURE**

The five basic steps in producing a LPESC plan are summarized below:

##### Step 1 - Data Collection

- A. Topography
- B. Drainage
- C. Soils
- D. Ground Cover
- E. Adjacent Areas
- F. Existing Development
- G. On and Off-Site Utilities



Step 2 - Data Analysis

- A. Topography - Slope gradients, lengths
- B. Drainage - Outline existing natural and manmade drainage patterns
- C. Soils - Erodibility (K) factors, permeability
- D. Ground Cover - Trees, grassy areas, sensitive or endangered vegetation
- E. Adjacent Areas - Streams, roads, buildings, etc.

Step 3 - Site Plan Development

- A. Fit development to terrain
- B. Locate construction in the least critical areas
- C. Utilize cluster development whenever possible
- D. Minimize paved areas
- E. Utilize the natural drainage system and natural drainage locations whenever possible

Step 4 - Plan for Erosion and Sediment Control

- A. Determine limits of clearing and grading
- B. Divide the site into drainage areas
  - Consider each area separately
- C. Select erosion and sediment control BMPs, emphasizing source control and vegetative BMPs.
  - Vegetative, especially buffers, preservation of natural vegetation and flagging
  - Structural
  - Management measures
- D. Plan for stormwater management

Step 5 - Include BMPs for the Control of Pollutants Other Than Sediment

- A. Review Chapter II-3 in this volume
- B. Select appropriate BMPs based on the practices which will be used on-site.

Step 6 - Plan Preparation

- A. Narrative
- B. Site Plan

**Note:** The LPESC plan may be a subset of the Stormwater Site Plan. Full details on how to prepare the Stormwater Site Plan and how the LPESC plan is integrated into it are provided in Chapter I-3. In particular, most of the work for steps 1 and 2 will have been done when preparing the Site Improvement Plan Base Map. The actual LPESC plan is part of the Site Improvement Plan. All the hydrologic and hydraulic information used to analyze and size the ESC facilities must be included in Section IX of the Technical Information Report.

II-4.4.1 Step 1 - Data Collection

Inventory the existing site conditions to gather information which will help develop the most effective erosion and sediment control plan. The information obtained should be plotted on a map and explained in the narrative portion of the plan.

- A. Topography - A small-scale topographic map of the site should be prepared to show the existing contour elevations at intervals of from 1 to 5 feet depending upon the slope of the terrain.
- B. Drainage Patterns - All existing drainage swales and patterns on the site should be located and clearly marked on the topographic map including all

existing underground storm drain pipe systems.

- C. Soils - Major soil type(s) on the site should be determined and shown on the topographic map. Soils information can be obtained from a soil survey if one has been published for the county. If a soil survey is not available, a request can be made to a district Soil Conservation Service Office. Commercial soils evaluations are also available. Soils information should be plotted directly onto the map or an overlay of the same scale for ease of interpretation.
- D. Ground Cover - The existing vegetation on the site should be shown. Such features as tree clusters, grassy areas, and unique or sensitive vegetation should be shown on the map. Unique vegetation may include existing trees above a given diameter. Local requirements regarding tree preservation should be investigated. In addition, existing denuded or exposed soil areas should be indicated.
- E. Adjacent Areas - Areas adjacent to the site should be delineated on the topographic map. Such features as streams, roads, lakes, wetlands, and wooded areas, etc., should be shown. These features should receive special attention during the construction project because of the potential for off-site damage.
- F. Existing Development - Existing buildings and facilities (if any) on-site or adjacent to the site should be shown on the topographic map.
- G. On and Off-Site Utilities - Identify all utility corridor locations, roadways, associated clearing limits and BMPs for all on-site and off-site utility construction.

#### II-4.4.2 Step 2 - Data Analysis

When all of the data in Step 1 are considered together, a picture of the site potentials and limitations should begin to emerge. Determination should be made to determine those areas which have potential critical erosion hazards. The following are some important points to consider in site analysis:

- A. Topography - The primary topographic considerations are slope steepness and slope length. Because of the effect of runoff, the longer and steeper the slope, the greater the erosion potential. When the percent of slope has been determined, areas of similar steepness should be outlined. Slope gradients can be grouped into three general ranges of soil erodibility:

0-7% - Low erosion hazard  
7-15% - Moderate erosion hazard  
>15% - High erosion hazard

Within these slope gradient ranges, the greater the slope length, the greater the erosion hazard. Therefore, in determining potential critical areas the planner should be aware of excessively long slopes. As a general rule, the erosion hazard will become critical if slope lengths exceed the following values:

0-7% - 300 feet  
7-15% - 150 feet  
>15% - 75 feet

These distances may be shorter in areas with highly erodible soils.

- B. Natural Drainage - Natural drainage patterns which consist of overland flow, swales and depressions, and natural watercourses, should be identified in order to plan around critical areas where water will concentrate. Where it is

possible, natural drainageways and discharge locations should be used to convey runoff over and off the site to avoid the expense and problems of constructing an artificial drainage system. Man-made ditches and waterways will become part of the erosion problem if they are not properly stabilized. Care should also be taken to be sure that increased runoff from the site will not erode or flood the existing natural drainage system. Possible sites for stormwater retention and detention should also be located at this point.

The site should also be checked for areas of saturated soil and/or areas where ground water may be encountered during construction. Construction in these areas should be avoided where possible.

- C. Soils - Such soils properties as flood hazard, natural drainage, depth to bedrock, depth to seasonal water table, permeability, shrink-swell potential, texture, and erodibility should exert a strong influence on land development decisions.
- D. Ground Cover - Ground cover is the most important factor in terms of preventing erosion. Any existing vegetation which can be saved will prevent erosion better than any constructed BMP. Trees and other vegetation protect the soil and beautify the site after construction. If the existing vegetation cannot be saved, consider such practices as staging construction, temporary seeding, or temporary mulching. Staging of construction involves stabilizing one part of the site before disturbing another. In this way, the entire site is not disturbed at once and the time without ground cover is minimized. Temporary seeding and mulching involve seeding or mulching areas which would otherwise lie open.

Buffers around water bodies or other sensitive areas should be delineated and the clearing limits flagged.

- E. Adjacent Areas - An analysis of adjacent properties should focus on areas downslope from the construction project. Water bodies which will receive direct runoff from the site are a major concern. The potential for sediment pollution and/or downstream channel erosion and deposition should be considered and addressed. The potential for sediment deposition on adjacent properties due to sheet and rill erosion should also be analyzed so that appropriate sediment trapping measures can be planned.

#### II-4.4.3 Step 3 - Site Plan Development

After analyzing the data and determining the site limitations, the planner can then develop a site plan. Locate the buildings, roads, and parking lots and develop landscaping plans to exploit the strengths and overcome the limitations of the site. The following are some points to consider when making these decisions:

- A. Fit the development to the terrain. The development of an area should be tailored to the existing site conditions to avoid unnecessary land disturbance and minimize erosion hazards and costs and other environmental impacts.
- B. Confine construction activities to the least critical areas. Any land disturbance in highly erodible areas will necessitate the installation of more costly control measures.
- C. Cluster buildings together. This minimizes the amount of disturbed area, concentrates utility lines and connections in one area, and provides more open natural space. The cluster concept not only lessens the erodible area and the amount of impervious surface, it reduces runoff, and generally reduces development costs.

- D. Minimize impervious areas. Keep paved areas such as parking lots and roads to a minimum. This goes hand in hand with cluster developments in eliminating the need for duplicating parking areas, access roads, etc.
- E. Utilize the natural drainage system. The natural drainage system and natural drainage locations of a site should be preserved instead of replaced with storm drains or concrete channels. The potential for downstream damages due to increased runoff can thus be minimized.

#### II-4.4.4 Step 4 - Plan for Erosion and Sediment Control

When the layout of the site has been decided upon, a plan to control erosion and sedimentation from the disturbed areas must be formulated. The Erosion and Sediment Control Requirements listed in Minimum Requirement #1 in Chapter I-2 establish a minimum level of control required for all projects.

The following general procedure is recommended for ESC control planning:

- A. Determine limits of clearing and grading. Decide exactly which areas must be disturbed in order to accommodate the proposed construction. Pay special attention to critical areas. Show all limits of clearing for flagging in the field.
- B. Divide the site into drainage areas. Determine how runoff will travel over the site. Consider how erosion and sedimentation can be controlled in each small drainage area before looking at the entire site. Remember, it is easier to control erosion than to contend with sediment after it has been carried downstream.
- C. Select erosion and sediment control BMPs. Erosion and sediment control BMPs can be divided into three broad categories: cover practices, structural practices, and management measures. Cover practices, such as leaving buffer strips, seeding and mulching are the preferred BMPs and should be used first. Structural practices, such as sediment ponds and inlet protection should be implemented only after cover practices are used as a first line of defense. Management measures are construction management techniques such as staging construction which, if properly utilized, can minimize the need for physical controls and possibly reduce costs.
  - 1. Cover Practices - Keep in mind that the first line of defense is to prevent erosion. This is accomplished by protecting the soil surface from raindrop impact and overland flow of runoff using source control BMPs. The best way to protect the soil surface is to preserve the existing ground cover. Where land disturbance is necessary, temporary seeding or mulching can be used on areas which will be exposed.

Erosion and sediment control plans must contain provisions for permanent stabilization of disturbed areas. Selection of permanent vegetation should include the following considerations:

- a. establishment requirements
  - b. adaptability to site conditions
  - c. aesthetics
  - d. maintenance requirements
- 2. Structural Practices - Structural practices are generally more costly and less efficient than are source controls. However, they are usually necessary since not all disturbed areas can be protected with vegetation. They are often used as a second or third line of defense in series with other vegetative or structural practices to capture sediment before it leaves the site.

It is very important that structural practices be selected, designed, and constructed according to the standards and specifications in Chapter II-5 of this volume. Improper use or inadequate installation can create problems which are greater than the structure was designed to solve.

3. Management Measures - Good construction management is as important as physical practices for erosion and sediment control, and there is generally little or no cost involved. Following are some management considerations which can be employed.
  - a. Sequence construction so that no area remains exposed for an unnecessarily long period of time.
  - b. Temporary seeding should be done immediately after grading.
  - c. When possible, avoid grading activities during November through March since these months have the highest potential for erosive rainfall.
  - d. On large projects, stage the construction so that one area can be stabilized before another is disturbed.
  - e. Develop and carry out a regular maintenance schedule for erosion and sediment control practices.
  - f. Physically mark off limits of land disturbance on the site with tape, signs or other methods, so the workers can see areas to be protected.
  - g. Make sure that all workers understand the major provisions of the erosion and sediment control plan.
  - h. Responsibility for implementing the erosion and sediment control plan should be designated to one individual (preferably the job superintendent or foreman).

- D. Properties and waterways downstream from the development site shall be protected from erosion due to increases in volume, velocity and peak flow rate of stormwater runoff.

#### II-4.4.5 Step 5 -Include BMPs for the Control of Pollutants Other than Sediment

- A. Review Chapter II-3 in this volume - This chapter provides information on common construction practices which cause pollution other than erosion and sedimentation. These range from nutrient and pesticide control to disposal of solid and/or dangerous wastes.
- B. Select appropriate BMPs based on the practices which will be used on-site - Based on the type of work to be done on-site, select the appropriate BMPs and include their use in the narrative plan. Areas where equipment washing may occur or where contaminated soils may be located on the site also should be noted on the site plan.

#### II-4.4.6 Step 6 - Prepare the Plan

All of the necessary planning work has been done in steps 1 through 5. The final step consists of consolidating the collected information and developing it into a specific erosion and sediment control plan for the project.

The plan consists of two parts: a narrative and a site plan. The narrative verbally explains the problems and their solutions with all necessary documentation. Justification should be provided for all solutions. The site plan is a series of maps or drawings pictorially explaining information contained in the narrative.

Following is a checklist of items which should be included in a narrative and on a site plan. This checklist can be used by a site planner as a quick reference to determine if all the major items are included in the erosion and sediment control plan.

#### II-4.4.7 Checklist for Erosion and Sediment Control Plans

##### Narrative

- Project description - Briefly describe the nature and purpose of the land disturbing activity, and the amount of grading involved.
- Existing site conditions - A description of the existing topography, vegetation, and drainage.
- Adjacent areas - A description of neighboring areas such as streams, lakes, residential areas, roads, etc., which might be affected by the land disturbance. Provide perimeter control of runoff on all necessary property boundaries.
- Soils - A brief description of the soils on the site giving such information as soil names, mapping unit, erodibility, permeability, depth, texture, and soil structure.
- Critical areas - A description of areas on the site which have potential serious erosion problems.
- Erosion and sediment control BMPs - A description of the BMPs which will be used to control erosion and sedimentation on the site. Specify the construction sequence.
- Permanent stabilization - A brief description, including specifications, of how the site will be stabilized after construction is completed.
- Stormwater management considerations - Will the development of the site result in increased peak rates of runoff? Will this potentially result in channel degradation downstream? If so, consideration must be given to stormwater control structures on the site (see Minimum Requirement #5 in Chapter I-2).
- Maintenance - A schedule of regular inspections and repair of erosion and sediment control structures should be set forth.
- Calculations - Any calculations made for the design of such items as sediment ponds, diversions, waterways, and calculations for runoff and stormwater detention basin design (if applicable). All calculations must bear the signature and stamp of an engineer licensed in the State of Washington.
- Non-ESC BMPs Required - Indicate which BMPs from Chapter II-3 will be used on-site.

##### Site Plan

- Vicinity map - A small map locating the site in relation to the surrounding area.
- Existing contours - Existing contours of the site should be shown on a map.

- Existing vegetation - The existing tree lines, grassy areas, or unique vegetation should be shown on a map.
- Soils - The boundaries of the different soil types should be shown on a map.
- Indicate north - The direction of north in relation to the site should be shown.
- Critical erosion areas - Areas with potentially serious erosion problems should be shown on a map.
- Existing drainage patterns - The dividing lines and the direction of flow for the different drainage areas should be shown on a map.
- Final contours - Changes to the existing contours should be shown on a map. Use a bold dashed line showing developed condition drainage divides.
- Limits of clearing and grading - Areas which are to be cleared and graded should be outlined on a map.
- Cut and Fill Slopes - Show all cut and fill slopes, indicating top/bottom of slope catch lines.
- Conveyance -
  - (1) Designate locations for grass-lined swales, interceptor trenches, or ditches.
  - (2) Show all drainage pipes, ditches, or cut-off trenches associated with erosion/sediment control.
  - (3) Provide all temporary pipe inverts or minimum slopes and cover.
  - (4) Show grades, dimensions, location, and direction of flow in all ditches and swales.
  - (5) Provide details of bypassing off-site runoff around clearing limits/disturbed areas and sediment pond/trap.
  - (6) Indicate locations and outlets of any possible dewatering systems.
- Location of BMPs - The locations of the erosion and sediment control and stormwater management BMPs used on the site should be shown on a map. In particular, locate the construction entrance and detail. Specify length, width, thickness and rock size of the entrance.
- Sediment Control Facilities -
  - (1) Show all the locations of sediment trap(s)/pond(s) (if required) and all associated pipes and structures.
  - (2) Dimension pond berm widths and all inside and outside pond slopes.
  - (3) Indicate the trap/pond storage required and the depth, length, and width dimensions.
  - (4) Provide typical section views throughout pond and outlet structure.
  - (5) Provide typical details of gravel cone and standpipe, and/or other filtering devices.

- (6) Detail stabilization techniques for outlet/inlet.
  - (7) Detail control/restrictor device location and details.
  - (8) Specify mulch and/or recommended cover of berms and slopes.
  - (9) Provide rock specifications and detail for rock check dam, if used.
  - (10) Specify spacing for rock check dams as required for actual slopes on-site.
  - (11) Provide front and side sections of typical rock check dams.
  - (12) Indicate locations and provide details and specifications for silt fabric fence (include installation detail).
- Detailed drawings - Any structural practices used that are not referenced to this manual or other local manuals should be explained and illustrated with detailed drawings.
- Non-ESC BMPs - Indicate any equipment washdown areas, areas of contaminated soils or other BMPs used where there are site-specific requirements.



CHAPTER II-5

STANDARDS AND SPECIFICATIONS FOR  
BEST MANAGEMENT PRACTICES FOR EROSION AND SEDIMENT CONTROL

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CHAPTER II-5

STANDARDS AND SPECIFICATIONS FOR  
BEST MANAGEMENT PRACTICES FOR EROSION AND SEDIMENT CONTROL

II-5.1 INTRODUCTION

Best Management Practices (BMPs) are defined as physical, structural and/or managerial practices, that when used singly or in combination, prevent or reduce pollution of water and have been approved by Ecology. This chapter contains the standards and specifications for erosion and sediment control BMPs which form the backbone of any Erosion and Sediment Control Plan.

II-5.2 STANDARDS AND SPECIFICATIONS FOR COVER PRACTICES

Specifications and design criteria of BMPs for erosion and sedimentation control can be broadly divided into two categories: cover practices (such as seeding and mulching) and structural practices (such as sediment ponds, filter fences, etc.) which require engineering standards and specifications. Structural control BMPs are dealt with in the next section.

Vegetative cover is the most important form of erosion control possible because it prevents or reduces erosion rather than attempting to trap sediment after soil has already eroded. In addition, it adds to the aesthetic and functional value of a development.

Cover practices can be divided into temporary and permanent measures. Temporary measures are implemented to provide a quick cover to soils that are exposed for longer than 2-7 days, or if an erosion problem already exists on the site during the development phase. They include:

- seeding
- mulching and matting
- clear plastic covering

Permanent measures are implemented both during and on completion of construction activities. They include:

- preserving natural vegetation
- buffer zones
- permanent seeding and planting
- sodding

## II-5.3 TEMPORARY COVER PRACTICES

## II-5.3.1 BMP E1.10: Temporary Seeding of Stripped Areas

Code:

TS

Symbol:

← TS →

Definition The establishment of a temporary vegetative cover on disturbed areas by seeding with appropriate rapidly growing annual plants.

Purpose

To provide temporary soil stabilization by planting grasses and legumes to areas which would remain bare for more than 7 days where permanent cover is not necessary or appropriate.

Conditions Where Practice Applies

- Permanent structures are to be installed or extensive re-grading of the area will occur prior to the establishment of permanent vegetation.
- Areas which will not be subjected to heavy wear by construction traffic.
- Areas sloping up to 10% for 100 feet or less (where temporary seeding is the only BMP used).

Advantages

- This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used (see BMP E1.35, Permanent Seeding and Planting).
- Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site.
- Temporary seeding offers fairly rapid protection to exposed areas.

Disadvantages/Problems

- Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. During the establishment period the bare soil should be protected with mulch (see BMP E1.15) and/or clear plastic covering (see BMP E1.20).
- If sown on subsoil, growth will be poor unless heavily fertilized and limed. Because over-fertilization can cause pollution of stormwater runoff, other practices such as mulching (BMP E1.15) alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems.
- Once seeded, areas cannot be used for heavy traffic.
- May require regular irrigation to flourish. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected. The use of low maintenance native species should be encouraged, and planting should be timed to minimize the need for irrigation.

Planning Considerations

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, the soil surface

itself should be protected. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover. Annual plants which sprout rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover. Temporary seeding is effective when combined with construction phasing so bare areas of the site are minimized at all times.

Temporary seeding may prevent costly maintenance operations on other erosion control systems. For example, sediment basin clean-outs will be reduced if the drainage area of the basin is seeded where grading and construction are not taking place. Perimeter dikes will be more effective if not choked with sediment.

Temporary seeding is essential to preserve the integrity of earthen structures used to control sediment, such as dikes, diversions, and the banks and dams of sediment basins.

Proper seedbed preparation and the use of quality seed are important in this practice just as in permanent seeding. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Design Criteria

- Time of Planting - Planting should preferably be done between April 1 and June 30, and September 1 through October 31. If planting is done in the months of July and August, irrigation may be required. If planting is done between November 1 and March 31, mulching shall be required immediately after planting. If seeding is done during the summer months, irrigation of some sort will probably be necessary.
- Site Preparation - Before seeding, install needed surface runoff control measures such as gradient terraces, interceptor dike/swales, level spreaders, and sediment basins.
- Seedbed Preparation - The seedbed should be firm with a fairly fine surface. Perform all cultural operations across or at right angles to the slope. See BMP E1.45, Topsoiling, and BMP E2.35, Surface Roughening for more information on seedbed preparation. A minimum of 2-4 inches of tilled topsoil is required.
- Fertilization - as per suppliers and/or Soil Conservation Service recommendations. Developments adjacent to water bodies must use non-phosphorus fertilizer.
- Seeding - seeding mixtures will vary depending on the exact location, soil type, slope, etc. Information on mixes may be obtained from local suppliers, the Washington State Department of Transportation, or the Soil Conservation Service. However, approval to use any particular mix must be obtained from the local government. The following seed mix is supplied as guidance.

<u>Name</u>	<u>Proportions By Weight</u>	<u>Percent Purity</u>	<u>Percent Germination</u>
Redtop ( <u>Agrostis alba</u> )	10%	92	90
Annual Rye ( <u>Lolium multiflorum</u> )	40%	98	90
Chewings Fescue ( <u>Festuca rubra commutata</u> )	40%	97	80
White Dutch Clover ( <u>Trifolium repens</u> )	10%	96	90

- "Hydro-seeding" applications with approved seed-mulch-fertilizer mixtures may also be used.

Maintenance

- Seeding should be supplied with adequate moisture. Supply water as needed, especially in abnormally hot or dry weather or on adverse sites. Water application rates should be controlled to prevent runoff.
- Re-seeding - Areas which fail to establish vegetative cover adequate to prevent erosion shall be re-seeded as soon as such areas are identified.
- All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment must be removed or stabilized on site. Disturbed soil areas resulting from removal should be permanently stabilized.

II-5.3.2 BMP E1.15: Mulching and Matting

Code:



Symbol:



Definition Application of plant residues or other suitable materials to the soil surface.

Purpose

To provide immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas.

Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface.

Conditions Where Practice Applies

- In areas which have been seeded either for temporary or permanent cover, mulching should immediately follow seeding.
- Areas which cannot be seeded because of the season, or are otherwise unfavorable for plant growth.
- Areas which have been seeded as specified in Temporary Seeding (BMP E1.10).
- In an area of greater than 2:1 slope, mulching should immediately follow seeding.

Advantages

- Mulching offers instant protection to exposed areas.
- Mulches conserve moisture and reduce the need for irrigation.
- Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings.

Disadvantages/Problems

- Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting.
- Thick mulches can reduce the soil temperature, delaying seed germination.
- Mulches such as straw, which are often applied to areas after grading must then be removed and either composted or landfilled. Straw is hollow, so it can actually draw water into the ground below it if the straw is at an angle.

Planning Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. A surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land (see Figure II-5.1 for a comparison of pollutant loading reductions for various mulches).

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.

Organic mulch materials, such as straw, wood chips, bark, and wood fiber, have been



found to be the most effective.

A variety of nets and mats have been developed for erosion control in recent years, and these are also used as mulches, particularly in critical areas such as waterways. They may be used to hold other mulches to the soil surface.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and on cut slopes and southern slope exposures. Table II-5.1 gives a comparison of costs based on 1988 figures.

#### Organic Mulches

Straw - Straw is the mulch most commonly used in conjunction with seeding. Its use is recommended where immediate protection is desired and preferably where the need for protection will be less than 3 months. The straw should come from wheat or oats, and may be spread by hand or machine. If the straw is not clean, weed growth can occur. Straw can be windblown and must be anchored down. Common anchoring methods are:

1. Crimping, disking, rolling or punching into the soil;
2. Covering with netting;
3. Spraying with a chemical or fiber binder (tackifier); and
4. Keeping moist. Natural precipitation can often provide sufficient moisture.(2)

Corn Stalks - These should be shredded into 4 to 6-inch lengths. Stalks decompose slowly and are resistant to windblow.

Wood Chips - Suitable for areas that will not be closely mowed, and around ornamental plantings. Chips decompose slowly and do not require tacking. They must be treated with 12 pounds nitrogen per ton to prevent nutrient deficiency in plants. Chips can be a very inexpensive mulch if they are obtained from trees cleared on the site. However, both wood and bark chips tend to wash down slopes of more than 6 percent and create problems by clogging inlet grates etc. and are therefore not preferred for use in those areas.

Bark Chips, Shredded Bark - By-products of timber processing. Used in landscaped plantings. Bark is also a suitable mulch for areas planted to grasses and not closely mowed; may be applied by hand or mechanically. Bark is not usually toxic to grasses or legumes, and additional nitrogen fertilizer is not required.

Wood Fiber - Used in hydro-seeding operations, applied as part of the slurry. These short cellulose fibers do not require tacking, although a tacking agent or soil binders are sometimes used with wood fiber. The longer the fiber length, the better the wood fiber will work in erosion control. This form of mulch does not provide sufficient protection to erodible soils to be used alone during the severe heat of summer or for late fall seedings. Wood fiber hydro-seed slurries may be used to tack straw mulch. This combination treatment is well suited for steep slopes and critical areas, and severe climate conditions.

There are other organic materials which make excellent mulches but are only available locally or seasonally. Creative use of these materials can reduce costs.

Manure Mulches - Manure mulches should be well-aged and are not recommended for use near waterbodies.

#### Chemical Mulches and Soil Binders

The use of synthetic, spray-on materials (except tacking agents used with hydro-seeding) is not recommended. A major problem with their use is the creation of impervious surfaces and, possibly, adverse effects on water quality. Research has

shown that they can cause more erosion when used than does bare exposed soil.

Nets and Mats - Used alone, netting does not retain soil moisture or modify soil temperature. It stabilizes the soil surface while grasses are being established, and is useful in grassed waterways and on slopes. Light netting may also be used to hold other mulches in place. Its relatively high cost makes it most suitable for small sites.

The most critical aspect of installing nets and mats is obtaining firm, continuous contact between the material and the soil. Without such contact, the material is useless and erosion occurs. It is important to use an adequate number of staples and to roll the material after laying it to ensure that the soil is protected.

Table II-5.1 Summary of Estimated Service Lives and Costs  
1988 Base - Horner, January, 1990

Technique <sup>a</sup>	Estimated Service Life (months)	Estimated Cost (\$/acre served) (6 months service)
Straw (4 T/ac)	3	3,200
Straw (1.25 T/ac)	3	2,500
Straw (4 T/ac) manure-mulched, fertilized, seeded	6	2,400
Jute mat	6	3,700
Excelsior	6	3,600
Woven straw blanket	6	4,100
Synthetic fiber blanket	6	3,300
Wood fiber mulch (1.25 T/ac) fertilized, seeded	6	1,300
Wood fiber mulch (1.25 T/ac) with tackifier (50 gal/ac), fertilized, seeded	6	1,900
Wood fiber mulch (1.25 T/ac) with tackifier (90 gal/ac), fertilized, seeded	6	2,100
Wood fiber mulch (1.25 T/ac) with tackifier (120 gal/ac), fertilized, seeded	6	2,300
Chemical agent	6	2,100
Plastic sheeting	6	2,300
Designed sedimentation pond	> 6	< 4,200
Non-designed pond	> 6	< 7,500

<sup>a</sup> The estimated cost of seeding where it was used is based on hydro-seeding (approximately \$500/acre).

Figure II-5.1 Mean TSS and Overall Pollutant Loading Reductions of Slope Treatments Relative to Controls from Horner, January, 1990

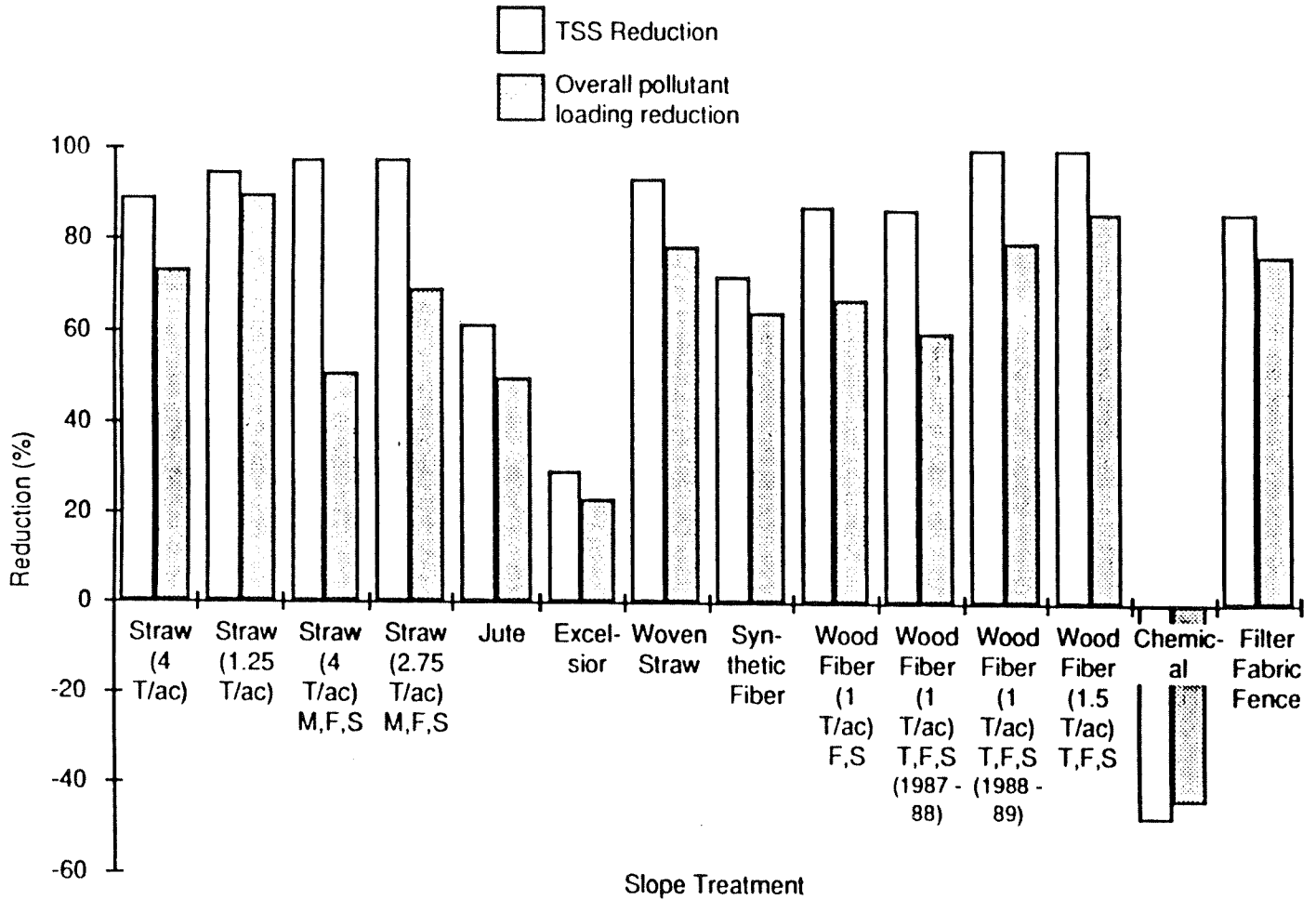


Figure 3. Mean TSS and Overall Pollutant Loading Reductions of Slope Treatments Relative to Controls

Design Criteria

- Site Preparation - Same as Temporary Seeding.
- Mulch Materials, Application Rates, and Specifications - See Table II-5.2.
- Erosion blankets (nets and mats) may be used on level areas, on slopes up to 50 percent, and in waterways. Where soil is highly erodible, nets shall only be used in connection with an organic mulch such as straw and wood fiber. Jute nets shall be heavy, uniform cloth woven of single jute yarn, which if 36 to 48 inches wide shall weigh an average of 1.2 lbs./linear yard. It must be so applied that it is in complete contact with the soil. If it is not, erosion will occur beneath it. Netting shall be securely anchored to the soil with No. 11 gauge wire staples at least 6 inches long, with an overlap of three inches.
- Excelsior blankets are considered protective mulches and may be used alone on erodible soils and during all times of year.
- See Figure II-5.2 for orientation of netting and matting.

Maintenance

- Mulched areas should be checked periodically, especially following severe storms, when damaged areas of mulch or tie-down material should be repaired.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

References

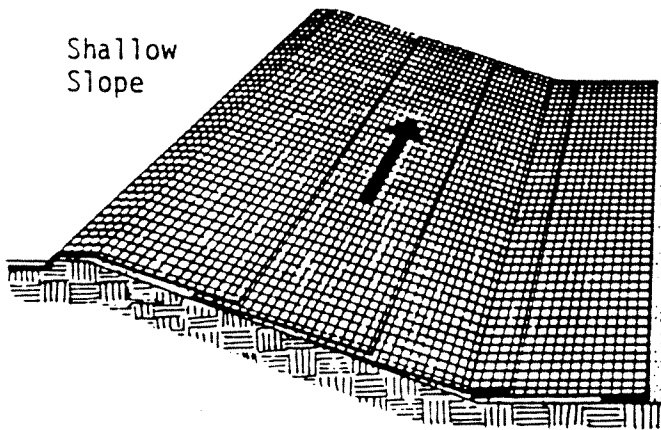
Horner, Richard R., Juno Guedry and Michael H. Korten Hof, Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control, Washington State Dept. of Transportation, WA-RD 200.1, January, 1990.

Table II-5.2 Guide to Mulch Materials, Rates and Uses

Mulch Material	Quality Standards	Application Rates		Depth of Application	Remarks <sup>1</sup>
		/1000 ft <sup>2</sup>	/acre		
Gravel, slag or crushed stone	Washed, ¾ - 1½" size	9 yds <sup>3</sup>		3 inches	Excellent mulch for short slopes and around woody plants & ornamentals. Use where subject to foot traffic. Approx. 2000 lbs/ yd <sup>3</sup>
Hay or straw	Air dried, free from unwanted seeds & coarse material	75-100 lbs. or 2-3 bales	1½-2½ tons or 90-120 bales	Minimum of 2 inches	Use where the mulching effect is to be maintained for >3 months. Is subject to wind blowing unless kept moist or tacked down. Most common & widely used mulching material. Can be used in critical erosion areas.
Wood fiber cellulose (partially digested wood fibers)	Dyed green should not contain growth inhibiting factors.	25 - 30 lbs.	1000-1500 lbs.		If used on critical areas, double the normal application rate. Apply w/hydromulcher. No tie-down required. Packaged in 100 lb. bags.

<sup>1</sup>All mulches will provide some degree of (1) erosion control, (2) moisture conservation, (3) weed control, and (4) reduction of soil crusting.

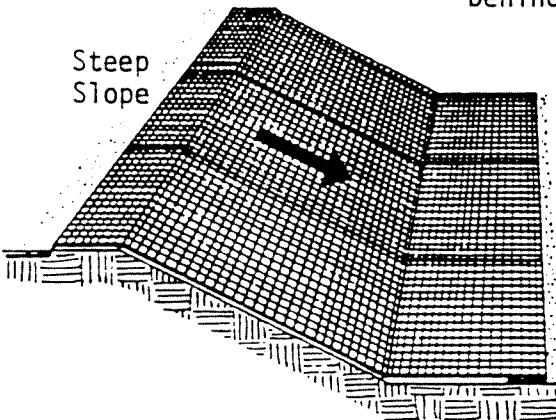
Figure II-5.2 Orientation of Netting and Matting



Shallow  
Slope

On shallow slopes, strips of netting may be applied across the slope.  
(Slopes up to 1:1)

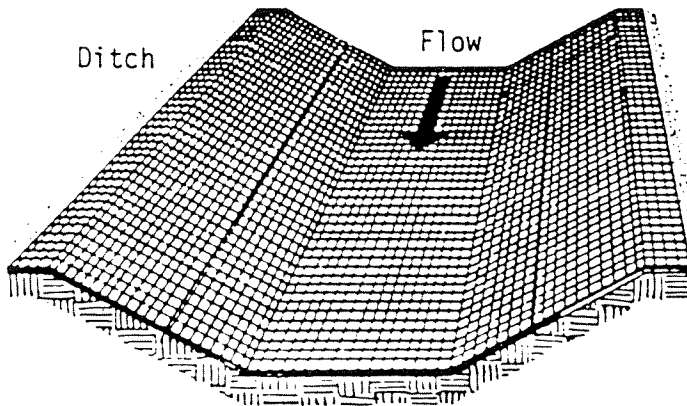
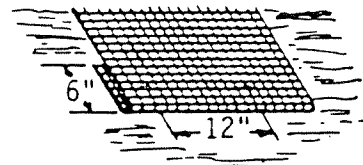
Where there is a berm at the top of the slope, bring the netting over the berm and anchor it behind the berm.



Steep  
Slope

On steep slopes, apply strips of netting parallel to the direction of flow and anchor securely.  
(Slopes greater than 1:1)

Bring netting down to a level area before terminating the installation. Turn the end under 6" and staple at 12" intervals.



Ditch

Flow

In ditches, apply netting parallel to the direction of flow. Use check slots of flow every 15 feet. Do not join strips in the center of the ditch.

II-5.3.3 BMP E1.20: Clear Plastic Covering

Code: (CPC)

Symbol: ←(C)→

Definition The covering with clear plastic sheeting of bare areas which need immediate protection from erosion.

Purpose

To provide immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, in particular during the specified seeding periods or as otherwise required by the local government. Clear plastic is also used to protect disturbed areas which must be covered during short periods of inactivity to meet November 1-March 31 cover requirements. Because of many disadvantages clear plastic covering is the least preferred covering BMP.

Conditions Where Practice Applies

- Disturbed areas which require immediate erosion protection.
- Areas seeded during the time period from November 1 to March 1.  
(Note: Plantings at this time require clear plastic covering for germination and protection from heavy rains.)

Advantages

- Clear plastic covering is a good method of protecting bare areas which need immediate cover and for winter plantings.
- May be quickly and easily placed.

Disadvantages/Problems

- There can be problems with vandals and maintenance.
- The sheeting will result in rapid, 100% runoff which may cause serious erosion problems and/or flooding at the base of slopes unless the runoff is properly intercepted and safely conveyed by a collecting drain. This is strictly a temporary measure, so permanent stabilization is still required.
- It is relatively expensive.
- The plastic may blow away if it is not adequately overlapped and anchored.
- Ultraviolet and possibly visible light can cause some types of plastic to become brittle and easily torn.
- Plastic must be disposed of at a landfill; it is not easily degradable in the environment.
- If plastic is left on too long during the spring it can severely burn any vegetation that has grown under it during cooler periods.

Design Criteria

- Clear plastic sheeting shall have a minimum thickness of 6 mil and meet the requirements of WSDOT/APWA Section 9-14.5.
- Covering shall be installed and maintained tightly in place by using sandbags or tires on ropes with a maximum 10 foot grid spacing in all directions. All seams shall be taped or weighted down full length and there shall be at least a 1 to 2 foot overlap of all seams. Seams should then be rolled and staked or

tied.

- Covering shall be installed immediately on areas seeded between November 1 to March 1, and remain until vegetation is firmly established.
- When the covering is used on unseeded slopes, it shall be left in place until the next seeding period.
- Sheeting should be toed in at the top of the slope to prevent surface flow beneath the plastic.
- Sheeting should be removed as soon as is possible once vegetation is well grown to prevent burning the vegetation through the plastic sheeting, which acts as a greenhouse.

#### Maintenance

- Check regularly for rips and places where the plastic may be dislodged. Contact between the plastic and the ground should always be maintained. Any air bubbles found should be removed immediately or the plastic may rip during the next windy period. Re-anchor or replace the plastic as necessary.

All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.



## II-5.4 PERMANENT COVER PRACTICES

II-5.4.1 BMP E1.25: Preserving Natural VegetationCode:  Symbol: 

Definition Minimizing exposed soils and consequent erosion by clearing only where construction will occur.

Purpose

To reduce erosion by preserving natural vegetation wherever practicable.

Condition Where Practice Applies

- Natural vegetation should be preserved on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.
- As required by local governments.

Advantages

Preserving natural vegetation will:

- Help reduce soil erosion.
- Beautify an area.
- Save money on landscaping costs.
- Provide areas for wildlife.
- Possibly increase the value of the land.
- Provide buffers and screens against noise.
- Moderate temperature changes and provide shade and cover habitat for surface waters and land. This is especially important where detention ponds drain to salmonid-bearing streams. Increases in water temperature tend to lower the dissolved oxygen available for aquatic life.

Disadvantages/Problems

- Saving individual trees can be difficult, and older trees may become a safety hazard. Cottonwood and alder trees are especially prone to blowdown.

Planning Considerations

*New development often takes place on tracts of forested land. In fact, building sites are often selected because of the presence of mature trees. However, unless sufficient care is taken and planning done, in the interval between buying the property and completing construction much of this resource is likely to be destroyed. The property owner is ultimately responsible for protecting as many trees as possible, with their understory and groundcover. This responsibility is usually exercised by agents--the planners, designers and contractors. It takes 20 to 30 years for newly planted trees to provide the benefits for which we value trees so highly.*

Design Criteria

Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

The preservation of individual plants is more difficult because equipment is generally used to remove unwanted vegetation. The points to remember when attempting to save individual plants are:

- Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. Local governments may also have ordinances to save natural vegetation and trees.
- Is the tree or shrub a desirable plant? Is it shallow-rooted, do the roots seek water, or are insects and disease a problem? Shallow-rooted plants can cause problems in the establishment of lawns or ornamental plants. Water-seeking roots can block sewer and tile lines. Insects and diseases can make the plant undesirable. This is especially true with aphid on alder and maple.
- Old and/or large plants do not generally adapt to changes in environment as readily as young plants of the same species. Usually, it is best to leave trees which are less than 40 years of age. Some of the hardwoods (Red alder, Cherry, etc.) mature at approximately 50 years of age. After maturity they rapidly decline in vigor. Conifers, after 40 years of age, may become a safety hazard due to the possibility of breakage or blowdown, especially where construction has left only a few scattered trees in an area that was formerly dense woods. While old large trees are sometimes desirable, the problem of later removal should be considered. Again, local governments may have requirements to preserve older, larger specimen trees. It is expensive to cut a large tree and to remove the tree and stump from a developed area. Thinning some branches from trees can provide avenues for wind and hence lessen the "sail" effect.
- Clearly flag or mark areas around trees that are to be saved. It is preferable to keep ground disturbance away from the trees at least as far out as the dripline.

Plants need protection from three kinds of injuries:

- Construction Equipment -- This injury can be above or below the ground level. Damage results from scarring, cutting of roots, and compaction of the soil. Such injuries can be prevented by roping or fencing a buffer zone around plants to be saved prior to construction (Figure II-5.3.).
- Grade Changes -- Changing the natural ground level will alter grades which affect the plant's ability to obtain the necessary air, water, and minerals. Minor fills usually do not cause problems although sensitivity between species does vary. Cedars are more sensitive. Trees can tolerate fill of 6 inches or less. For shrubs and other plants the fill should be less. When there are major changes in grade, it may become necessary to supply air to the roots of plants. This can be done by placing a layer of gravel and a tile system over the roots before the fill is made. A tile system protects a tree from a raised grade.

The tile system should be laid out on the original grade leading from a dry well around the tree trunk. The system should then be covered with small stones to allow air to circulate over the root area (see Figure II-5.3).

Lowering the natural ground level can seriously damage trees and shrubs. The highest percentage of the plant roots are in the upper 12 inches of the soil and cuts of only 2-3 inches can cause serious injury. To protect the roots it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant (Figure II-5.3).

- Excavations -- Protect trees and other plants when excavating for tile, water, and sewer lines. Where possible, the trenches should be routed around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or with power augers.

If it is not possible to route the trench around plants to be saved, then the following should be observed:

Cut as few roots as possible. When you have to cut -- cut clean. Paint cut root ends with a wood dressing like asphalt base paint.

Backfill the trench as soon as possible.

Tunnel beneath root systems as close to the center of the main trunk to preserve most of the important feeder roots.

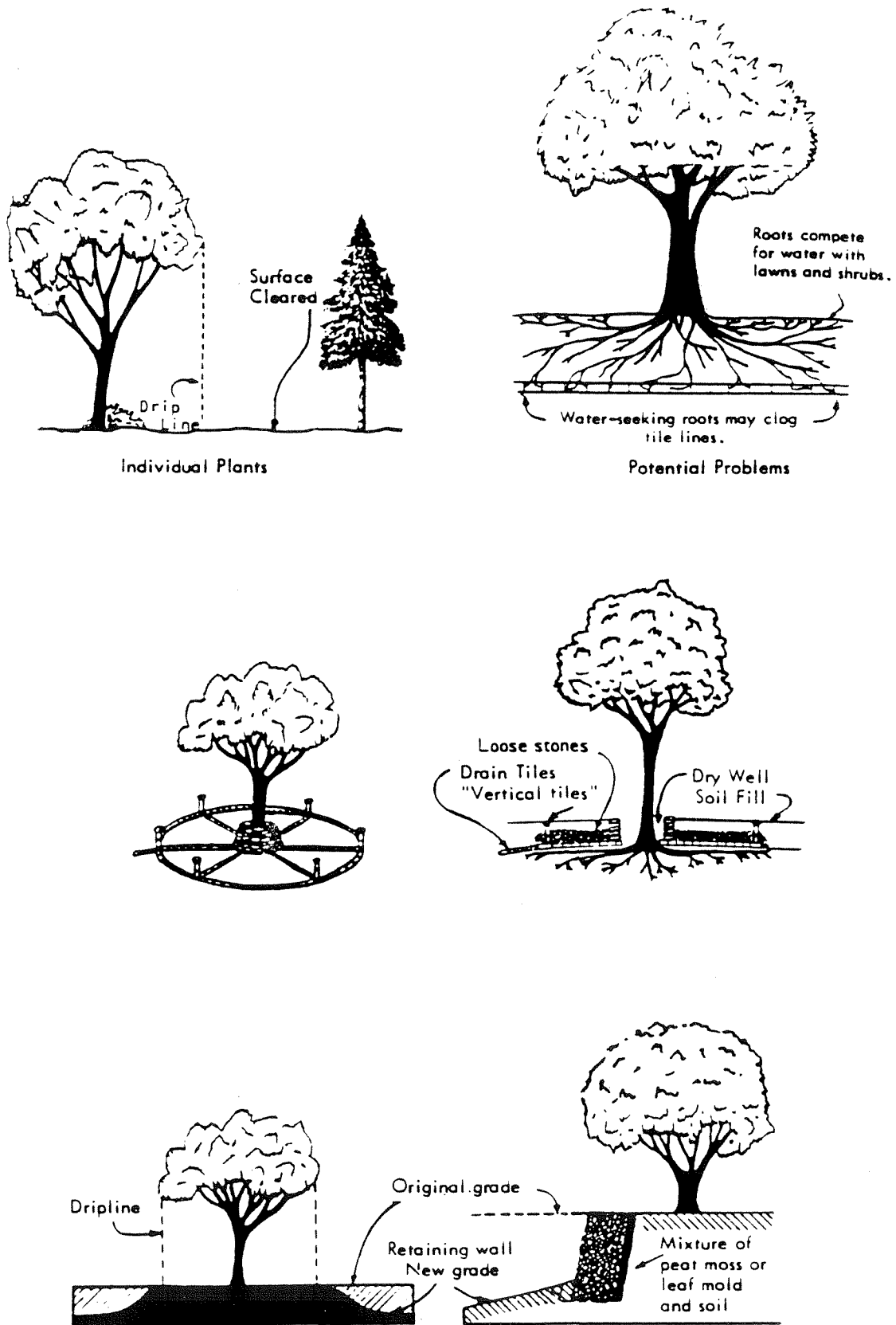
Some problems that can be encountered with a few specific trees are:

- Maple, Dogwood, Red alder, Western hemlock, Western red cedar and Douglas fir do not readily adjust to changes in environment and special care should be taken to protect these trees.
- The tipover hazard of Pacific silver fir is high while that of Western hemlock is moderate. The danger of tipover increases where dense stands have been thinned. Other species (unless they are on shallow, wet soils under 20 inches deep) have a low tipover hazard.
- Cottonwoods, maples, and willows have water-seeking roots. These can cause trouble in sewer lines and filter fields. On the other hand, they thrive in high moisture conditions that other trees would succumb to.
- Thinning operations in pure or mixed stands of Grand fir, Pacific silver fir, Noble fir, Sitka spruce, Western red cedar, Western hemlock, Pacific dogwood, and Red alder can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

#### Maintenance

- Inspect flagged areas regularly to make sure flagging has not been removed. If tree roots have been exposed or injured, re-cover and/or seal them.

Figure II-5.3 Preserving Natural Vegetation



II-5.4.2 BMP E1.30: Buffer Zones

Code:



Symbol:



Definition and Purpose An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and runoff velocities.

Conditions Where Practice Applies

- Natural buffer zones are used along streams and other bodies of water that need protection from erosion and sedimentation. Vegetative buffer zones can be used to protect natural swales and incorporated into natural landscaping of an area.

Advantages

- Buffer zones provide critical habitat adjacent to streams and wetlands, as well as assist in controlling erosion, especially on unstable steep slopes. Buffers along streams and other water bodies also provide wildlife corridors, a protected area where wildlife can move from one place to another.
- Act as a visibility and noise screen.

Disadvantages/Problems

- Extensive buffers will increase development costs.

Design Criteria

- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Leave all unstable steep slopes in natural vegetation.
- Fence or flag clearing limits and keep all equipment and construction debris out of the natural areas.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.
- Vegetative buffer zones for streams, lakes or other waterways should be a minimum of 100 feet wide on each side with increases subject to other on-site sensitive conditions, existing vegetative conditions and erosion hazard potential (see Table II-5.3 for setback guidelines).

Table II-5.3 Minimum Recommended Guidelines for Undisturbed Vegetative Setbacks From Wetlands, Streams, Lakes and Other Sensitive/Critical Areas: (Expressed in feet from "ordinary high water mark".) <sup>1</sup>

Wetlands<sup>2</sup>

Category I	High intensity	300 feet
	Low intensity	200 feet
Category II	High intensity	200 feet
	Low intensity	100 feet
Category III	High intensity	100 feet
	Low intensity	50 feet
Category IV	High intensity	50 feet
	Low intensity	25 feet

Streams: To be completed at a later date.

Lakes: To be completed at a later date.

<sup>1</sup> The term "ordinary high water mark" means the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area.

<sup>2</sup> Source: Model Wetlands Protection Ordinance, Dept. of Ecology, September, 1990. Note: These buffer ranges have been established to reflect the impact of intense land uses on wetland functions and values. The ratings system (Categories I-IV) are based on the Puget Sound Wetlands Rating System as set out in the same document.

<sup>3</sup> Poor, fair, good and excellent conditions refers to percent coverage and growing condition of vegetation.

<sup>4</sup> Erosion hazard ratings are based on the percent slope and hydrologic soil group of bare ground, as defined by the SCS.

NOTE: If ground cover is improved through reseeding reduce recommendations to next level within the same category except for excellent rating which is minimum specification.

Maintenance

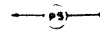
- Inspect the area frequently to make sure flagging remains in place and the area remains undisturbed.

II-5.4.3 BMP El.35: Permanent Seeding and Planting

Code:



Symbol:



Definition The establishment of perennial vegetative cover on disturbed areas.

Purpose

To establish permanent vegetation (such as grasses, legumes and trees and shrubs) as rapidly as possible to prevent soil erosion by wind or water, and to improve wildlife habitat and site aesthetics.

To provide pollutant filtration (biofiltration) in vegetation-lined channels and to establish constructed wetlands as required (see BMP RW.10 in Chapter III-4 and RV.05 in Chapter III-6).

Conditions Where Practice Applies

- Graded, final graded or cleared areas where permanent vegetative cover is needed to stabilize the soil.
- Areas which will not be brought to final grade for a year or more.
- Vegetation-lined channels.
- Retention or detention ponds as required.

Advantages

- Well established grass and ground covers can give an aesthetically pleasing, finished look to a development.
- Once established, the vegetation will serve to prevent erosion and retard the velocity of runoff.

Disadvantages/Problems

- Vegetation and mulch cannot prevent soil slippage and erosion if soil is not inherently stable.
- Coarse, high grasses that are not mowed can create a fire hazard in some locales. Very short mowed grass, however, provides less stability and sediment filtering capacity.
- Grass planted to the edge of a watercourse may encourage fertilizing and mowing near the water's edge and increase nutrient and pesticide contamination.
- May require regular irrigation to establish and maintain.

Planning Considerations

*Vegetation controls erosion by reducing the velocity and the volume of overland flow and protecting the bare soil surface from raindrop impact.*

*Areas which must be stabilized after the land has been disturbed require vegetative cover. The most common and economical means of establishing this cover is by seeding grasses and legumes.*

*Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.*

Consider the microclimate(s) within the development area. Low areas may be frost pockets and require hardier vegetation since cold air tends to sink and flow towards low spots. South-facing slopes may be more difficult to re-vegetate because they tend to be sunnier and drier.

Disadvantages which must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, and a need for water and appropriate climatic conditions during germination.

There are so many variables in plant growth that an end product cannot be guaranteed. Much can be done in the planning stages to increase the chances for successful seeding. Selection of the right plant materials for the site, good seedbed preparation, timing, and conscientious maintenance are important. Whenever possible, native species of plants should be used for landscaping. These plants are already adapted to the locale and survivability should be higher than with exotic species.

Native species are also less likely to require irrigation, which can be a large maintenance burden and is neither cost-effective nor ecologically sound.

If non-native plant species are used, they should be tolerant of a large range of growing conditions and as low-maintenance as possible.

#### Design Criteria

- Vegetation cannot be expected to supply an erosion control cover and prevent slippage on a soil that is not stable due to its texture, structure, water movement, or excessive slope.
- Seeding should be done immediately after final shaping, except during the period of November 1 through March 1, when the site should be protected by mulching or plastic covering until the next seeding period.
- Permanent vegetation may be in the form of grass-type growth by seeding or sodding, or it may be trees or shrubs, or a combination of these. Establishing this cover may require the use of supplemental materials, such as mulch or jute netting (see BMP E1.15).
- Site Preparation: Install needed surface runoff control measures such as gradient terraces, berms, dikes, level spreaders, waterways, and sediment basins prior to seeding or planting.
- Seeding Grasses and Legumes: Seedbed Preparation -- If infertile or coarse textured subsoil will be exposed during land shaping, it is best to stockpile topsoil and respread it over the finished slope at a minimum 2 to 6-inch depth and roll it to provide a firm seedbed. If construction fills have left soil exposed with a loose, rough, or irregular surface, smooth with blade and roll. If cuts or construction equipment have left a tightly compacted surface, break with chisel plow or other suitable implement. Perform all cultural operations across or at right angles to the slope (contoured), such as with cat tracks on the final pass. The seedbed should be firm with a fairly fine surface.
- Soil Amendments: Rates will depend on site characteristics and soil, but as a guide, apply lime at the rate of 100 pounds per 1,000 square feet. Apply actual nitrogen at the rate of 1-2 pounds per 1,000 sq. feet, phosphoric acid at the rate of 1.5 pounds per 1,000 sq. feet, and potassium at the rate of 1.5 pounds per 1,000 sq. feet. Work in lime and other nutrients to a depth of a minimum of 4 inches with suitable equipment. Scatter amendments uniformly and work into the soil during seedbed preparation.
- Seeding: Apply an appropriate mixture to the prepared seedbed at a rate of 120 lbs/acre. (Seed mixture may be varied by the local government to take account of local conditions).



Urban Application:

<u>Name</u>	<u>Portions by Weight</u>	<u>Percent Purity</u>	<u>Germination</u>
Kentucky Bluegrass	30%	85	80
Creeping Red Fescue	40%	98	90
Perennial Rye	30%	95	90

Rural Application:

Kentucky Bluegrass ( <u>Poa pratensis</u> )	15%	85	80
Tall Fescue ( <u>Festuca arundinacea</u> )	40%	95	90
Perennial Rye ( <u>Lolium perenne</u> )	30%	95	90
Chewings Fescue	15%	95	90

Cover the seed with topsoil or mulch no deeper than  $\frac{1}{2}$  inch. It is better to work topsoil into the upper soil layer rather than spread a layer of it directly onto the top of the native soil.

"Hydro-seeding" applications with approved seed-mulch-fertilizer mixtures may also be used.

Wetlands Seed Mixtures: For newly created wetlands, a wetlands specialist should design plantings to provide the best chance of success. As a guide apply the following mixture at a rate of 60 lbs/acre, and/or additional tubers for cattail, bulrush, slough sedge, as required by the local government. See Chapter III-4, Volume III for more information on constructed wetlands.

**Do not under any circumstances use introduced, invasive plants like reed canarygrass (Phalaris arundinacea) or purple loosestrife (Lythrum salicaria). Using plants such as these will cause many more problems than they will ever solve.**

<u>Name</u>	<u>Proportions by Weight</u>	<u>Percent Purity</u>	<u>Germination</u>
Red Top ( <u>Agrostis alba</u> )	30%	92	80
Birdsfoot Trefoil ( <u>Lotus corniculatus</u> )	30%	90	80
Creeping Red Fescue	40%	98	90

Tree and Shrub Planting

Besides their erosion and sediment control values, trees and shrubs also provide natural beauty and wildlife benefits. When used for the latter, they are usually more effective when planted in clumps or blocks. These procedures should be followed:

1. Trees and shrubs will do best in topsoil. If no topsoil is available, they can be established in subsoil with proper amendment. If trees and shrubs are to be planted in subsoil, particular attention should be paid to amending the soil with generous amounts of organic matter. Mulches should also be used.
2. Good quality planting stock should be used. Normally one or two-year old deciduous seedlings, and three or four-year old coniferous transplants, when properly produced and handled are adequate. Stock should be kept cool and moist from time of receipt and planted as soon as possible.

3. Competing vegetation, if significant, should be pulled out of the area where the plant or plants are to be placed.

Maintenance

Inspect seeded areas for failure and make necessary repairs and reseed immediately. Conduct or follow-up survey after one year and replace failed plants where necessary.

- If vegetative cover is inadequate to prevent rill erosion, overseed and fertilize in accordance with soil test results.
- If a stand has less than 40% cover, reevaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand following seedbed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results. If the season prevents resowing, mulch or jute netting is an effective temporary cover.

II-5.4.4 BMP E1.40: Sodding

Code: (SO)

Symbol: ←(SO)→

Definition Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod.

Purpose

To establish permanent turf for immediate erosion protection or to stabilize drainageways where concentrated overland flow will occur.

Conditions Where Practice Applies

- Disturbed areas which require immediate vegetative cover.
- Waterways carrying intermittent flow, where immediate stabilization or aesthetics are factors and other locations which are particularly suited to stabilization with sod.

Advantages

- Sod will give immediate protection.
- Sod gives an immediate vegetative cover, which is both effective in checking erosion and is aesthetically pleasing.
- Good sod has a high density of growth which is superior in protection to a recently seeded area.
- Sod can be placed at any time of the year provided that soil moisture is adequate and the ground is not frozen.

Disadvantages/Problems

- Sod is expensive.
- Sod is heavy and handling costs are high.
- Good quality sod, free from weed species, may be difficult to obtain.
- If laid in an unfavorable season, midsummer irrigation may be required. This also applies to very droughty sandy soils.
- Grass species in the sod may not be suitable for site conditions.
- If mowing is required, do not use grass sod on slopes steeper than 3:1 (use minimum maintenance ground covers).
- If not anchored or drained properly, sod will "roll up" in grassed waterways.

Design Criteria

- Shape and smooth the surface to final grade in accordance with the approved grading plan.
- Use of topsoil shall be in accordance with the requirements of Topsoiling (BMP E1.50).
- Add lime to reach a soil pH value of 6.5 (based on soil tests).
- Fertilize according to a soil test or in the absence of a test use available

nitrogen, phosphorus and potash as prescribed for permanent seeding. Use fertilizers that are not highly soluble.

- Work lime and fertilizer into the soil 1 to 2 inches deep and smooth the surface.
- Lay strips of sod beginning at the lowest area to be sodded and perpendicular to the direction of water flow. Wedge strips securely in place. Square the ends of each strip to provide for a close, tight fit. Stagger joints at least 12 inches. Staple if on steep slopes.
- Roll the sodded area and irrigate.
- When sodding is carried out in alternating strips, or other patterns, seed the areas between the sod immediately after sodding.
- Sod should be free of weeds and be of uniform thickness (Approx. 1 in.) and should have a dense root mat for mechanical strength.

#### Maintenance

- Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed as necessary.

II-5.4.5 BMP E1.45: Topsoiling

Code:



Symbol:



While not a permanent cover practice in itself, topsoiling has been included in this section because it is an integral component of preparing permanent cover to those areas where there is an unsuitable soil surface for plant growth. Use of in-situ or imported topsoil is always preferable to planting in subsoil.

Definition Preserving and using topsoil to enhance final site stabilization with vegetation.

Purpose

To provide a suitable growth medium for final site stabilization with vegetation.

Conditions Where Practice Applies

- Preservation or importation of topsoil is determined to be the most effective method of providing a suitable growth medium, and the slopes are less than 2:1.
- Applicable to those areas with highly dense or impermeable soils or areas where planting is to be done in subsoil, where mulch and fertilizer alone would not provide a suitable growth medium.

Advantages

- Topsoil stockpiling ensures that a good growth medium will be available for establishing plant cover on graded areas. It has a high organic matter content and friable consistency, water holding capacity and nutrient content.
- The stockpiles can be used as noise and view baffles during construction.

Disadvantages/Problems

- Stripping, stockpiling, and reapplying topsoil, or importing topsoil may not always be cost-effective. It may also create an erosion problem if improperly secured.
- Unless carefully located, storage banks of topsoil may also obstruct site operations and therefore require double handling.
- Topsoiling can delay seeding or sodding operations, increasing exposure time of denuded areas.
- Most topsoil contains some weed seeds.

Planning Considerations

*Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the major zone of root development, carrying much of the nutrients available to plants, and supplying a large share of the water used by plants.*

*Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown. Topsoiling is a required procedure when establishing vegetation on shallow soils, and soils of critically low pH (high acid) levels.*

*If topsoiling is to be done, the following items should be considered:*

1. *Whether an adequate volume of topsoil exists on the site. Topsoil should be spread at a depth of 2-4 inches. More topsoil will be needed if the subsoil is*

rocky.

2. Location of the topsoil stockpile so that it meets specifications and does not interfere with work on the site.
3. Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.
4. Care must be taken not to apply to subsoil if the two soils have contrasting textures. Sandy topsoil over clayey subsoil is a particularly poor combination, as water creeps along the junction between the soil layers and causes the topsoil to slough.
5. If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method to prevent a lack of bonding is to actually work the topsoil into the layer below for a depth of at least 6 inches.

#### Design Criteria

- Field exploration of the site shall be made to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). Areas of natural ground water recharge should be avoided.
- Stripping shall be confined to the immediate construction area. A 4 to 6 inch stripping depth is common, but depth may vary depending on the particular soil. All surface runoff control structures shall be in place prior to stripping.
- Stockpiling of topsoil shall occur in the following manner:
  - a. Side slopes of the stockpile shall not exceed 2:1.
  - b. An interceptor dike with gravel outlet and silt fence shall surround all topsoil stockpiles.
  - c. Erosion control seeding or covering with clear plastic or other mulching materials (see BMPs E1.10, E1.20) of stockpiles shall be completed within 7 days of the formation of the stockpile.
- Topsoil shall not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.
- Previously established grades on the areas to be topsoiled shall be maintained according to the approved plan.

#### Maintenance

- Cover piles with clear plastic covering until needed.

**II-5.5 STANDARDS AND SPECIFICATIONS FOR STRUCTURAL AND BIOMECHANICAL PRACTICES**

Structural and biomechanical control practices are used to either reduce erosion or retain sediment on the construction site. The BMPs in this section have been divided into two basic groups based on these characteristics. The standards and specifications of each BMP are presented in the same format used for nonstructural practices.

Structural erosion control BMPs include measures for site stabilization (such as stabilized construction entrances), slope protection (such as pipe slope drains) and drainageway protection (such as level spreaders). Sediment control BMPs include filter fences, berms, and sediment traps. Table II-2.2 in Chapter II-2 gives the coding for these and all other BMPs in the volume.

Structural control is more effective when combined with vegetative protection and appropriate grading practices as part of an Erosion and Sediment Control (ESC) Plan (see the supplemental guidelines on preparing an ESC plan). Control measures may be either permanent or temporary depending on whether they will remain in use after development is complete.

Although temporary structures are emphasized in this section, they may be combined with permanent control facilities to provide protection of downstream properties during construction. Temporary ESC facilities provide siltation control, but downstream erosion protection must also be provided. Accordingly, the allowable discharge from development sites shall not exceed 50% of the pre-development peak flow for the 2-year, 24-hour storm.

It is also important not to disturb areas of natural ground water discharge and/or retention. To accomplish this, a permanent detention pond may have to be constructed first with modifications allowing it to temporarily function as a sediment pond. Or, a control structure as specified in Chapter III-4 of the Runoff Control Volume may be required on the outlet of the sediment pond.

The design of structural measures for erosion and sedimentation control is accomplished by carefully predetermining appropriate factors. The design storm, maximum drainage area, slope and other restrictions are noted for each BMP. The design criteria and limitations are important; if they are not observed, the simplest measures will fail and erosion control will not be achieved.

In most ESC designs, especially for sites larger than 5 acres, several small structures will function more effectively than a single large structure. For example, a combination of BMPs, such as filter fences, temporary dikes/swales, and several small sediment traps/ponds (depending on subbasin configuration) may be used as opposed to a single large sediment pond.

Maintenance is also of critical importance for proper operation of structural BMPs and must be considered in their design. Maintenance requirements and frequency vary with each BMP and its performance criteria. At a minimum, the ESC plan shall require monthly maintenance, or following each runoff producing storm (whichever occurs more frequently), for silt removal and proper operation of all ESC facilities. ESC facilities may have to be replaced or relocated depending on their performance under field conditions.

The following factors should be considered when designing structural control measures:

- Use material available on-site whenever possible.
- Keep structures simple and take advantage of permanent facilities unless the permanent structures are for infiltration.
- Install the most important control structures first.

- Install BMPs correctly; visit the site during and after storms to be sure that all structures are properly located, constructed, and functioning as designed.
- Install control measures in sequences which minimize land disturbance. For example, install interceptor dikes/swales and drainage trenches before seeding to avoid disturbing the seedbed. Avoid disturbing or removing existing vegetation whenever possible.
- Do not block a natural drainageway. Make certain that all necessary permits have been obtained before starting any work in a wetland, stream, or other sensitive area.
- Place control measures out of the way of construction operations.
- Make field modifications where necessary with the approval of the local jurisdiction.
- Provide access for maintenance.


Although design and construction standards and specifications are presented in some detail, this section is not a substitute for training in hydraulic and construction engineering. The materials presented are guidelines to assist in the design of erosion control measures. The standards and specifications provided should not be considered rigid requirements except where statutory requirements are indicated. Where local experience has shown that an alternate design will work better, it may be used as long as it meets the requirements contained found in Chapter I-2 and is approved by the local government. Designers are encouraged to continuously seek out new, more reliable solutions for controlling erosion and sediment.



II-5.6 STRUCTURAL EROSION CONTROL BMPs.

II-5.6.1 BMP E2.10: Stabilized Construction Entrance and Tire Wash

Code: (CE)

Symbol: 

Definition A temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site.

Purpose

To reduce the amount of mud, dirt, rocks, etc. transported onto public roads by motor vehicles or runoff by constructing a stabilized pad of rock spalls at entrances to construction sites and washing of tires during egress.

Conditions Where Practice Applies

- Whenever traffic will be leaving a construction site and moving directly onto a public road or other paved areas.

Advantages

- Mud on vehicle tires is significantly reduced which avoids hazards caused by depositing mud on the public roadway.
- Sediment, which is otherwise contained on the construction site, does not enter stormwater runoff elsewhere.

Planning Considerations

*Construction entrances provide an area where mud can be removed from vehicle tires before they enter a public road. If the action of the vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road. If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried off-site. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles.*

*It is important to note that this BMP will only be effective if sediment control is used throughout the rest of the construction site.*

Design Criteria

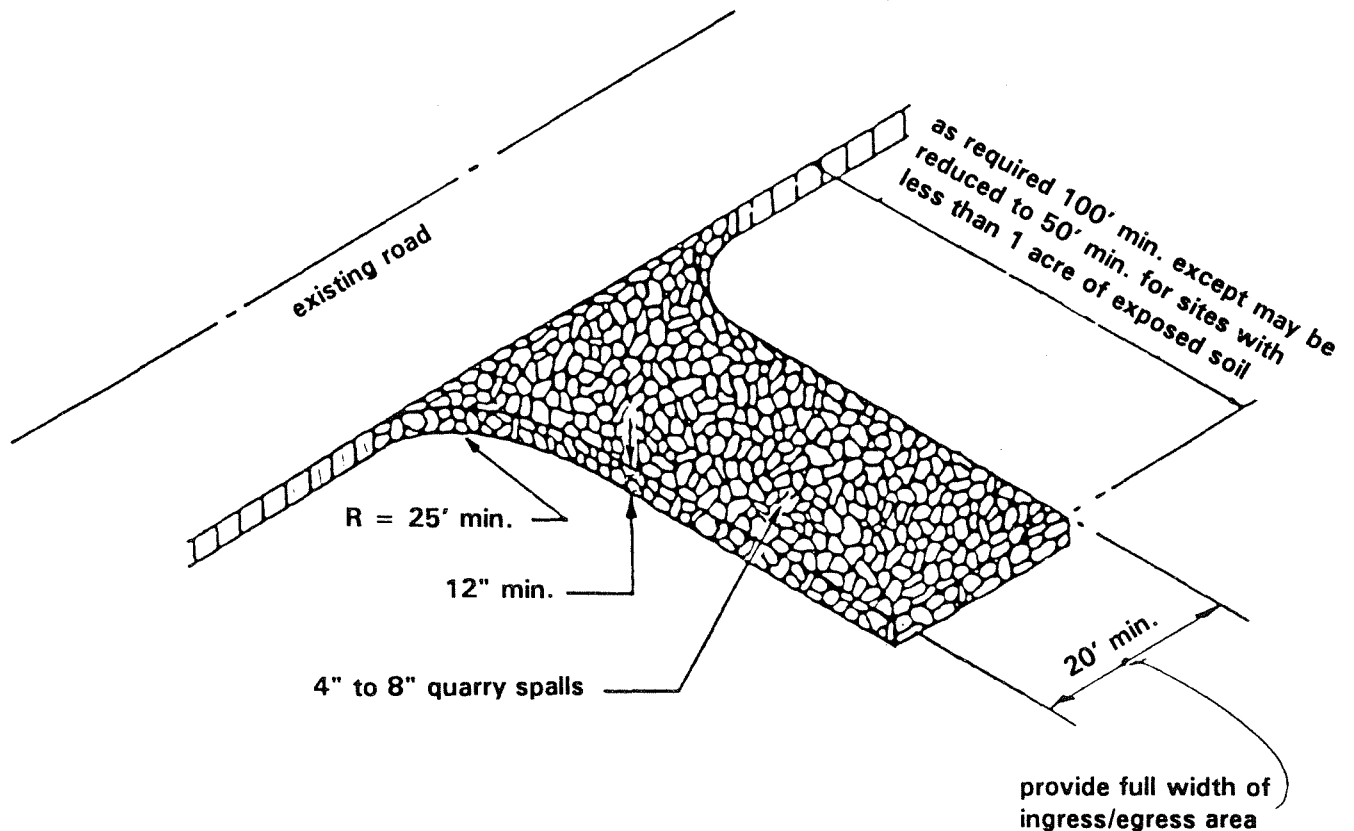
- Material should be quarry spalls (where feasible), 4 inches to 8 inches size.
- The rock pad shall be at least 12 inches thick and 100 feet in length for sites more than 1 acre; and may be reduced to 50 feet in length for sites less than 1 acre.
- A filter fabric fence (see BMP E3.10) should be installed down-gradient from the construction entrance in order to contain any sediment-laden runoff from the entrance.
- Width shall be the full width of the vehicle ingress and egress area (minimum 20 feet).
- Additional rock should be added periodically to maintain proper function of the pad.
- See Figure II-5.4 for details.



- Tire washing should be done before the vehicle enters a paved street. Washing should be done on an area covered with crushed rock and the wash water should be drained to a sediment retention facility such as a sediment trap or basin.
- The volume of wash water produced by tire washing should be included when calculating the sediment trap or basin size.

Maintenance

- The entrance shall be maintained in a condition which will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing with 2-inch stone, as conditions demand, and repair and/or cleanout of any structures used to trap sediment. All materials spilled, dropped, washed, or tracked from vehicles onto roadways or into storm drains must be removed immediately.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.4 Stabilized Construction Entrance



II-5.6.2 BMP E2.15: Construction Road StabilizationCode: Symbol: 

Definition The temporary stabilization with stone of access roads, subdivision roads, parking areas, and other on-site vehicle transportation routes immediately after grading.

Purpose

- To reduce erosion of temporary road beds by construction traffic during wet weather.
- To reduce the erosion and therefore regrading of permanent road beds between the time of initial grading and final stabilization.

Conditions Where Practice Applies

- Wherever rock-base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.
- Note: Exceptions may be granted in areas with gravelly soils, such as the Everett series, as approved by the local government.

Advantages

- Efficiently constructed road stabilization not only reduces on-site erosion but can significantly speed on-site work, avoid instances of immobilized machinery and delivery vehicles, and generally improve site efficiency and working conditions during adverse weather.

Disadvantages/Problems

- Measures on temporary roads must be cheap not only to install but also to demolish if they interfere with the eventual surface treatment of the area.
- Application of aggregate to construction roads may need to be made more than once during a construction period.

Planning Considerations

Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires which generate significant quantities of sediment that may pollute nearby streams or be transported off-site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.

Immediate stabilization of such areas with stone may cost money at the outset, but it may actually save money in the long run by increasing the usefulness of the road during wet weather.

Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Design Criteria

- A 6-inch course of 2 to 4-inch crushed rock, gravel base, or crushed surfacing base course shall be applied immediately after grading or the completion of utility installation within the right-of-way. A 4-inch course of asphalt treated base (ATB) may be used in lieu of the crushed rock, or as advised by the local government.
- Where feasible, alternative routes should be made for construction traffic; one for use in dry condition, the other for wet conditions which incorporate the measures listed below.
- Temporary roads should follow the contour of the natural terrain to the maximum extent possible. Slope should not exceed 15 percent. Roadways should be carefully graded to drain transversely. Provide drainage swales on each side of the roadway in the case of a crowned section, or one side in the case of a super-elevated section. Drainage swales shall be designed in accordance with the standards given in Chapter III-2.
- Installed inlets shall be protected to prevent sediment-laden water entering the drain sewer system (see Section II-5.8.5 on Storm Drain Inlet Protection BMP E3.30).
- Simple gravel berms without a trench can be used for less traveled roads.
- Undisturbed buffer areas should be maintained at all stream crossings.
- Areas adjacent to culvert crossings and steep slopes should be seeded and mulched and/or covered.
- Dust control should be used when necessary (see BMP E2.20).

Maintenance

- Inspect stabilized areas regularly, especially after large storm events. Add crushed rock if necessary and restabilize any areas found to be eroding.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

II-5.6.3 BMP E2.20: Dust Control

Code: (DC)

Symbol: ←(DC)→

Definition Reducing surface and air movement of dust during land disturbing, demolition, and construction activities.

Purpose

To prevent surface and air movement of dust from exposed soil surfaces.

Conditions Where Practice Applies

- In areas (including roadways) subject to surface and air movement of dust where on-site and off-site damage is likely to occur if preventive measures are not taken.

Advantages

- A decrease in the amount of dust in the air will decrease the potential for accidents and respiratory problems.

Disadvantages/Problems

- Use of water on-site to control dust emissions, particularly in areas where the soil is already compacted, can cause a runoff problem where there wasn't one.

Planning Considerations

*Construction activities inevitably result in the exposure and disturbance of soil. Fugitive dust is emitted both during the activities (i.e., excavation, demolition, vehicle traffic, human activity) and as a result of wind erosion over the exposed earth surfaces. Large quantities of dust are typically generated in "heavy" construction activities, such as road and street construction and subdivision, commercial and industrial development, which involve disturbance of significant areas of soil surface. Research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earthmoving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.*

*In planning for dust control, remember that the less soil is exposed at any one time, the less potential there will be for dust generation. Therefore, phasing a project and utilizing temporary stabilization practices upon the completion of grading can significantly reduce dust emissions.*

Design Criteria


- Minimize the period of soil exposure through use of temporary ground cover and other temporary stabilization practices (see Seeding and Mulching, BMPs E1.10 and E1.15).
- Sprinkle the site with water until surface is wet. Repeat as needed. To prevent carryout of mud onto street, refer to Stabilized Construction Entrance (BMP E2.10).
- Spray exposed soil areas with approved dust palliative. Oil should not be used for dust suppression. Check with the local government to see which other dust palliatives may be used in the area.

Maintenance

- Respray area as necessary to keep dust to a minimum.

II-5.7.4 BMP E2.25: Pipe Slope Drains

Code: (PSD)

Symbol: 

Definition A pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized water course or a sediment trapping device or onto a stabilization area.

Purpose

To carry concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of slide-prone soils.

Conditions Where Practice Applies

- Where a temporary (or permanent) measure is needed for conveying runoff down a slope without causing erosion.

Advantages

- Slope drains provide a potentially effective method of conveying water safely down steep slopes.

Disadvantages/Problems

- Care must be taken to correctly site drains and not underdesign them. Also, when clearing takes place prior to installing these drains, care must be taken to revegetate the entire easement area, otherwise erosion tends to occur beneath the pipeline, resulting in gully formation.

Planning Considerations

*There is often a significant lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. This situation also occurs on slope construction which is temporarily delayed before final grade is reached. Temporary slope drains can provide valuable protection of exposed slopes until permanent drainage structures can be installed. When used in conjunction with diversion dikes, temporary slope drains can be used to convey stormwater from the entire drainage area above a slope to the base of the slope without erosion. It is very important that these temporary structures be installed properly since their failure will often result in severe gully erosion. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be staked securely.*

Design Criteria

- The capacity for temporary drains shall be sufficient to handle a 10-year, 24-hour peak flow. This may be computed using the conveyance design method in Chapter III-1 of the Runoff Control Volume. Permanent pipe slope drains shall be sized for the 25-year 24-hour peak flow.
- The maximum drainage area allowed per pipe<sup>®</sup> is ten acres. For larger areas, a rock-lined channel or more than one pipe shall be installed (see Volume III Chapter III-2).
- The entrance shall consist of a standard flared end section for culverts 12 inches and larger with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance shall be at least 3 percent (Figure II-5.5).

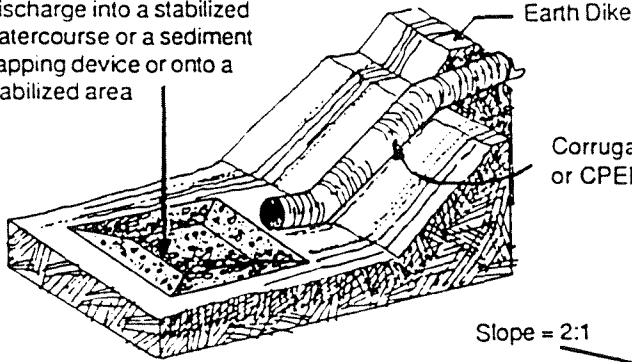
- The soil around and under the pipe and entrance section shall be thoroughly compacted to prevent undercutting.
- The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.
- Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.
- Interceptor dikes shall be used to direct runoff into a slope drain. The height of the dike shall be at least 1 foot higher at all points than the top of the inlet pipe.
- The area below the outlet must be stabilized with a riprap apron (see BMP E2.70, Outlet Protection, for the appropriate outlet material).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.
- Materials specifications for the type of pipe used shall be set by the local government.

#### Maintenance

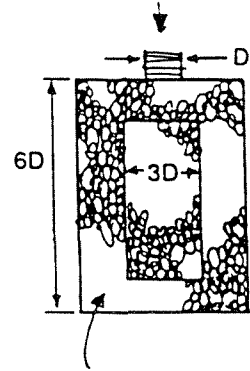
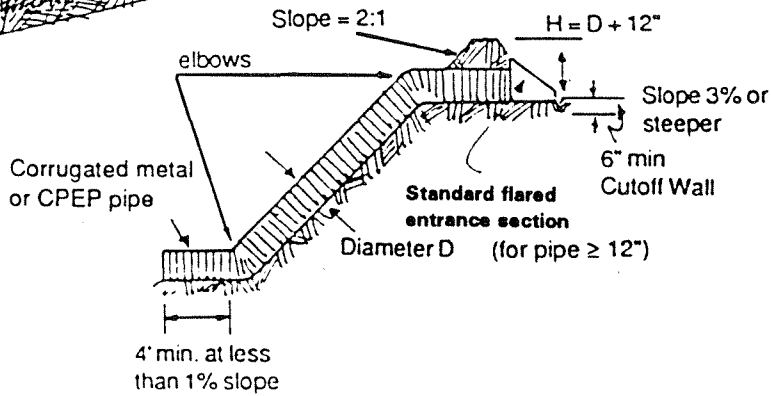
- Check inlet and outlet points regularly, especially after heavy storms. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced with compacted earth or sand bags. The outlet point should be free of erosion and installed with appropriate outlet protection (see BMP E2.70).
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.5 Pipe Slope Drains

Discharge into a stabilized watercourse or a sediment trapping device or onto a stabilized area



Corrugated metal or CPEP pipe



Riprap per Table III-2.6  
Depth of apron shall be equal to pipe diameter



II-5.6.5 BMP E2.30: Subsurface Drains

Code:



Symbol:



Definition A perforated conduit such as a pipe, tubing, or tile installed beneath the ground to intercept and convey ground water.

Purpose

To provide a dewatering mechanism for draining excessively wet, sloping soils-- usually consisting of an underground perforated pipe that will intercept and convey ground water.

Conditions When Practice Applies

- Wherever excessive water must be removed from the soil. The soil must be deep and permeable enough to allow an effective system to be installed.

Advantages

- Subsurface drains often provide the only practical method of stabilizing excessively wet, sloping soils.

Disadvantages/Problems

- Problems may be encountered with tree roots (see Maintenance).
- Pipes cannot be located under heavy vehicle crossings.

Planning Considerations

*Subsurface drainage systems are of two types; relief drains and interceptor drains. Relief drains are used either to lower the water table in order to improve the growth of vegetation, or to remove surface water. They are installed along a slope and drain in the direction of the slope. They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern (Figure II-5.6).*

*Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout (Figure II-5.7).*

Design Criteria

- Subsurface drain shall be sized for the required capacity. The minimum diameter for a subsurface drain shall be four inches.
- The minimum velocity required to prevent silting is 1.4 ft./sec. The line shall be graded to achieve at least this velocity.
- Filter material and fabric shall be used around all drains for proper bedding and filtration of fine materials.
- The outlet of the subsurface drain shall empty into a sediment trap or pond. If free of sediment, it shall empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.
- The strength and durability of the pipe shall meet the requirements of the site in accordance with the manufacturer's specifications.

Construction Specifications

- The trench shall be constructed on a continuous grade with no reverse grades or low spots.
- Soft or yielding soils under the drain shall be stabilized with gravel or other suitable material.
- Deformed, warped, or otherwise unsuitable pipe shall not be used.
- Filter material shall be placed as specified with at least 3 inches of material on all sides of the pipe.
- Backfilling shall be done immediately after placement of the pipe. No sections of pipe shall remain uncovered overnight or during a rainstorm. Backfill material shall be placed in the trench in such a manner that the drain pipe is not displaced or damaged.

Maintenance

- Subsurface drains shall be checked periodically to ensure that they are free-flowing and not clogged with sediment.
- The outlet shall be kept clean and free of debris.
- Surface inlets shall be kept open and free of sediment and other debris.
- Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees as a last resort. Drain placement should be planned to minimize this problem.
- Where drains are crossed by heavy vehicles, the line shall be checked to ensure that it is not crushed.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.6 Subsurface Drain Layout

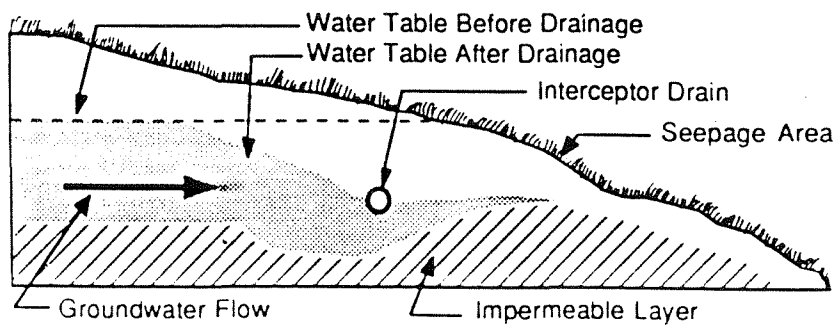
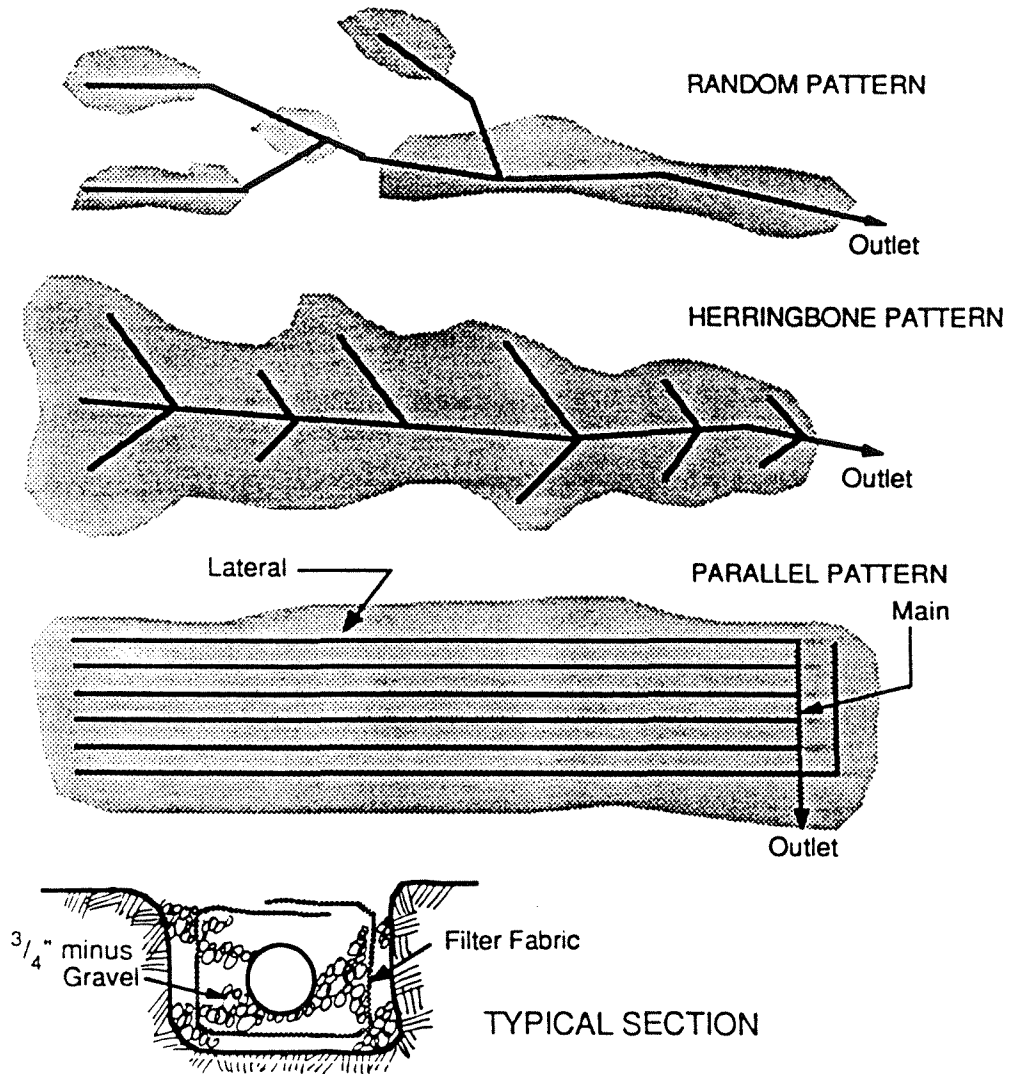


Figure II-5.7 Effect of Subsurface Drain on Water Table

II-5.7.6 BMP E2.35: Surface Roughening

Code:



Symbol:



Definition Provision of a rough soil surface with horizontal depressions created by operating a tiller or other suitable equipment on the contour or by leaving slopes in a roughened condition by not fine grading them.

Purpose

To aid in establishment of vegetative cover, reduce runoff velocity, increase infiltration, and provide for sediment trapping.

Conditions Where Practice Applies

- All slopes steeper than 3:1, and greater than 5 vertical feet, require surface roughening; either stair-step grading, grooving, furrowing, or tracking if they are to be stabilized with vegetation.

Advantages

- Surface roughening provides some instant erosion protection on bare soil while vegetative cover is being established.
- It is an inexpensive and simple erosion control measure.

Disadvantages/Problems

- While this is a cheap and simple method of erosion control, it is of limited effectiveness in anything more than a moderate storm.

Planning Considerations

Graded areas with smooth, hard surfaces give a false impression of "finished grading" and a job well done. It is difficult to establish vegetation on such surfaces due to reduced water infiltration and the potential for erosion. Rough slope surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, but they encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity.

Rough, loose soil surfaces give lime, fertilizer, and seed some natural coverage. Niches in the surface provide microclimates which generally provide a cooler and more favorable moisture level than hard flat surfaces; this aids seed germination.

There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include stair-step grading, grooving, and tracking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

1. Disturbed areas which will not require mowing may be stair-step graded, grooved, or left rough after filling.
2. Stair-step grading is particularly appropriate in soils containing large amounts of soft rock. Each "step" catches material which sloughs from above, and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth moving equipment.
3. Areas which will be mowed (these areas should have slopes less steep than 3:1) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.

4. *It is important to avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all, but is not as effective as other forms of roughening, as the soil surface is severely compacted and runoff is increased.*

#### Design Criteria

Graded areas with slopes greater than 3:1 but less than 2:1 should be roughened before seeding (Figures II-5.8a,b). This can be accomplished in a variety of ways, including "track walking," or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.

Graded areas steeper than 2:1 should be stair-stepped with benches as shown in Figure II-5.9. The stair-stepping will help vegetation become established and also trap soil eroded from the slopes above.

#### Maintenance

- Areas which are graded in this manner should be seeded as quickly as possible.
- Regular inspections should be made of the area. If rills appear, they should be re-graded and re-seeded immediately.

Figure II-5.8(a) Heavy Equipment Can Be Used To Mechanically Scarify Slopes

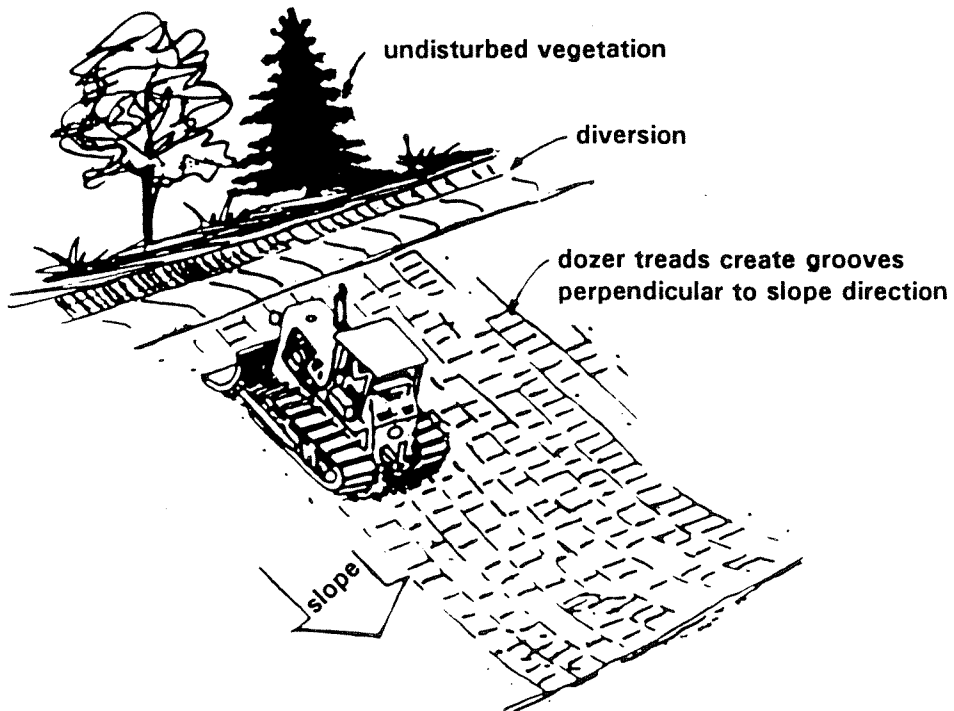
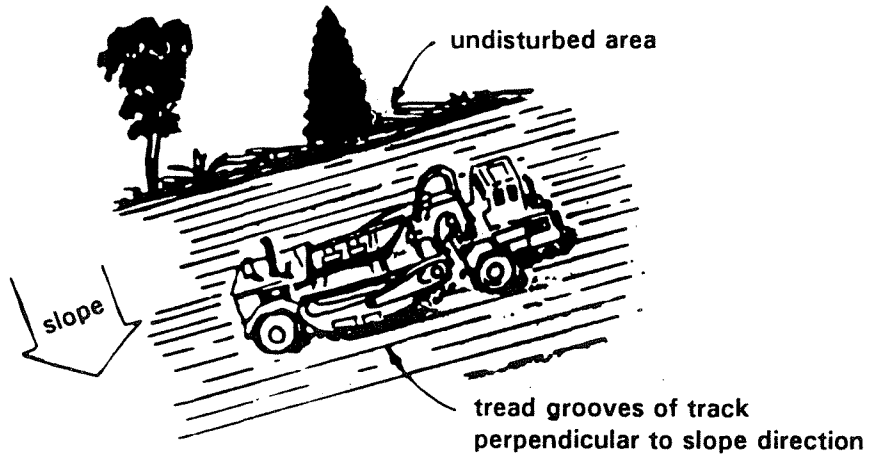
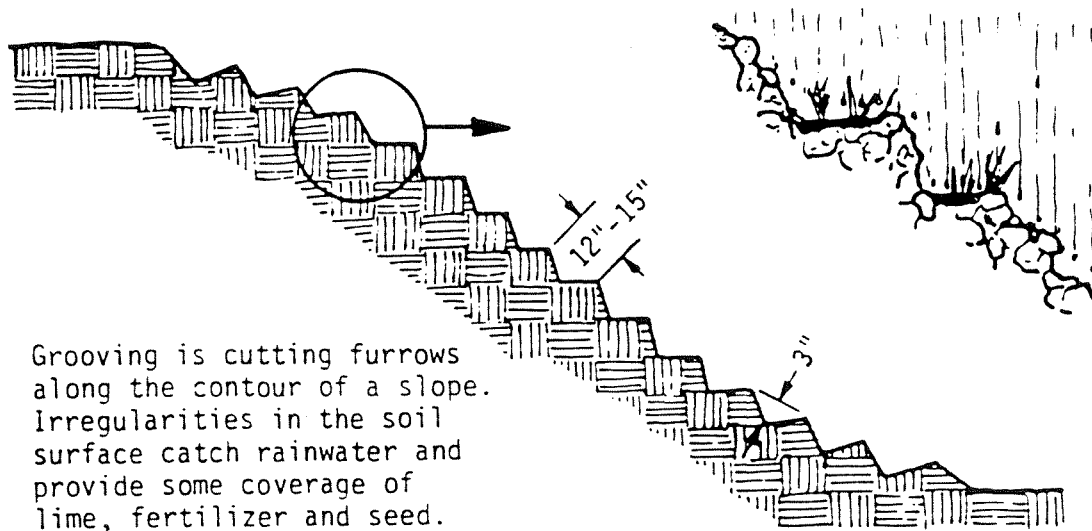
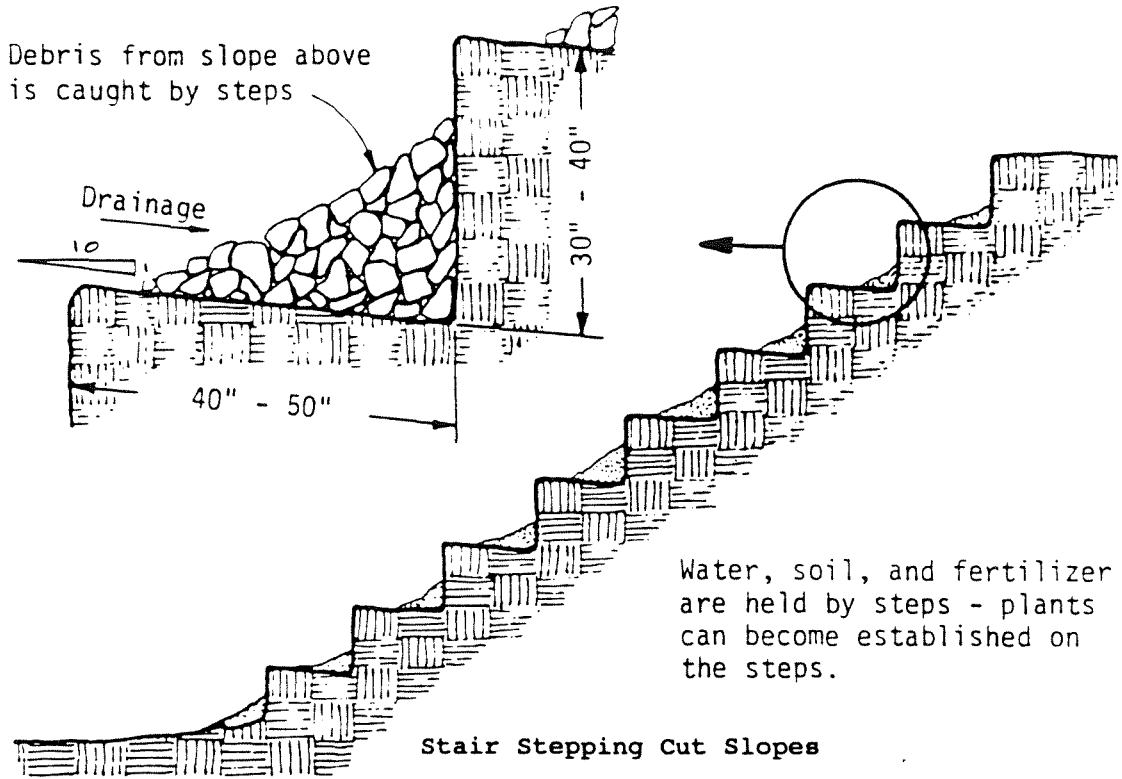


Figure II-5.8(b) Unvegetated Slopes Should be Temporarily Scarified to Minimize Runoff Velocities


Figure II-5.9 Stair-Stepping Cut Slopes and Grooving Slopes



Grooving Slopes

II-5.7.7 BMP E2.40: Gradient Terraces

Code: (GT)

Symbol: 

Definition An earth embankment or a ridge-and-channel constructed with suitable spacing and with an acceptable grade.

Purpose

To reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a nonerosive velocity. (This standard covers the planning and design of gradient terraces and does not apply to diversions.)

Conditions Where Practice Applies

- Gradient terraces normally are limited to denuded land having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Gradient terraces may be used only where suitable outlets are or will be made available.

Advantages

- Gradient terraces lower the velocity of runoff, increase the distance of overland flow, and reduce effective hydraulic gradient. They also hold moisture and minimize sediment.

Disadvantages/Problems

- May significantly increase cut and fill costs and cause sloughing if excessive water infiltrates soils.

Design Criteria

- The maximum spacing of gradient terraces should be determined by the following method:  $V.I. = xs + y$

Where: V.I. = vertical interval in feet  
 $x$  = 0.8 for Washington<sup>1</sup>  
 $s$  = land slope in feet per 100 feet  
 $y$  = a soil and cover variable with values from 1.0 to 4.0<sup>2</sup>

- The minimum constructed cross-section should meet the design dimensions.
- The top of the constructed ridge should not be lower at any point than the design elevation plus the specified overfill for settlement. The opening at the outlet end of the terrace should have a cross section equal to that specified for the terrace channel.

<sup>1</sup> U.S. Soil Conservation Service, National Engineering Handbook

<sup>2</sup>Values of "y" are influenced by soil erodibility and cover practices. The lower values are applicable to erosive soils where little to no residue is left on the surface. The higher value is applicable only to erosion-resistant soils where a large amount of residue (1½ tons of straw/acre equivalent) is on the surface.



- Channel Grade - Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length. For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is nonerosive for the soil type with the planned treatment.
- Outlet - All gradient terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or tile outlet. In all cases the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover should be used in the outlet channel.
- The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

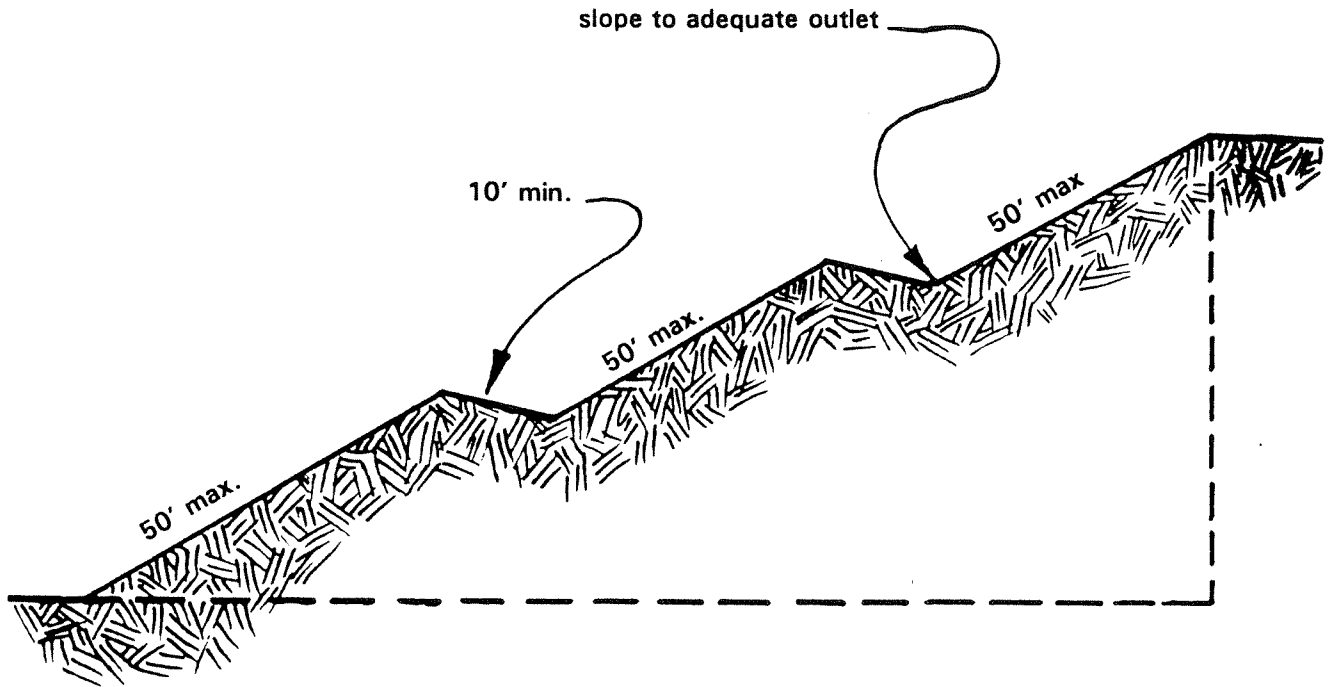
#### Specifications

- Vertical spacing determined by the above methods may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet (Figure II-5.10).
- The drainage area above the top should not exceed the area that would be drained by a terrace of equal length with normal spacing.
- Capacity - The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.
- Cross-Section - The terrace cross-section should be proportioned to fit the land slope. The ridge height should include a reasonable settlement factor. The ridge should have a minimum top width of 3 feet at the design height. The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace can be constructed wide enough to be maintained using a small cat.

#### Maintenance

- Maintenance should be performed as needed. Terraces should be inspected regularly; at least once a year, and after large storm events.

Figure II-5.10 Gradient Terraces



II-5.7.8 BMP E2.45: Bioengineered Protection of Very Steep Slopes

Code: (SSP)

Symbol: ←(SSP)→

Definition Steep slope protection using a combination of vegetative and mechanical measures.

Purpose

To stabilize steep banks.

Conditions Where Practice Applies

- Slopes of steep grade, cut and fill banks, and unstable soil conditions that cannot be stabilized using ordinary vegetative techniques.

Advantages

- Vegetation reduces sheet erosion on slopes and impedes sediment at the toe of the slope.
- Where soils are unstable and liable to slip due to wet conditions, utilization of soil moisture by vegetation can reduce the problem.
- Shrubs and trees shelter slopes against the impact of rainstorms, and the humus formed by decaying leaves further helps to impede runoff.
- Mechanical measures help to stabilize soil long enough to allow vegetation to become established.

Disadvantages/Problems

- The planting of non-seeded material such as live willow brush is a specialized operation and cannot be highly mechanized or installed by unskilled labor.
- The methods described are effective but require a complete knowledge of soil, hydrology, and other physical data to design measures that will adequately solve the problem.

Design Criteria

The following bioengineering methods can be used after slopes have been protected by diversion of runoff (covered in BMP E2.55) or through the terracing of slopes (BMP E2.40).

- Sod walls or retaining banks are used to stabilize terraces. Sod is piled by tilting it slightly toward the slope and should be backfilled with soil and compacted as they are built up. Sod walls can be as steep as 1:8 but should not be higher than 5 feet (Figure II-5.11a).
- Timber frame stabilization is effective on gradients up to 1:1 and involves the following steps in construction: 1) Lay soil retarding frames of 2 x 4 in. vertical members and 1 x 4 in. horizontal members on slopes. Frames on slopes over 15 feet in length need to be anchored to slope to prevent buckling. 2) Attach 14 gauge galvanized tire wires for anchoring wire mesh. 3) Fill frames with moist topsoil and compact the soil. 4) Spread straw 6 inches deep over slope. 5) Cover straw with 14 gauge 4-inch mesh galvanized reinforced wire. 6) Secure wire mesh at least 6 feet back of top slope. 7) Plant ground cover plants through straw into topsoil (Figure II-5.11b).
- Woven willow whips (Figure II-5.11c) may be used to form live barriers for immediate erosion control. Construction: 1) 3 foot poles are spaced at 5 foot

distances and driven into the slope to a depth of 2 feet. 2) 2 foot willow sticks are inserted between poles at one foot distances. 3) Live willow branches of 5 foot length are sunk to a depth of 1 inch and interwoven with poles and stocks. 4) Spaces between the woven 'fences' are filled with topsoil. Fences are generally arranged parallel to the slope or in a grid pattern diagonal to the direction of the slope.

- Berm Planting. 1) Excavate ditches from 3 to 5 feet apart along the slope and shape a berm on the downslope side. Construct ditches with 5 percent longitudinal slope. 2) Plant rooted cuttings on 3 foot centers and mulch. Suitable trees are willow, alder, birch, pine, and selected shrubs. In extremely dry situations, rooted cuttings can be planted in biodegradable plastic bags that are watered at the time of planting (Figure II-5.11d).
- Brush Layers. 1) Prepare 3 foot "niches" as shown. 2) Lay unrooted 5 foot live branches of willow or poplar at close spacing. 3) Starting at foot of slope, backfill lower ditch with excavated material from ditch above it. Operation should be carried out during dormant season (Figure II-5.11e).

#### Maintenance

- Regardless of the stabilization method used, inspections should be made on a regular basis to make sure the system is functioning correctly.
- Note: There are a number of manufacturers who provide prefabricated bioengineered devices for the protection of steep slopes.

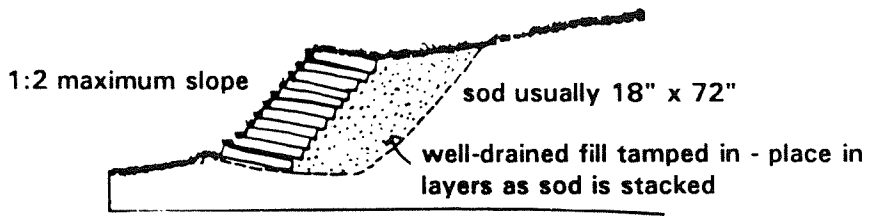


Figure II-5.11(a) Sod Retaining Bank

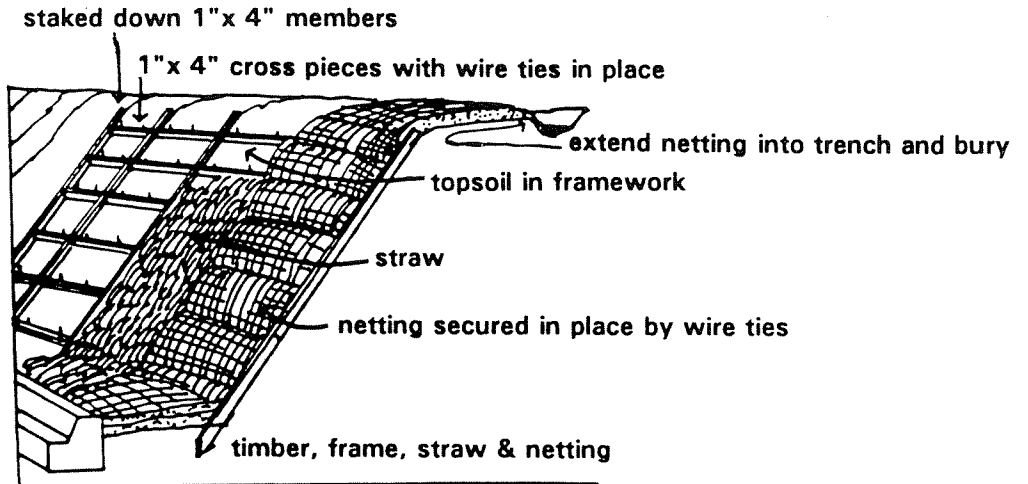


Figure II-5.11(b) Timber Frame Stabilization

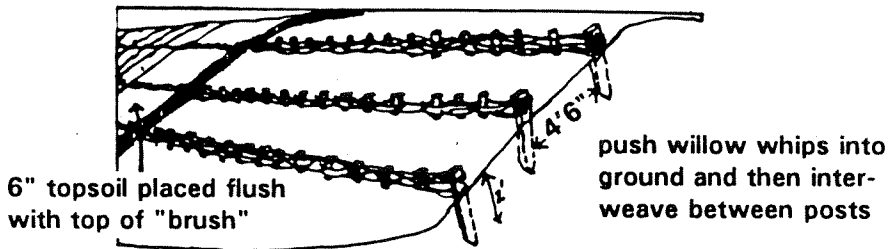


Figure II-5.11(c) Woven Willow Whips

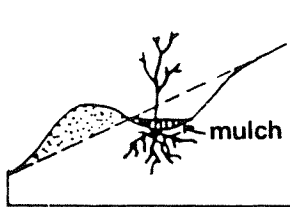


Figure II-5.11(d) Berm Planting

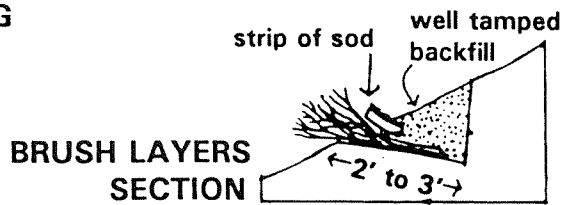


Figure II-5.11(e) Brush Layers

II-5.7.9 BMP E2.50: Level Spreader

Code:

LS

Symbol:



**Definition** A temporary outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope.

Purpose

To convert concentrated runoff to sheet flow and release it onto areas stabilized by existing vegetation or an engineered filter strip.

Condition Where Practice Applies

- To be constructed on undisturbed areas that are stabilized by existing vegetation and where concentrated flows are anticipated to occur at 0 percent grade.

Advantages

- Level spreaders disperse the energy of concentrated flows, reducing erosion potential and encouraging sedimentation.

Disadvantages/Problems

- If the level spreader has any low points, flow tends to concentrate there. This concentrated flow can create channels and cause erosion. If the spreader serves as an entrance to a water quality treatment system, short-circuiting of the forebay may happen and the system will be less effective in removing sediment and particulate pollutants.

Planning Considerations

*Interceptor dikes and swales (BMP E2.55) call for a stable outlet for concentrated stormwater flows. The level spreader can be used for this purpose provided the runoff is relatively free of sediment. If properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stable undisturbed area.*

*Particular care must be taken during construction to ensure that the lower lip of the structure is level. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gravel lip over which the runoff must flow when exiting the spreader. Regular maintenance is essential for this practice.*

Design Criteria

- The grade of the channel for the last 20 feet of the dike or interceptor entering the level spreader shall be less than or equal to 1 percent. The grade of the level spreader shall be 0 percent to ensure uniform spreading of storm runoff (Figure II-5.12).
- A 6-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2 to 4 inch or 3/4 inch to 1½ inch size.
- The spreader length will be determined by estimating the flow expected from the 25-year, 24-hour design ( $Q_{25}$ ), and selecting the appropriate length from the following table:

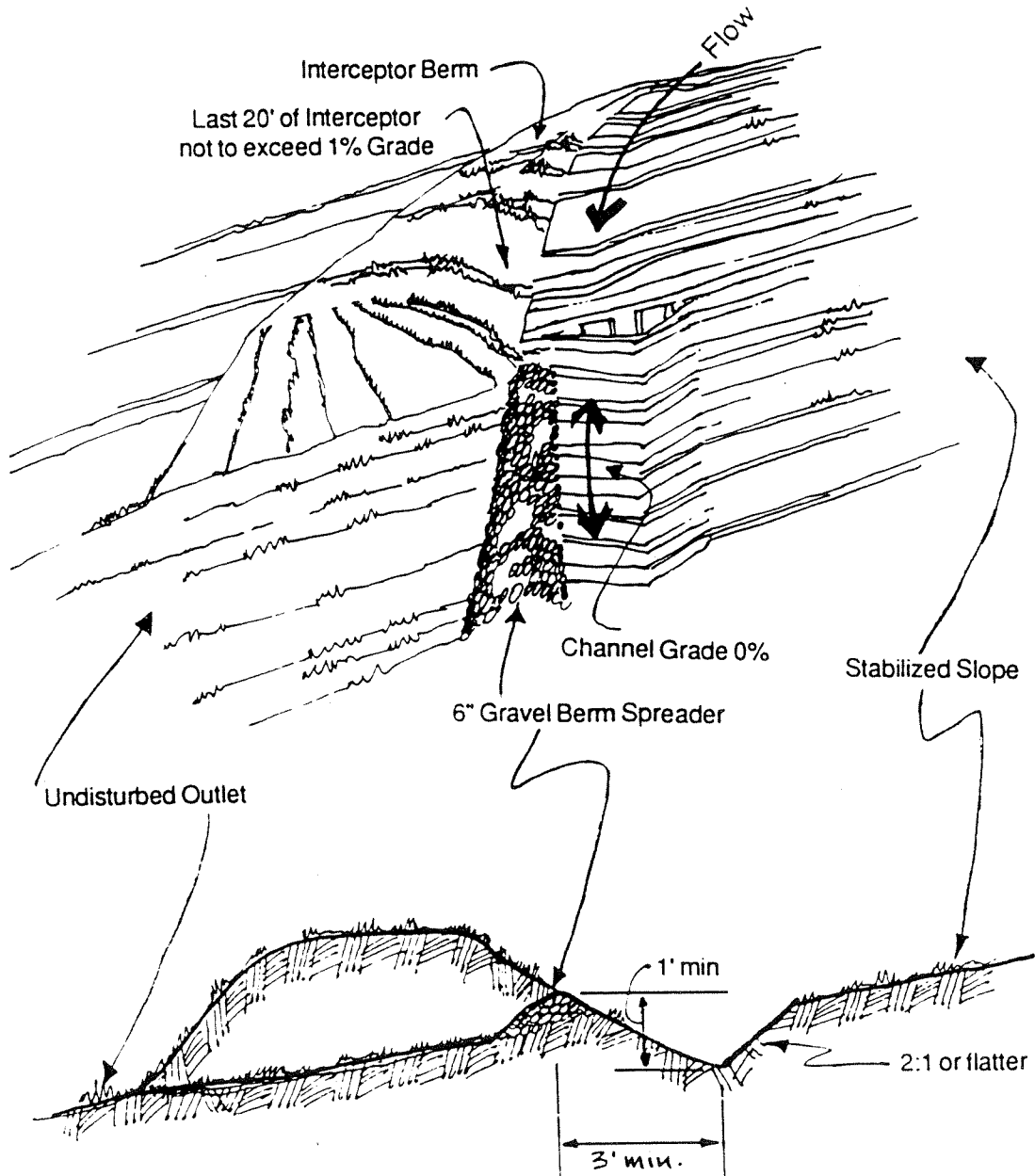
<u>Q<sub>s</sub>, in CFS</u>	<u>Min. Length, in Feet</u>
0 - 0.1	15
0.1 - 0.2	20
0.2 - 0.3	30
0.3 - 0.4	40

- The width of the spreader should be at least 6 feet.
- The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.
- The slope of the undisturbed outlet should not exceed 6% percent.

Maintenance

- The spreader should be inspected after every runoff event to ensure that it is functioning correctly. The contractor should avoid the placement of any material on or prevent construction traffic across the structure. If the spreader is damaged by construction traffic, it shall be immediately repaired.


Figure II-5.12 Level Spreader





II-5.7.10 BMP E2.55: Interceptor Dike and Swale

Code: (IDS)

Symbol: 

Definition A ridge of compacted soil or a swale with vegetative lining located at the top or base of a sloping disturbed area.

Purpose

To intercept storm runoff from drainage areas above unprotected slopes and direct it to a stabilized outlet.

Conditions Where Practice Applies

- Where the volume and velocity of runoff from exposed or disturbed slopes must be reduced. When an interceptor dike/swale is placed above a disturbed slope, it reduces the volume of water reaching the disturbed area by intercepting runoff from above (Figures II-5.13a,b). When it is placed horizontally across a disturbed slope, it reduces the velocity of runoff flowing down the slope by reducing the distance that the runoff can flow directly downhill.

Advantages

- This BMP provides a practical, inexpensive method to divert runoff from erosive situations.

Disadvantages/Problems

- None

Planning Considerations

A temporary diversion dike or swale is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on a sloping disturbed area. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.

If the dike or swale is going to remain in place for longer than 15 days, it shall be stabilized with temporary or permanent vegetation. The slope behind the dike or swale is also an important consideration. The dike or swale must have a positive grade to assure drainage, but if the slope is too great, precautions must be taken to prevent erosion due to high velocity of flow.

This practice is considered an economical one because it uses material available on the site and can usually be constructed with equipment needed for site grading. The useful life of the practice can be extended by stabilizing the dike or swale with vegetation.

Design Criteria

- Interceptor dikes shall meet the following criteria:

Top Width	2 feet minimum.
Height	18 inches minimum. Measured from upslope toe and at a compaction of 90 percent ASTM D698 standard proctor.
Side Slopes	2:1 or flatter.

Grade Topography dependent, except that dike shall be limited to grades between 0.5 and 1.0 percent.

Horizontal Spacing of Interceptor Dikes

Slopes	<5%	=	300 feet
Slopes	5-10%	=	200 feet
Slopes	10-40%	=	100 feet

Stabilization

Slopes	=	<5%	Seed and mulch applied within 5 days of dike construction (see BMP E1.10).
Slopes	=	5-40%	Dependent on runoff velocities and dike materials. Stabilization should be done immediately using either sod or riprap to avoid erosion.

Outlet

The upslope side of the dike shall provide positive drainage to the dike outlet. No erosion shall occur at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.

Other

Minimize construction traffic over temporary dikes.

• Interceptor swales shall meet the following criteria:

Bottom Width	2 feet minimum; the bottom shall be level.		
Depth	1 foot minimum.		
Side Slope	2:1 or flatter.		
Grade	Maximum 5 percent, with positive drainage to a suitable outlet (such as a sediment trap).		
Stabilization	Seed as per BMP E1.10 Temporary Seeding, or E2.75 Riprap 12 inches thick pressed into the bank and extending at least 8 inches vertical from the bottom.		
Swale Spacing			
Slope of disturbed area:	<5%	=	300 feet
	5-10%	=	200 feet
	10-40%	=	100 feet
Outlet	Level Spreader or Riprap to stabilized outlet/sedimentation pond.		

Maintenance

- The measure should be inspected after every major storm and repairs made as necessary. Damage caused by construction traffic or other activity must be repaired before the end of each working day.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.13(a) Temporary Interceptor Dikes

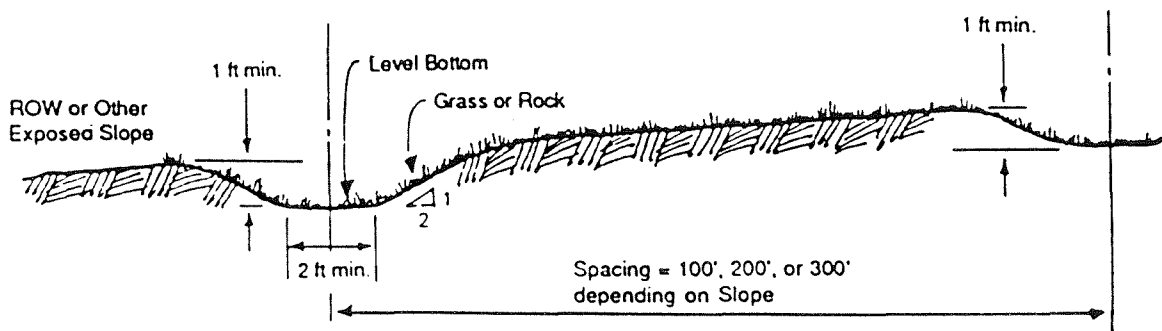
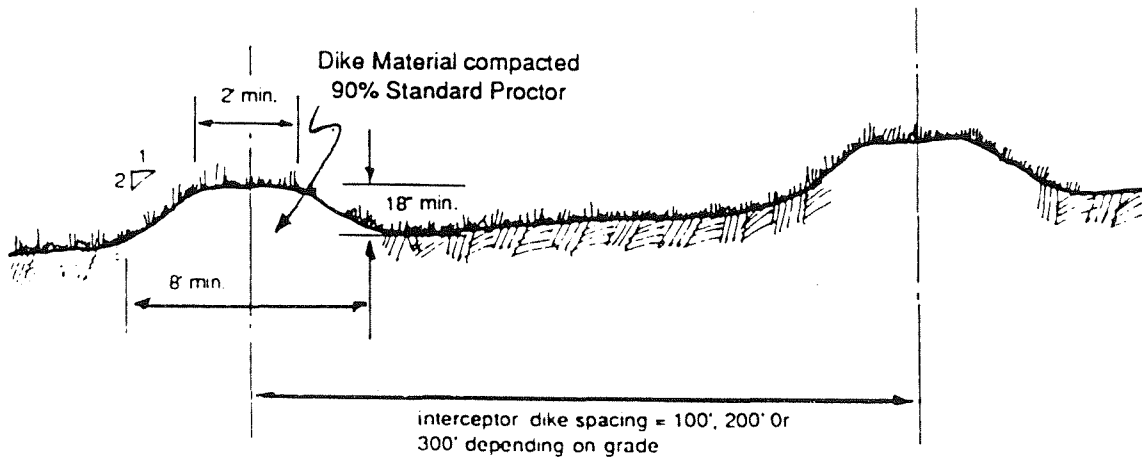


Figure II-5.13(b) Interceptor Swale

## II-5.7.11 BMP E2.60: Check Dams

Code:



Symbol: A symbol consisting of a horizontal line with a triangle pointing to the right at its center, and a vertical line segment extending downwards from the triangle's base.

Definition Small dams constructed across a swale or drainage ditch.

Purpose

To reduce the velocity of concentrated flows, reducing erosion of the swale or ditch, and to slow water velocity to allow retention of sediments.

Conditions Where Practice Applies

- Where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible and, therefore, velocity checks are required.
- In small open channels which drain 10 acres or less. No check dams may be placed in streams (unless approved by the State Departments of Fisheries or Wildlife as appropriate). Other permits may also be necessary.
- Check dams in association with sumps work more effectively at slowing flow and retaining sediment.

Advantages

- Check dams not only prevent gully erosion from occurring before vegetation is established, but also cause a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, these check dams can remain as permanent installations with very minor regrading, etc. They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to precipitate further sediment coming off that site.

Disadvantages/Problems

- Because of their temporary nature, many of these measures are unsightly, and they should be removed or converted to permanent check dams before dwelling units are rented or sold.
- Removal may be a significant cost depending on the type of check dam installed.
- Temporary check dams are only suitable for a limited drainage area.
- Clogging by leaves in the fall may be a problem.

Planning Considerations

Check dams can be constructed of either stone, logs, or pea gravel filled sandbags. Log check dams may be more economical from the standpoint of material costs, since logs can often be salvaged from clearing operations. However, log check dams require more time and hand labor to install. Stone for check dams, on the other hand, must generally be purchased. However, this cost is offset somewhat by the ease of installation.

If stone check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone from the channel when the dam is removed. This should include any stone which has washed downstream.

Since log check dams are embedded in the soil, their removal will result in more disturbance of the soil than will removal of stone check dams. Consequently, extra care should be taken to stabilize the area when log dams are used in permanent

ditches or swales.

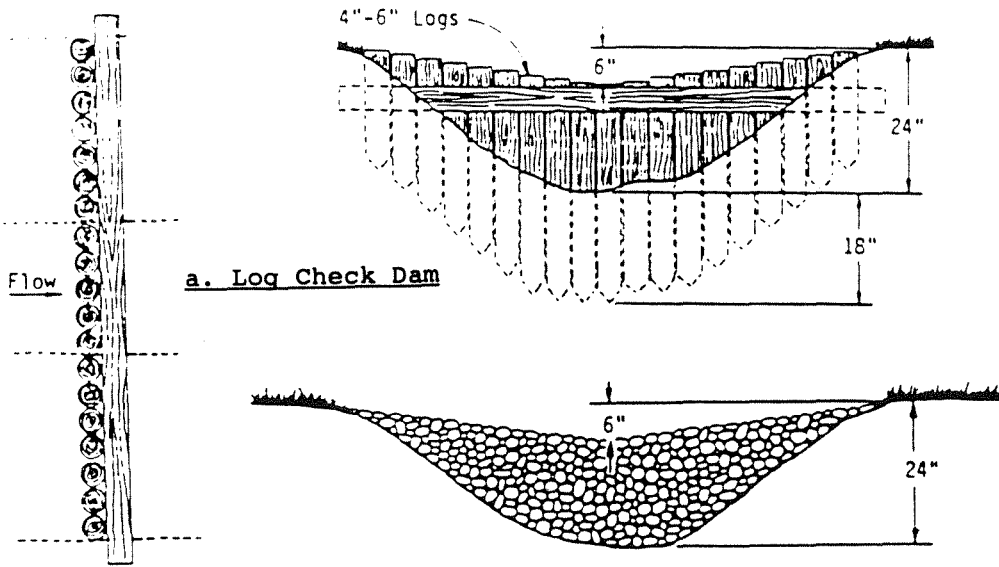
#### Design Criteria

- Check dams can be constructed of either rock, pea-gravel filled bags or logs (Figures II-5.14a,b). Provide a deep sump immediately upstream (see Figure II-5.14c).
- The maximum spacing between the dams shall be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam (Figure II-5.14c).
- Rock check dams shall be constructed of appropriately sized rock. The rock must be placed by hand or mechanical placement (no dumping of rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.
- Log check dams shall be constructed of 4 to 6-inch diameter logs. The logs shall be embedded into the soil at least 18 inches (Figure II-5.14a).
- In the case of grass-lined ditches and swales, check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.

#### Maintenance

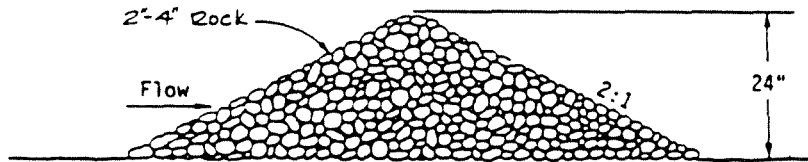
- Check dams shall be monitored for performance and sediment accumulation during and after each runoff producing rainfall. Sediment shall be removed when it reaches one half the sump depth.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.14 Check Dams



a. Log Check Dam

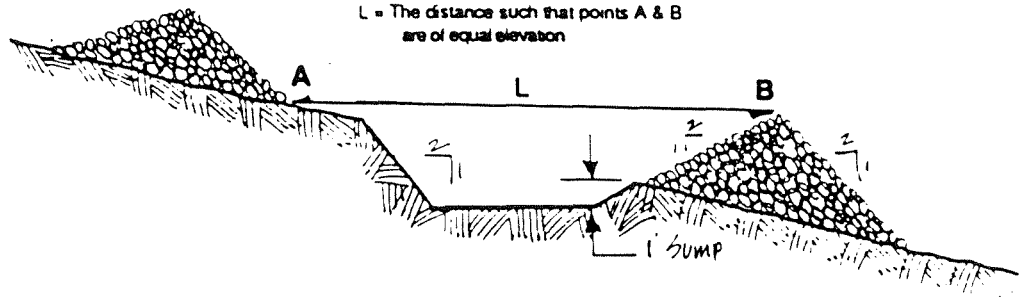
NO SCALE



b. Rock Check Dam

NO SCALE

L = The distance such that points A & B are of equal elevation



c. Spacing Between Check Dams

II-5.7.12 BMP E2.70: Outlet Protection

Code:



Symbol:



Definition Structurally lined aprons or other acceptable energy dissipating devices placed at the outlets or pipes or paved channel sections.

Purpose

To prevent scour at stormwater outlets, and to minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

Condition Where Practice Applies

- Applicable to the outlets of all pipes, interceptor swale outlets, and channel sections where the velocity of flow at the design capacity of the outlet will exceed the permissible velocity of the receiving channel or area.

Advantages

- Plunge pools which can develop without outlet protection may severely weaken the embankment and thus threaten its stability.
- Protection can prevent scouring at a culvert mouth and thus prevent gully erosion which may gradually extend upstream.

Disadvantages/Problems

- Some types of structures may be unsightly.
- Sediment removal may be difficult.

Planning Considerations

*An outfall is defined as a concentrated discharge point which directs collected surface water flows into an open drainage feature, natural or manmade. These drainage features include ditches, channels, swales, closed depressions, wetlands, streams, rivers, ponds, lakes, or other open bodies of water. In nearly every case, the outfall will consist of a pipe discharging flows from a storm pipe system, a culvert, or a detention facility.*

Design Criteria

See Sections III-2.3.4 and 2.3.5 in the Runoff Control Volume.

Maintenance

All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual. Rock may need to be added if sediment builds up in the pore spaces of the outlet pad.



II-5.7.13 BMP E2.75: Riprap

Code:



Symbol:



Definition A permanent, erosion-resistant ground cover of large, loose, angular stone.

Purpose

To slow the velocity of concentrated runoff or to stabilize slopes with seepage problems and/or non-cohesive soils by placement of large, loose, angular stone.

Conditions Where Practice Applies

- Soil-water interfaces, where the soil conditions, water turbulence, water velocity, and expected vegetative cover, are such that the soil may erode under the design flow conditions.

Advantages

- Riprap offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion. It is simple to install and maintain.
- Riprap provides some water quality benefits by increasing roughness and decreasing the velocity of the flow, inducing settling.

Disadvantages/Problems

- Riprap is more expensive than vegetated slopes.
- Riprap does not provide the habitat enhancement that other vegetative BMPs do.

Planning ConsiderationsGraded vs. Uniform Riprap

Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Riprap sizes can be designated by either the diameter or the weight of the stones. It is often misleading to think of riprap in terms of diameter, since the stones should be rectangular instead of spherical. However, it is simpler to specify the diameter of an equivalent size of spherical stone. Table II-5.4 below lists some typical stones by weight, spherical diameter and the corresponding rectangular dimensions. These stone sizes are based upon an assumed specific weight of 165 lbs./ft<sup>3</sup>

Design Criteria

Also see Table III-2.27, Rock Protection at Outfalls in the Runoff Control Volume.

Table II-5.4 Size of Riprap Stones

Weight (lbs)	Mean Spherical Diameter (ft)	Rectangular Shape	
		Length (ft)	Width, Height (ft)
50	0.8	1.4	0.5
100	1.1	1.75	0.6
150	1.3	2.0	0.67
300	1.6	2.6	0.9
500	1.9	3.0	1.0
1000	2.2	3.7	1.25
1500	2.6	4.7	1.5
2000	2.75	5.4	1.8
4000	3.6	6.0	2.0
6000	4.0	6.9	2.3
8000	4.5	7.6	2.5
20000	6.1	10.0	3.3



Since graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in mixture for which some percentage, by weight, will be smaller. For example,  $d_{85}$  refers to a mixture of stones in which 85 percent of the stone by weight would be smaller than the diameter specified. Most designs are based on  $d$ . In other words, the design is based on the median size of stone in the mixture.

#### Sequence of Construction

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

#### Maintenance

- Riprap coverings should be inspected on a regular basis and after every large storm event.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

II-5.7.14 BMP E2.80: Vegetative Streambank StabilizationCode: Symbol: 

Definition The use of vegetation to stabilize streambanks.

Purpose

To protect streambanks against erosion through vegetative means.

Condition Where Practice Applies

- Applicable to water areas and all land uses. To be used to stabilize banks in swales, creeks, streams, and rivers as well as man-made ditches, canals and impoundments, including ponds and storage basins.

Advantages

- Streambank vegetation can break wave action and the velocity of flood flows.
- Roots and rhizomes stabilize streambanks.
- The reduction of velocity can lead to the deposit of water-borne soil particles.
- Certain reeds and bulrushes have the capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, phenols, and indols (1).
- Plants regenerate themselves and adapt to changing natural situations, thus offering a distinct economic advantage over mechanical stabilization.
- Wildlife and fisheries habitat is improved.

Disadvantages/Problems

- Native plants may not be carried by regular nurseries and may need to be collected by hand, or obtained from specialty nurseries. Nurseries which carry these plants may require a long lead time for large orders.
- Flow retarding aspects of vegetated waterways need to be taken into account.

Planning Considerations

A primary cause of stream channel erosion is the increased frequency of bank-full flows which often results from upstream development. Most natural stream channels are formed with a bank-full capacity to pass the runoff from a storm with a 1.5 to 2-year recurrence interval. However, in a typical urbanizing watershed, stream channels may become subject to a 3 to 5-fold increase in the frequency of bank-full flows if stormwater runoff is not properly managed. As a result, stream channels that were once parabolic in shape and covered with vegetation may be transformed into wide rectangular channels with barren banks.

In recent years, a number of structural measures have evolved to strengthen and protect the banks of rivers and streams. These methods, when employed correctly, immediately ensure satisfactory protection of the banks. However, many such structures are expensive to build and to maintain. Without constant upkeep, they are exposed to progressive deterioration by natural agents. The materials used often prevent the reestablishment of native plants and animals, especially when the

*design is executed according to standard cross-sections which ignore natural variations of the stream system. Very often these structural measures destroy the appearance of the site. Additionally, structural stabilization and channelization can alter the hydrodynamics of a stream and only serve to transfer erosion potential and associated problems downstream.*

*In contrast, the utilization of living plants instead of or in conjunction with structures has many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. The repair and maintenance of structures is unnecessary where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective when the cover consists of natural plant communities adapted to their site.*

### Design Criteria

- Design must be prepared based on criteria and input/review by a qualified fisheries biologist.
- Streambanks can be divided into: 1) aquatic plant zones at the mean low-water level (MWL); 2) reed bank zones covered at bankfull stage (BF); 3) lower riparian zones or open floodway zones naturally covered with willows and shrubby plants (OF); 4) upper riparian areas or flood fringe areas that would naturally be covered with canopy-forming trees (FF) (see Figure II-5.15a).
- Aquatic plants are often considered weeds and a nuisance though they do slow down streamflow and protect the streambed. Primary emphasis of streambank stabilization lies in the bankfull zone.
- The reed bank zone forms a permeable obstacle, slowing down current waves by friction. Suitable plants can be found by consulting the guidelines found in Chapter III-5. Their shoots, with a root clump, can be planted in pits at 1/2 to 1 a foot depth below water, or in a reed roll as in Figure II-5.15b. A trench 1-1/2 feet wide and deep is dug behind a row of stakes; wire netting is then stretched from both sides between upright planks; coarse gravel is dumped on this and covered with reed clumps until the two edges of the netting can just be held together with wire. The upper edge of the roll should not be more than two inches above water level. Finally, the planks are taken out and gaps in the ditch are backfilled.
- The lower riparian zone in the Puget Sound region has a natural growth of willow, alder, cottonwood, small maples, and various berries. These vegetative types can be reintroduced on denuded floodplains to stabilize the soil with their roots. In periods of high water, their upper branches reduce the speed of the current and thereby the erosive force of water. The most commonly used vegetative stabilizer for this zone is willow because of its capability to develop secondary roots on cut trunks and to throw up suckers. Willows are planted either as individual cuttings bound together in various forms or wired together in "fascines."
- Fascines (Figure II-5.16a) have a diameter of 3 to 12 inches and contain brushwood and sticks and coarse gravel or rubble in the center tightly wound around. Packed fascine-work (Figure II-5.16b) can be employed on cut banks. It consists of 1 foot layers of branches covered with young, freshly cut shoots secured by stakes. The spaces between the shoots are filled with dirt and another layer is added on top. Another technique is the use of willow mattresses (Figure II-5.16c) made from 4 to 6 foot willow switches set into 6-inch trenches held down by stakes that are braided or wired together. The entire mattress is lightly covered with dirt. A variation of this method is the brush-mesh technique which is designed to stabilize breached cut banks and to encourage the deposition of sediment (Figure II-5.16d). It involves the following steps:

1. Placement of poles at 10 foot distance.
  2. Placement of large branches and brush facing the stream.
  3. Setting cuttings of live willow branches between the brush vertically, and
  4. Securing vertical willows with cuttings set diagonally facing the streamflow.
- Slip banks of the lower riparian zone and tidal banks can be stabilized with grass (3). First the bank needs to be graded to a maximum slope of 3:1. Topsoil should be conserved for reuse; lime (2 tons/acre) and fertilizer (1,000 lbs/acre of 10:10:10) should be applied. Coarse grass and beach grass should be planted at the water's edge to trap drift sand; and bermuda grass, suitable for periodic inundation, should occupy the face of the slope, followed by tall fescue on higher ground.

#### Maintenance

- Streambanks are always vulnerable to new damage. Repairs are needed periodically. Banks should be checked after every high-water event is over. Gaps in the vegetative cover should be fixed at once with new plants, and mulched if necessary. Fresh cuttings from other plants on the bank can be used, or they can be taken from mother-stock plantings if they are available.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

#### References

- (1) Seibert, P., Importance of Natural Vegetation for the Protection of the Banks of Streams, Rivers and Canals: Freshwater, The Council of Europe. Manhattan Publishing Co., New York, 1968.
- (2) U.S. Soil Conservation Service, Interim Standards and Specifications for Vegetative Tidal Bank Stabilization, College Park, Maryland, 1969.
- (3) Schiectl, Hugo, Bioengineering for Land Reclamation and Conservation, University of Alberta Press, 1980.

Figure II-5.15a  
Streambank Vegetative  
Zones

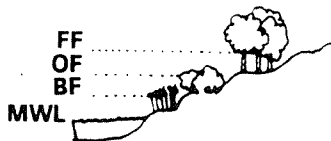


Figure II-5.15b  
Reed Roll

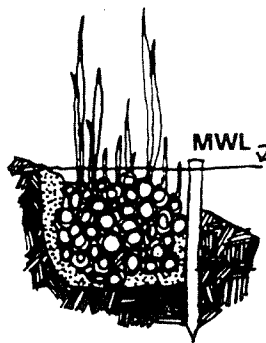


Figure II-5.16a  
Fascines

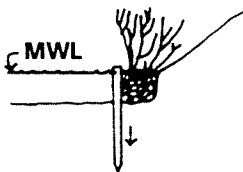


Figure II-5.16b  
Packed Fascine-Work

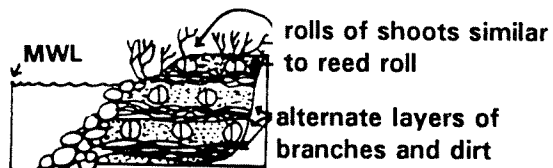


Figure II-5.16c  
Willow Mattress

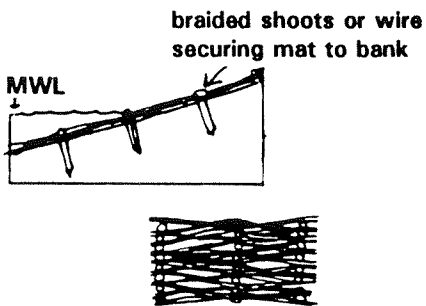


Figure II-5.16d  
Brush-Mesh Protection



II-5.7.15 BMP E2.85: Bioengineering Methods of Streambank Stabilization

Code:



Symbol:



Definition Methods of stabilizing streambanks through a combination of vegetative and mechanical means.

Purpose

To provide protection of critical sections of streambank where ordinary vegetative means of protection are not feasible or offer insufficient protection.

Conditions Where Practice Applies

- To be used in streams with swift flow where the flow/soil conditions exceed the stabilizing effect of purely vegetative channel protection.

Advantages

- Mechanical materials provide for interim and immediate stabilization until vegetation takes over.
- Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself.
- Aesthetic benefits and wildlife habitat.

Disadvantages/Problems

- Slightly higher initial cost and need for professional advice. (It is recommended that the services of a qualified bioengineer be sought for this work).
- The methods described are effective but require a complete knowledge of soils, hydrology, and other physical data to design measures that will adequately solve the problem and stand up to the test of time.

Design Criteria

Streams in urban settings may carry an increase in runoff of such great magnitude that they cannot be maintained in a natural state. In these cases bioengineering methods can provide for stabilization without complete visual degradation and they can provide higher effectiveness than purely mechanical techniques. This applies primarily to: 1) the reed bank zone (BF) and 2) the lower riparian zone (OF) (Figure II-5.17a). The following techniques apply to the reed bank zone:

Reed berms (Figure II-5.17b), consisting of a combination of reeds and riprap, break wave action, and erosion of banks by currents. Banks should not exceed a 2:1 slope. Riprap is placed to form a berm that extends beyond the surface at mean low-water level, separating the reed bed from the body of water.

Willow jetties (Figure II-5.17c) can be constructed at the water level to stabilize a cutbank by deflecting the current and by encouraging deposition of sediment. Steps:

1. Dig ditches diagonally to direction of flow, and place fill to form berm downstream from ditch.

2. Set 2-foot willow branches (4 feet may be needed) at 45° angle and 3-inch spacing facing downstream.
3. Weigh down branches with riprap extending beyond water level.

Willow gabions (Figure II-5.17d) can be used when a hard-edged effect is desired to deflect the eroding flow of water. Live willow branches, pointing downstream, are inserted through the wire mesh when the gabion is packed with stone and an addition of finer materials. Branches need to be long enough to extend through the gabion into the soil of the bank. They also should be placed at an angle back into the slope.

Piling revetment (Figure II-5.17e) with wire facings is especially suited for the stabilization of cutbanks with deep water. It involves the following steps:

1. Drive heavy timbers (8-12 inch diameter) on 6 to 8-foot centers along bank to be protected to point of refusal or one half length of pile below maximum scour.
2. Fasten heavy wire fencing to the post and if the streambed is subject to scour, extend it horizontally on the streambed for a distance equal to the anticipated depth of scour and weight with concrete blocks. As scour occurs, this section will drop into place.
3. Pile brush on the bank side of the fence, and plant willow saplings on bank to encourage sediment deposits.

In the lower riparian zone (Figure II-5.17f) (open floodway) bank stabilization efforts should be concentrated on critical areas only. The stabilizing effect of riprap can be supplemented with willows which will bind soil through their roots and screen the bank. Banks can be paved with stone (set in sand). Willow cuttings in joints need to be long enough to extend to natural soil and should have 2 to 4 buds above surface. Willow branches in riprap should be installed simultaneously. Branches should extend 1 foot into the soil below stone and 1½ feet above ground, pointing downstream.

Willow branch mat revetment (Figure II-5.17g) takes the following steps to install:

1. Grade slope to approximately 2:1 and excavate a 3 foot ditch at the toe of slope.
2. Lay live willow brush with butts upslope and anchor mat in the ditch below normal waterline by packing with large stones.
3. Drive 3-foot willow stakes 2½ feet on center to hold down brush; connect stakes with No. 9 galvanized wire and cover brush slightly with dirt to encourage sprouting.

#### Maintenance

- Costs vary according to local availability of labor. However, there are practically no maintenance costs for the vegetation once it is established, since it holds the banks 'naturally' as compared to concrete 'improvement' that constantly needs repairs.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.



References

- (1) USDA, Soil Conservation Service, Engineering Field Manual for Conservation Practices, 1969.
- (2) USDA, Soil Conservation Service, Farm Planners Engineering Handbook for the Upper Mississippi Region, Agricultural Handbook #57, 1953.
- (3) Schiectl, H. Bioengineering for Land Reclamation and Conservation, University of Alberta Press, 1980.
- (4) Gray, Donald H. and Leiser, A.T, Biotechnical Slope Protection and Erosion Control, Leiser Van Reinhold Inc., 1982.

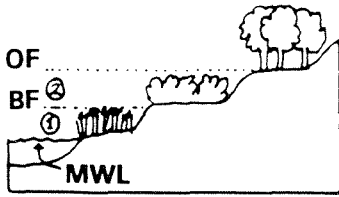


Figure II-5.17a  
Reed Bank Zone (BF)  
and Lower Riparian Zone (OF)

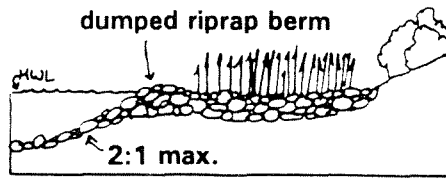


Figure II-5.17b  
Reed Berm

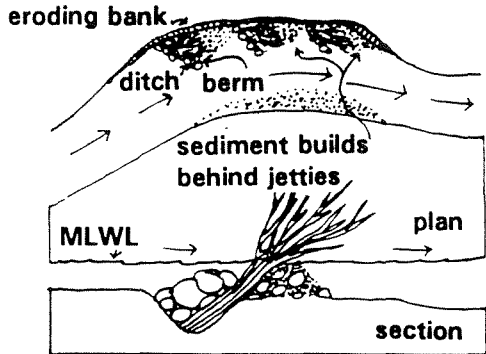


Figure II-5.17c  
Willow Jetty

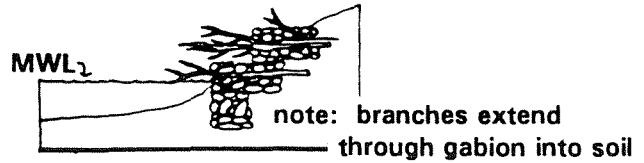


Figure II-5.17d  
Willow Gabion

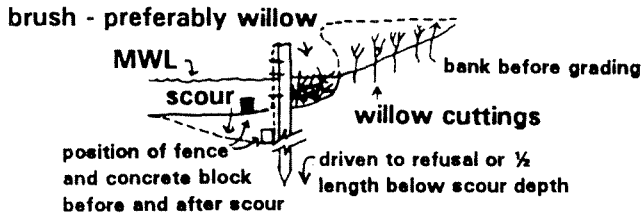


Figure II-5.17e  
Piling Revetment

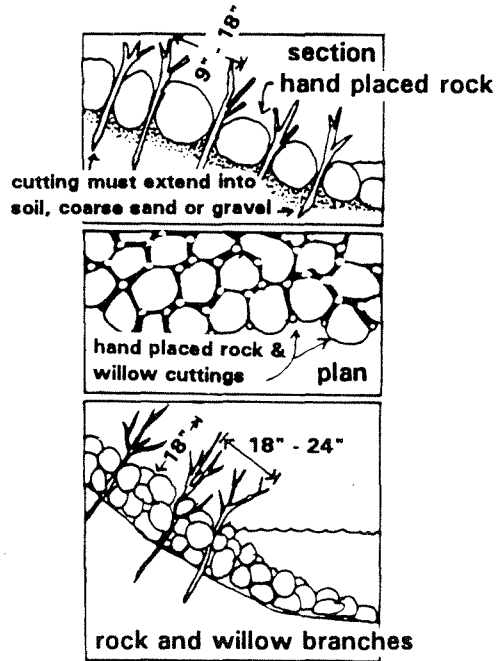


Figure II-5.17f  
Willow Branches in Riprap

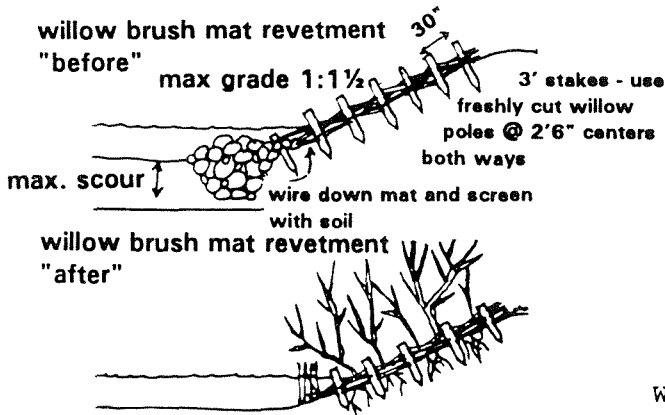




Figure II-5.17g  
Willow Branch Mat Revetment

II-5.7.16 BMP E2.90: Structural Streambank Stabilization

Code: 

Symbol: 

Definition Methods of stabilizing the banks and streams with permanent structures.

Purpose

To protect streambanks from the erosive forces of moving water, where vegetative or bioengineered methods are insufficient or infeasible.

Conditions Where Practice Applies

- Streambank sections, where excessive erosion is anticipated because of highly erodible soils.

Advantages

- Permanent structural measures are an effective method of preventing severe streambank erosion.

Disadvantages/Problems

- Most types of structural stabilization do not offer any water quality benefits except for the potential for reduced erosion and downstream siltation.

Planning Considerations

*Stream channel erosion problems vary widely in type and scale and there are many different structural stabilization techniques which have been employed with varying degrees of effectiveness. The purpose of this specification is merely to point out some of the practices which are available and to establish some broad guidelines for their selection and design. Such structures should be planned and designed in advance by a professional engineer licensed in the state of Washington. Many of the practices referenced here involve the use of manufactured products and should be designed and installed in accordance with manufacturer's specifications.*

*Before selecting a structural stabilization technique, the designer should carefully evaluate the possibility of using vegetative stabilization (BMP E2.80) or bioengineering measures (BMP E2.85) to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics, and, in most instances, HPAs from the state Departments of Fisheries and Wildlife may require this method.*

Design Criteria

- Design must be prepared based on criteria and input/review from a qualified fisheries biologist.
- Since each reach of channel requiring protection is unique, measures for streambank protection shall be installed according to a plan and adapted to the specific site. Design shall be developed according to the following principles:
  - a. Bottom scour shall be controlled, by either natural or structural means, before any permanent type of bank protection can be considered feasible. See Chapter III-2, Volume III for channel design.

- b. Stream requirements must be met.

These include, but are not necessarily limited to, development limitations imposed by the local government's Sensitive Area Ordinance (if applicable), the requirements of the Shoreline Management Act and permit requirements from State and Federal agencies such as a Hydraulic Project Approval (HPA, Washington Depts. of Fish and Wildlife), Dam Safety (Washington Dept. of Ecology), and Navigation, Shoreline and Section 101 and 404 permits for the Corps of Engineers.

- c. Special attention shall be given to maintaining and improving habitat for fish and wildlife.
- d. Structural measures must be effective for the design flow and be capable of withstanding greater flows without serious damage.
- The following structural streambank stabilization measures may be considered:
    - a. Riprap - heavy angular stone placed on the streambank to provide armor protection against erosion.
    - b. Gabion - rectangular, pervious, semi-flexible rock-filled wire baskets which can be used to armor streambanks.
    - c. Reinforced Concrete - retaining walls or bulkheads used to armor eroding sections of streambank.
    - d. Log Cribbing - retaining structure built of logs to protect streambanks from erosion. (Log cribbing can have vegetation inserted between logs.)
    - e. Grid Pavers - modular concrete units with interspersed void areas which can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation.

#### Maintenance

- Inspections should be made regularly and after each large storm event. Repairs should be made as quickly as possible after the problem occurs.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

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**II-5.8 SEDIMENT RETENTION****II-5.8.1 BMP E3.10: Filter Fence**

Code:



Symbol:

**Definition** A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The filter fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support.

**Purpose**

1. To intercept and detain small amounts of sediment under sheet flow conditions from disturbed areas during construction operations in order to prevent sediment from leaving the site.
2. To decrease the velocity of sheet flows.

**Conditions Where Practice Applies**

- Filter fences must be provided just upstream of the point(s) of discharge of runoff from a site, before the flow becomes concentrated. They may also be required:
  1. Below disturbed areas where runoff may occur in the form of sheet and rill erosion; wherever runoff has the potential to impact downstream resources.
  2. Perpendicular to minor swales or ditch lines for contributing drainage areas up to one acre in size.

**Advantages**

- Downstream riparian areas will not be damaged by sediment deposits originating from the development.
- Sediment will not cause damage to fish habitat.

**Disadvantages/Problems**

- Filter fences are not practical where large flows of water are involved, hence the need to restrict their use to drainage areas of one acre or less, and flow rates of less than 0.5 cfs. This flow should not be concentrated; it should be spread out over many linear feet of filter fabric fence.
- Problems may arise from incorrect selection of pore size and/or improper installation.
- Filter fences should not be constructed in streams or used in V-shaped ditches. They are not an adequate method of runoff control for anything deeper than sheet or overland flow.

**Planning Considerations**

Laboratory work at the Virginia Highway and Transportation Research Council has shown that silt fences can trap a much higher percentage of suspended sediments than can straw bales. Silt fences are preferable to straw barriers in many cases. However, while the failure rate of silt fences is lower than that of straw barriers, there are many instances locally in which silt fences have been improperly

installed. The installation methods outlined here can improve performance.

#### *Fabric Types:*

There are four types of material used for filter fabric fences; woven slit-film fabric, woven monofilament fabrics, woven composites (of differing materials) and non-woven heat-treated or needle punched fabrics. Slit-film fabrics are made from woven sheets of nonporous polymers. The sheets are very thin but are cut or slit in wider bands to form the threads which are then woven into the fabric. Since slit-film weaves use strands that are quite thin, the resulting woven fabric has little rigidity, and pore spaces are not uniform. Wire fencing must be used as a backing for this type of filter fabric fence. While this type of fabric is generally cheapest and the most widely used, the additional costs of the wire fence installation must be figured in.

Woven monofilament fabrics are made from uniform spun or extruded filaments which are then woven to form the fabric. They are usually thicker and thus more rigid than slit-film fabrics. The pores in monofilament fabrics are regularly spaced and the increased rigidity offers more resistance to pore distortion. The material has a very low flow-through rate. Woven composites are similar in structure but use more than one fiber type.

Non-woven fabrics are made by using either continuous filaments or short staple fibers. These fibers are then bonded together by various processes that can include a needling process that intertwines the fibers physically, or a thermal or chemical bonding operation that fuses adjacent fibers together. The resulting fabric has a random fiber orientation and may have a thickness that ranges from thick felt to a relatively thin fabric.

King County Conservation District recently completed tests on 18 different types of filter fabrics. Their results have been incorporated into the design criteria.

#### Design Criteria

- Drainage area of 1 acre or less or in combination with sediment basin in a larger site.
- Maximum slope steepness (normal (perpendicular) to fence line) 1:1.
- Maximum sheet or overland flow path length to the fence 100 feet.
- No concentrated flows greater than 0.5 cfs.
- Selection of a filter fabric is based on soil conditions at the construction site (which affect the apparent opening size (AOS) fabric specification) and characteristics of the support fence (which affect the choice of tensile strength). The designer shall specify a filter fabric that retains the soil found on the construction site yet will have openings large enough to permit drainage and prevent clogging. The larger the AOS number, the smaller the AOS size of the opening in the fabric.
- The material used in a filter fabric fence must have sufficient strength to withstand various stress conditions and it also must have the ability to allow passage of water while retaining soil particles. The ability to pass flow through must be balanced with the material's ability to trap sediments.

The following criteria are recommended for selection of the AOS:

1. Because of the properties of soils in the Puget Sound basin, field work must be done to determine the optimum AOS for filter fence installations. Because of glaciation, many soils in this area contain both cobbles and

finer particles of soil. Including gravels and larger sizes skews the results towards an AOS which is too small to capture suspended settleable solids and reduce TSS. Monofilament and non-woven geotextiles must have a minimum AOS of 70 when used in glacial soils. Composites and slit film fabrics must be extra-strength to perform similarly; in their case the AOS range may be from 40-60. In areas where Mazama ash is plentiful in the soil profile, a larger AOS will be necessary, or, fabric with an AOS of 70 should be used for outwash soils.

2. For all other soil types, the AOS should be determined by first passing soil through a #10 sieve (2.0 mm). Based on the amount of the remaining soil, by weight, which passes through a U.S. standard sieve No. 200, select the AOS to retain 85 percent of the soil. Where direct discharge to a stream, lake, or wetland will occur, then the AOS shall be no larger than Standard Sieve No. 100.

Non-woven and regular strength slit film fabrics shall be supported with wire mesh. Filter fabric material shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0°F. to 120°F.

#### Standard Notes

In addition to the Technical Information Report (see Chapter I-3) required by the local government when preparing an erosion and sediment control plan, add the following notes to the Filter Fabric Fence Detail (Figure II-5.18):

- a. The filter fabric shall be purchased in a continuous roll cut to the length of the barrier to avoid use of joints. When joints are necessary, filter cloth shall be spliced together only at a support post, with a minimum 6 inch overlap, and both ends securely fastened to the post.
- b. Posts shall be spaced a maximum of 6 feet apart and driven securely into the ground a minimum of 30 inches (where physically possible).
- c. A trench shall be excavated approximately 8 inches wide and 12 inches deep along the line of posts and upslope from the barrier. The trench shall be constructed to follow the contour.
- d. When slit film filter fabric is used, a wire mesh support fence shall be fastened securely to the upslope side of the posts using heavy-duty wire staples at least 1 inch long, tie wires or hog rings. The wire shall extend into the trench a minimum of 4 inches and shall not extend more than 36 inches above the original ground surface.
- e. Slit film filter fabric shall be wired to the fence, and 20 inches of the fabric shall extend into the trench. The fabric shall not extend more than 36 inches above the original ground surface. Filter fabric shall not be stapled to existing trees. Other types of fabric may be stapled to the fence.
- f. When extra-strength or monofilament fabric and closer post spacing are used, the wire mesh support fence may be eliminated. In such a case, the filter fabric is stapled or wired directly to the posts with all other provisions of Standard Note "e" applying. Extra care should be used when joining or overlapping these stiffer fabrics.
- g. Local governments may specify the use of properly compacted native material. In many instances, this may be the preferred alternative because the soil forms a more continuous contact with the trench below, and use of native materials

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cuts down on the number of trips that must be made on and off-site. If gravel is used instead, the trench shall be backfilled with  $\frac{3}{4}$ -inch minimum diameter washed gravel. Care must be taken when using gravel to ensure good contact between the fabric and the trench bottom to prevent undercutting.

- h. Filter fabric fences shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized. Retained sediment must be removed and properly disposed of, or mulched and seeded.

#### Maintenance

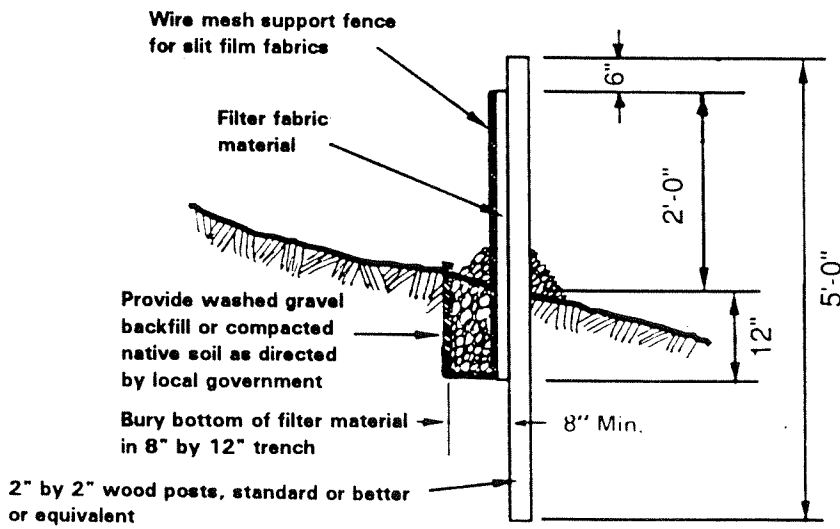
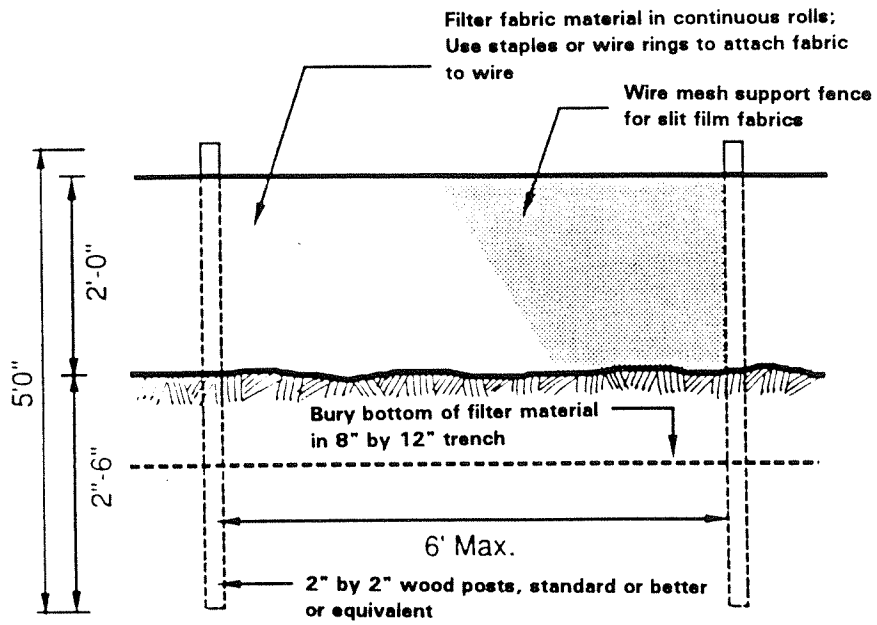
- Inspect immediately after each rainfall, and at least daily during prolonged rainfall. Repair as necessary.
- Sediment must be removed when it reaches approximately one third the height of the fence, especially if heavy rains are expected.
- Any sediment deposits remaining in place after the filter fence is no longer required shall be dressed to conform with the existing grade, prepared and seeded.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

#### References:

- (1) Kulzer, Louise, Considerations for Using Geotextiles in Silt Fence Applications, Metro Technology Transfer Publication, Nov., 1988.
- (2) Varney, Dick, An Evaluation of Geotextiles as Filter Fabric Fence Using Local Soils for Planning and Engineering, King County Conservation District, Sept., 1991.
- (3) Varney, Dick, personal communication, March 4, 1992.



Figure II-5.18 Filter Fabric Fence Detail



II-5.8.2 BMP E3.15 Straw Bale Barrier

Code:



Symbol:



Definition A temporary sediment barrier consisting of a row of entrenched and anchored straw bales.

Purpose

1. To intercept and detain small amounts of sediment from disturbed areas of limited extent to prevent sediment from leaving the site.
2. To decrease the velocity of sheet flows and low-to-moderate level channel flows.

Conditions Where Practice Applies

- Below disturbed areas subject to sheet and rill erosion.
- Where the size of the drainage area is no greater than 1/4 acre per 100 feet of barrier length; the maximum slope length behind the barrier is 100 feet; and the maximum slope gradient behind the barrier is 50 percent (2:1).
- In minor swales or ditch lines where the maximum contributing drainage area is no greater than 2 acres.
- Where effectiveness is required for less than 3 months.
- Under no circumstances should straw bale barriers be constructed in live streams or in swales where there is the possibility of a washout.

Advantages

- When properly used, straw bale barriers are an inexpensive method of sediment control.

Disadvantages/Problems

- Straw bale barriers are easy to misuse and can become contributors to a sediment problem instead of a solution.
- It is difficult to tell if bales are securely seated and snug against each other.

Planning Considerations

*Based on observations made locally and in Virginia, Pennsylvania, Maryland, and other parts of the nation, straw bale barriers have not been as effective as many users had hoped they would be. There are three major reasons for such ineffectiveness.*

1. *Improper use of straw bale barriers has been a major problem. Straw bale barriers have been used in streams and drainageways where high water velocities and volumes have destroyed or impaired their effectiveness.*
2. *Improper placement and installation of the barriers, such as staking the bales directly to the ground with no soil seal or entrenchment, has allowed undercutting and end flow. This has resulted in additions to, rather than removal of, sediment from runoff waters.*

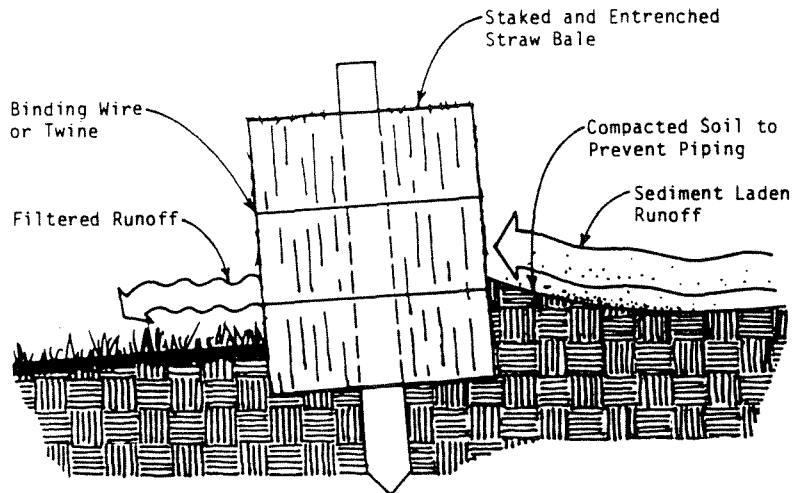
3. *Inadequate maintenance lowers the effectiveness of these barriers. For example, trapping efficiencies of carefully installed straw bale barriers on one project in Virginia dropped from 57 percent to 16 percent in one month due to lack of maintenance.*

*There are serious questions about the continued use of straw bale barriers as they are presently installed and maintained. Averaging approximately \$4.00 per linear foot, the thousands of straw bale barriers used annually represent sufficient expense that optimum installation procedures should be emphasized. If such procedures are carefully followed, straw bale barriers can be quite effective. Therefore, continued designation of straw bale barriers as a BMP will be contingent upon significant improvement in the installation and maintenance procedures applied to their use.*

#### Design Criteria

- A formal design is not required.
- Sheet Flow Applications
  1. Bales shall be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.
  2. All bales shall be either wire-bound or string-tied. Straw bales shall be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales in order to prevent deterioration of the bindings (Figure II-5.19).
  3. The barrier shall be entrenched and backfilled. A trench shall be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. The trench must be deep enough to remove all grass and other material which might allow underflow. After the bales are staked and chinked (filled by wedging), the excavated soil shall be backfilled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to 4 inches against the uphill side of the barrier (Figure II-5.19).
  4. Each bale shall be securely anchored by at least 2 stakes or re-bars driven through the bale. The first stake in each bale shall be driven toward the previously laid bale to force the bales together. Stakes or re-bars shall be driven deep enough into the ground to securely anchor the bales. Stakes should not extend above the bales but instead should be driven in flush with the top of the bale for safety reasons.
  5. The gaps between the bales shall be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency. Wedging must be done carefully in order not to separate the bales.
  6. Inspection shall be frequent and repair or replacement shall be made promptly as needed.
  7. Straw bale barriers shall be removed when they have served their usefulness, but not before the upslope areas have been permanently stabilized.
- Channel Flow Applications
  1. Bales shall be placed in a single row, lengthwise, oriented perpendicular to the contour, with ends of adjacent bales tightly abutting one another.

Figure II-5.19 Cross-Section of a Properly Installed Straw Bale Barrier

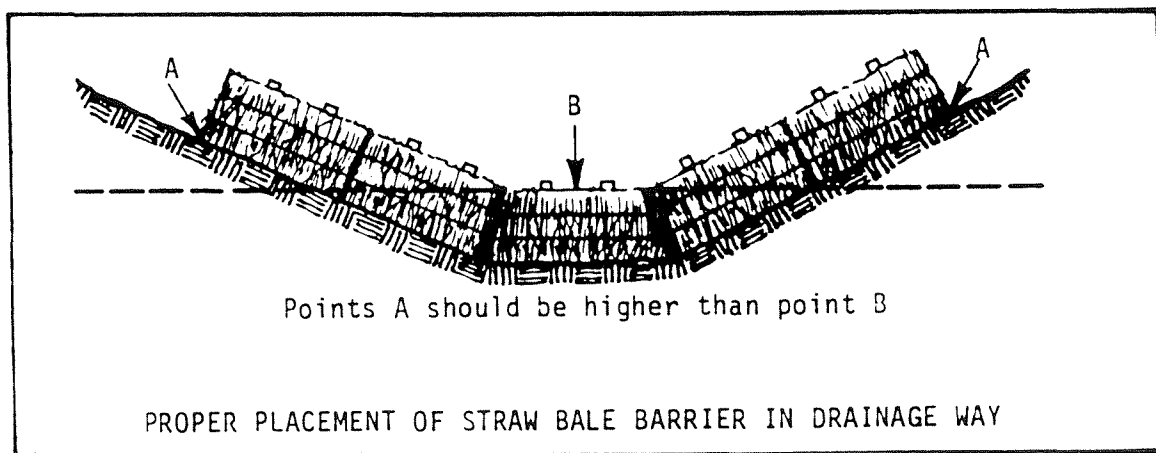
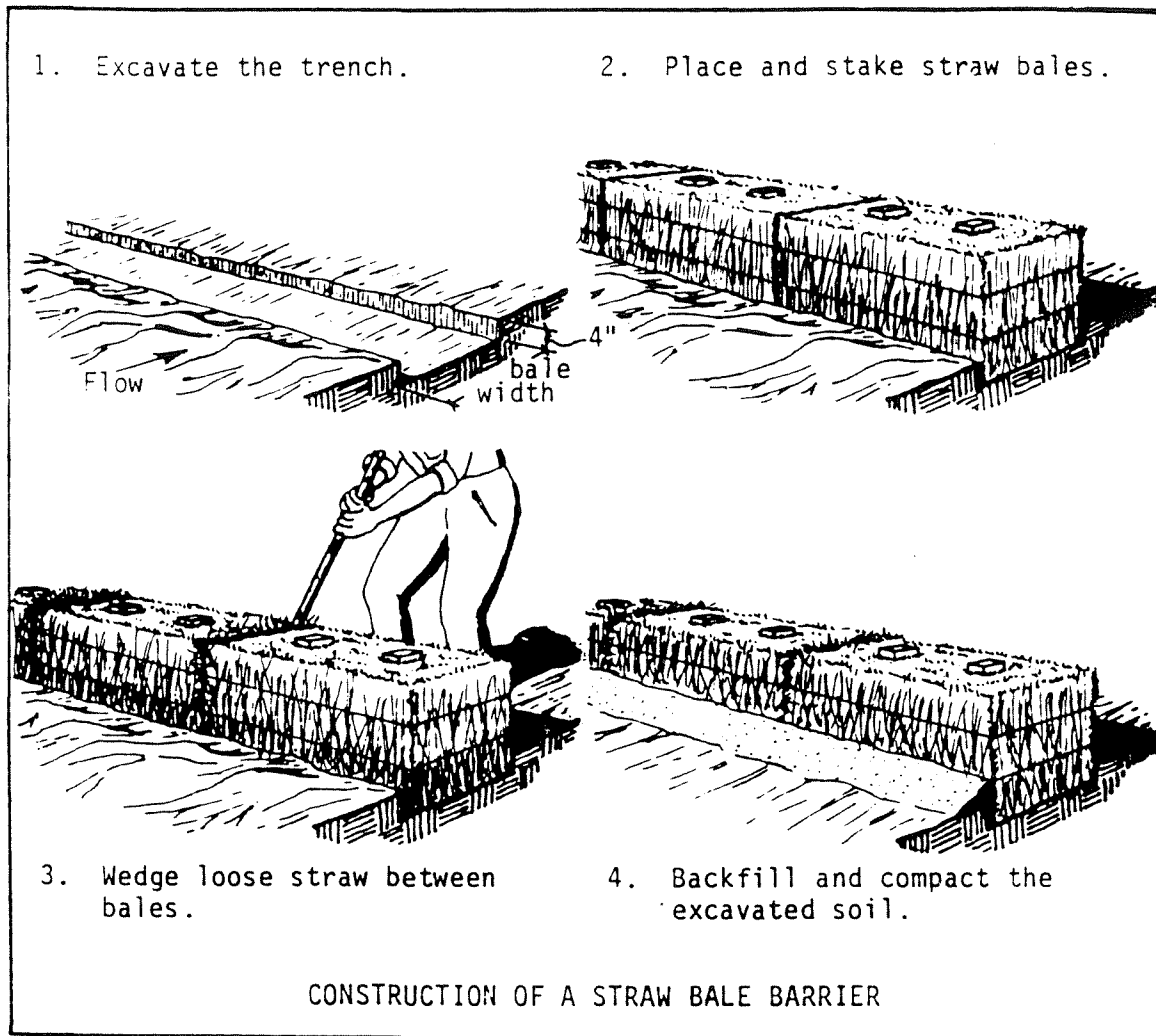


2. The remaining steps for installing a straw bale barrier for sheet flow applications apply here, with the following addition.
3. The barrier shall be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale (Figure II-5.20) to assure that sediment-laden runoff will flow either through or over the barrier but not around it.

#### Maintenance

- Straw bale barriers shall be inspected immediately after each runoff-producing rainfall and at least daily during prolonged rainfall.
- Close attention shall be paid to the repair of damaged bales, end runs, and undercutting beneath bales.
- Necessary repairs to barriers or replacement of bales shall be accomplished promptly.
- Sediment deposits should be removed after each runoff-producing rainfall. They must be removed when the level of deposition reaches approximately one-half the height of the barrier.
- Any sediment deposits remaining in place after the straw bale barrier is no longer required shall be dressed to conform to the existing grade, prepared and seeded.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.20 Proper Installation of a Straw Bale Barrier



II-5.8.3 BMP E3.20: Brush Barrier

Code:

BB

Symbol:



**Definition** A temporary sediment barrier constructed at the perimeter of a disturbed area from residue materials available from cleaning and grubbing on-site.

Purpose

To intercept and retain sediment from limited disturbed areas.

Conditions Where Practice Applies

- Below disturbed areas of less than one quarter acre that are subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier. Note: This does not replace a sediment trap or pond.

Advantages

- Brush barriers can often be constructed using materials found on-site.

Problems

- None

Planning Considerations

*Organic litter and spoil material from site clearing operations is usually burned or hauled away to be dumped elsewhere. Much of this material can be used effectively on the construction site itself. During clearing and grubbing operations, equipment can push or dump the mixture of limbs, small vegetation, and root mat along with minor amounts of soil and rock into windrows along the toe of a slope where erosion and accelerated runoff are expected. Anchoring a filter fabric over the berm enhances the filtration ability of the barrier. Because brush barriers are fairly stable and composed of natural materials, maintenance requirements are small. Material containing large amounts of wood chips should not be used because of the potential for leaching from the chips.*

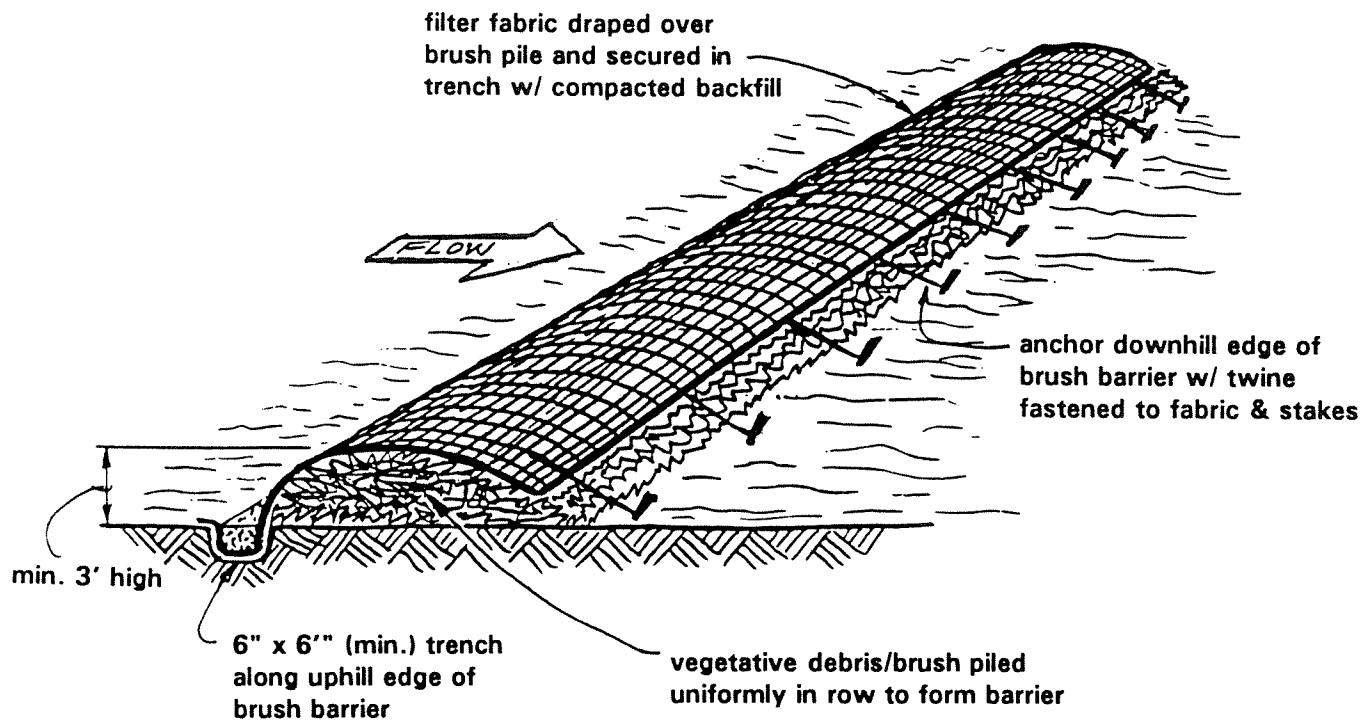
Design Criteria

- Height 3 feet (minimum) to 5 feet (maximum).
- Width 5 feet at base (minimum) to 15 feet (maximum).
- Filter fence anchored over the berm will enhance its filtration capacity.
- Further design details are illustrated in Figure II-5.21.

Maintenance

- Brush barriers generally require little maintenance, unless there are very heavy deposits of sediment. Occasionally, tearing of the fabric may occur.
- When the barrier is no longer needed the fabric can be removed to allow natural establishment of vegetation within the barrier. Over time the barrier will rot.

Figure II-5.21 Brush Barrier



II-5.8.4 BMP E3.25: Gravel Filter Berm

Code:



Symbol:

GFB

Definition A gravel berm constructed on rights-of-way or traffic areas within a construction site.

Purpose

To retain sediment from traffic areas by using a filter berm of gravel or crushed rock.

Conditions Where Practice Applies

- Where a temporary measure is needed to retain sediment from rights-of-way or in traffic areas on construction sites.

Advantages

- This is a very efficient method of sediment removal.

Disadvantages/Problems

- This BMP is more expensive to install than are other BMPs which use materials found on-site.

Design Criteria

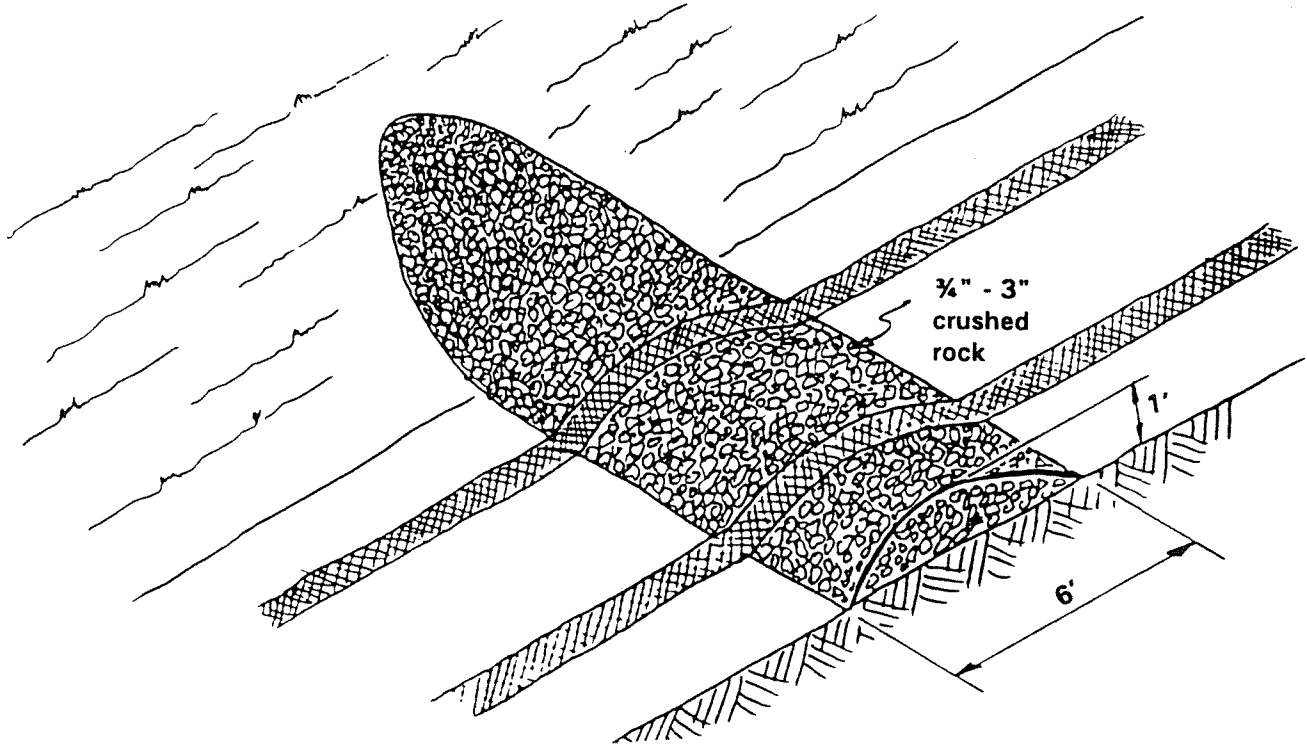
- Berm material shall be  $\frac{1}{4}$  to 3 inches in size, washed, well-graded gravel or crushed rock with less than 5 percent fines (Figure II-5.22).
- Spacing of berms:
  - every 300 feet on slopes less than 5 percent
  - every 200 feet on slopes between 5 and 10 percent
  - every 100 feet on slopes greater than 10 percent
- Berm dimensions:
  - 1 foot high with 3:1 side slopes
  - 8 linear feet per 1 cfs runoff based on the 10-year, 24-hour design storm.

Maintenance

- Regular inspection is required; sediment shall be removed and filter material replaced as needed.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.



Figure II-5.22 Gravel Filter Berm



II-5.8.5 BMP E3.30: Storm Drain Inlet Protection

Code:



Symbol:



Definition A sediment filter or an excavated impounding area around a storm drain, drop inlet, or curb inlet.

Purpose

To prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area.

Conditions Where Practice Applies

- Where storm drain inlets are to be made operational before permanent stabilization of the disturbed drainage area. Different types of structures are applicable to different conditions:
  - a. Filter Fabric Fence - applicable where the inlet drains a relatively small (less than 1 acre) flat area (less than 5 percent slope). (see Figure II-5.23). Do not place fabric under grate as the collected sediment may fall into the drain when the fabric is retrieved. This practice cannot easily be used where the area is paved because of the need for driving stakes to hold the material.
  - b. Block and Gravel Filter - applicable where heavy flows (greater than 0.5 cfs) are expected (Figure II-5.24).
  - c. Gravel and Wire Mesh Filter - applicable where flows greater than 0.5 cfs are expected and construction traffic may occur over the inlet (Figure II-5.25).

Advantages

- Inlet protection prevents sediment from entering the storm drain system and clogging it.

Disadvantages/Problems

- Sediment removal may be difficult, especially under high flow conditions.

Planning Considerations

*Storm sewers which are made operational before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. In cases of extreme sediment loading, the storm sewer itself may clog and lose a major portion of its capacity. To avoid these problems, it is necessary to prevent sediment from entering the system at the inlets.*

*There are several types of inlet filters and traps which have different applications dependent upon site conditions and type of inlet. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by the Plan Approving Authority of the local government (see Design Criteria for the description of a new method currently under development by Emcon Northwest). Note that these various inlet protection devices are for drainage areas of less than one acre. Runoff from larger disturbed areas should be routed through a Temporary Sediment Trap or Pond (see BMPs E3.35, E3.40).*

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*The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible, preventing erosion and stopping sediment at its source.*

#### Design Criteria

- Grates and spaces of all inlets should be secured to prevent seepage of sediment-laden water.
- All inlet protection measures should include sediment sumps of 1 to 2 feet in depth, with 2:1 side slopes (Figure II-5.23).
- Installation procedure for filter fabric fence:
  - a. Place 2 inch by 2 inch wooden stakes around the perimeter of the inlet a maximum of 3 feet apart and drive them at least 8 inches into the ground. The stakes must be at least 3 feet long.
  - b. Excavate a trench approximately 8 inches wide and 12 inches deep around the outside perimeter of the stakes.
  - c. Staple the filter fabric (for materials and specifications, see BMP E3.10, Filter Fence) to wooden stakes so that 32 inches of the fabric extends out and can be formed into the trench. Use heavy-duty wire staples at least  $\frac{1}{2}$  inch in length.
  - d. Backfill the trench with  $\frac{3}{4}$  inch or less washed gravel all the way around.
- Installation procedure for block and gravel filter:
  - a. Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with one-half inch openings. If more than one strip is necessary, overlap the strips. Place filter fabric over the wire mesh.
  - b. Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, so that the open ends face outward, not upward. The ends of adjacent blocks should abut. The height of the barrier can be varied, depending on design needs, by stacking combinations of blocks that are 4 inches, 8 inches, and 12 inches wide. The row of blocks should be at least 12 inches but no greater than 24 inches high (Figure II-5.24).
  - c. Place wire mesh over the outside vertical face (open end) of the concrete blocks to prevent stone from being washed through the blocks. Use hardware cloth or comparable wire mesh with one half inch openings.
  - d. Pile washed stone against the wire mesh to the top of the blocks. Use  $\frac{3}{4}$  to 3 inch gravel.
- Installation procedure for gravel and wire mesh filter:
  - a. Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with  $\frac{1}{2}$  inch openings. If more than one strip of mesh is necessary, overlap the strips. Place filter fabric over wire mesh.
  - b. Extend the filter fence/wire mesh beyond the inlet opening at least 18 inches on all sides. Place  $\frac{3}{4}$  to 3-inch gravel over the filter fabric/wire mesh. The depth of the gravel should be at least 12 inches

over the entire inlet opening (see Figure II-5.25).

Experimental Inlet Protection BMP:

EMCON Northwest, Inc. has recently developed a catchbasin filter (patent pending) that prevents sediments and other contaminants from entering storm drainage systems. The catchbasin filter is inserted in the catchbasin just below the grating. The catchbasin filter is equipped with a sediment trap and up to three layers of a fiberglass filter material (see Figure II-5.26). This type of system may not be applicable in all catchbasins but would work well at construction sites, industrial facilities, service stations, marinas/boatyards, etc.

During research and development of the catchbasin filter, EMCON Northwest, Inc. has found that particulates as small as 15 microns are retained by the filter. Additionally, high levels of particulate heavy metals, oil and grease and TSS have been removed at both industrial facilities and construction sites. The catchbasin filter is equipped with an overflow mechanism which allows it to pass peak flows up to 240 gallons per minute. Effective filtration can be accomplished at flows as high as 40 gallons per minute.

For further information, contact John MacPherson at EMCON Northwest Inc., (206) 485-5000.

*Please note that this information is presented for informational purposes only. While this technology appears to be an effective method of controlling some types of pollutants, Ecology is not in a position to confirm or deny its efficacy at this time.*

Maintenance

- For systems using filter fabric: inspections should be made on a regular basis, especially after large storm events. If the fabric becomes clogged, it should be replaced. Sediment should be removed when it reaches approximately one-half the height of the fence. If a sump is used, sediment should be removed when it fills approximately one half the depth of the hole.
- For systems using stone filters: If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.23 Filter Fabric Fence Inlet Filter

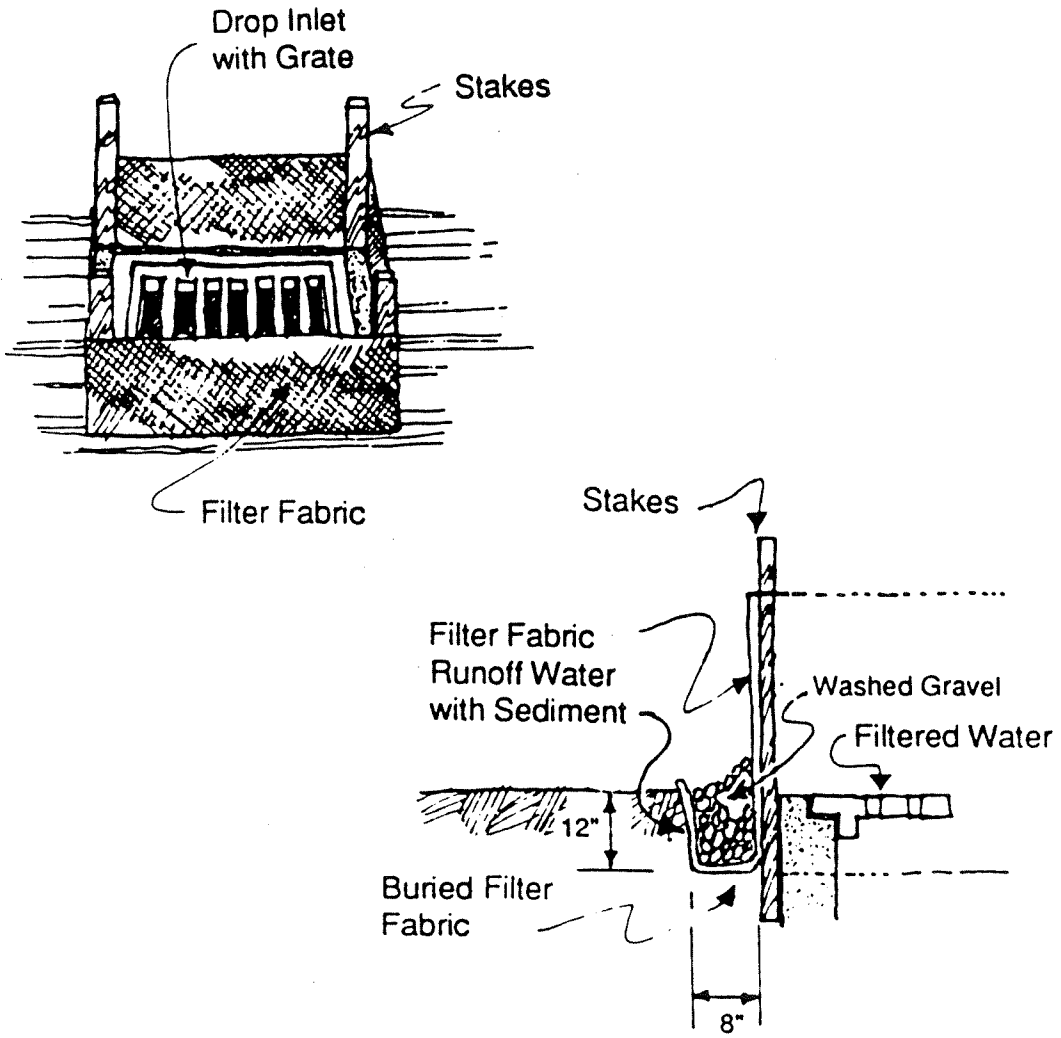


Figure II-5.24 Block and Gravel Filter

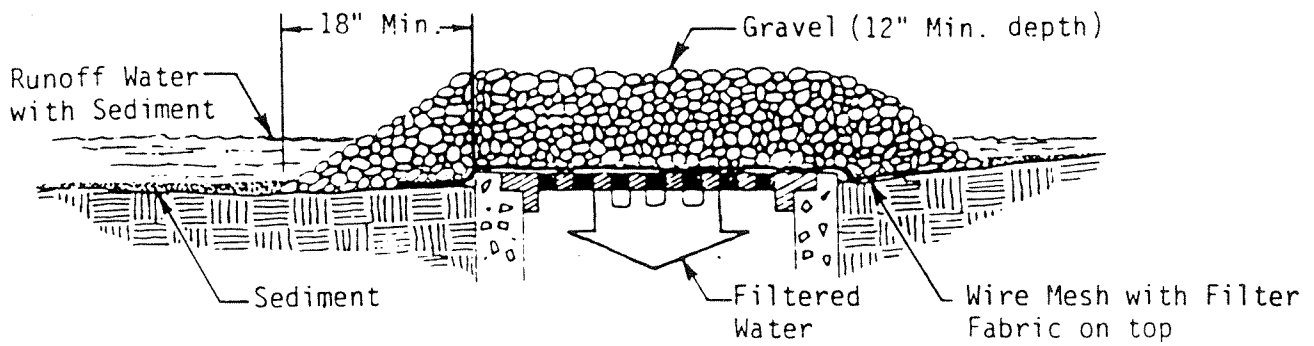
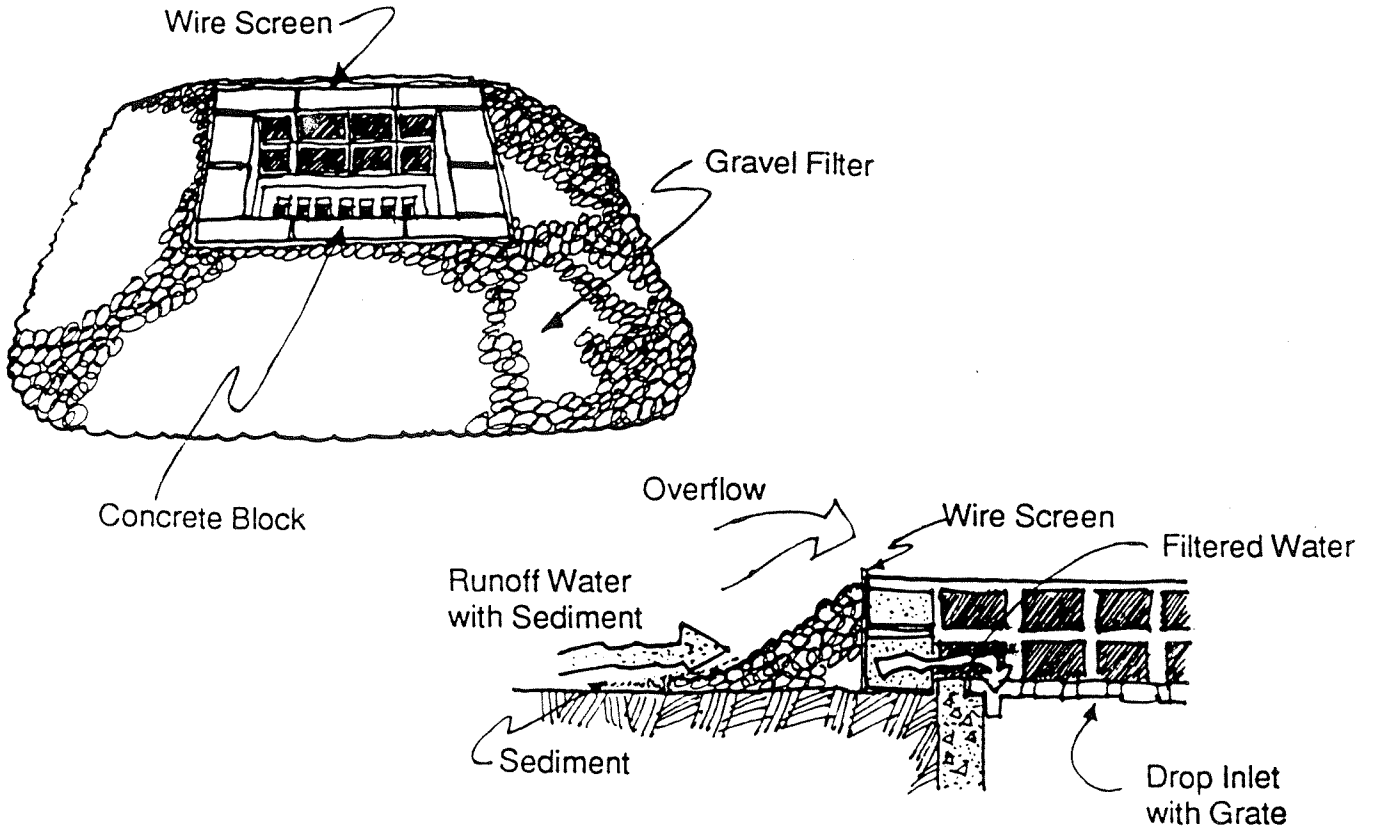
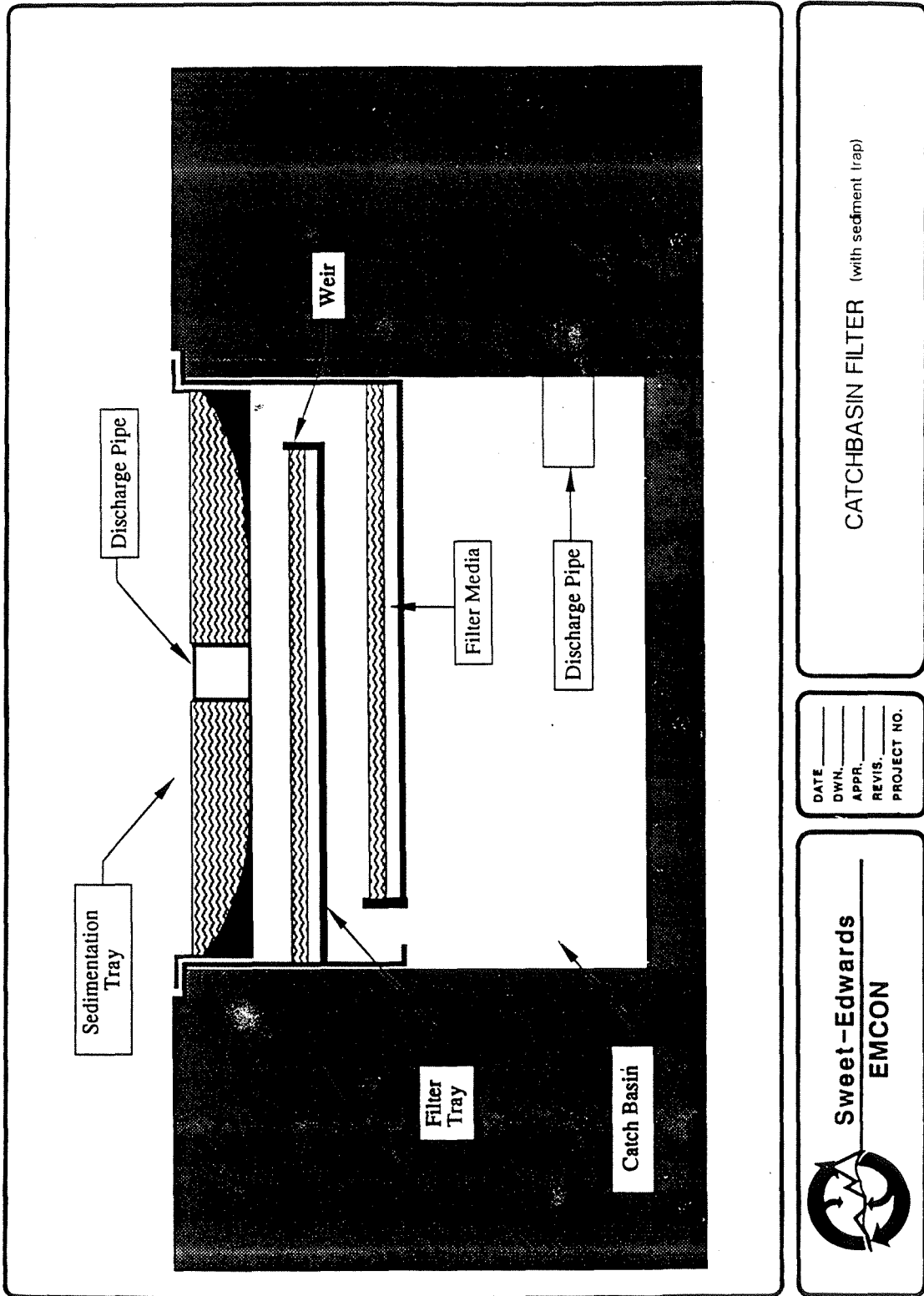


Figure II-5.25 Gravel and Wire Mesh Filter

Figure II-5.26 Experimental Catchbasin Filter With Sediment Trap



II-5.8.6 BMP E3.35: Sediment Trap

Code:

ST

Symbol:



Editor's Note: Based on comments that were received during the technical review period of the manual, BMPs E3.35 (Sediment Trap) and E3.40 (Sediment Pond) were revised and the use of the Universal Soil Loss Equation to calculate the sediment storage volume was dropped. Instead, volume calculations are to be based on one of the methods found in Volume III, Runoff Control, and a constant depth for sediment storage.

It is important to understand that sizing is perhaps less important for these BMPs (because of their temporary nature) than is constant maintenance. Inspections must be made and sediment removed regularly for either of these BMPs to function well.

Definition A small temporary ponding area, with a gravel outlet, formed by excavation and/or by constructing an earthen embankment.

Purpose

To collect and store sediment from sites cleared and/or graded during construction. It is intended for use on relatively small building areas, with no unusual drainage features, and projected quick build-out time. It should help in reducing silt-laden runoff. This silt-laden runoff clogs off-site conveyance systems and destroys habitat, particularly in streams. The trap is a temporary measure (with a design life of approximately 6 months) and is to be maintained until the site area is permanently protected against erosion by vegetation and/or structures.

Conditions Where Practice Applies

- Proposed building sites where the tributary drainage area is less than 3 acres.

Advantages

- Downstream riparian properties will not be damaged by sediment deposits originating from that development.
- Sediment deposits downstream will not reduce the capacity of the stream channel.
- Sediment will not cause the clogging of downstream impoundments and other facilities.

Disadvantages/Problems

- Serves only limited areas.
- Sediment traps (and ponds, see BMP E3.40) are only practically effective in removing sediment down to about the medium silt size fraction. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated, emphasizing the need to control erosion to the maximum extent first.

Planning Considerations

*Sediment traps should be used only for small drainage areas. If the contributing drainage area is greater than 3 acres, refer to Sediment Ponds (see BMP E3.40), or subdivide the catchment area (see Figure II-5.27).*

*Sediment must be periodically removed from the trap. Plans shall detail how this*



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*sediment is to be disposed of, such as by use in fill areas on-site, or removal to an approved off-site dump. Sediment traps, along with other perimeter controls, shall be installed before any land disturbance takes place in the drainage area.*

### Safety

See Section II-5.8.7, Sediment Ponds (BMP E3.40).

### Design Criteria

The sediment trap may be formed completely by excavation or by construction of a compacted embankment. It shall have a 1.5 foot deep sump for sediment storage. The outlet shall be a weir/spillway section, with the area below the weir acting as a filter for sediment and the upper area as the overflow spillway depth.

- See Figures II-5.27 and II-5.28 for details.
- The temporary sediment trap volume can be found by computing the detention volume required for the 2-year, 24-hour design storm using one of the approved methods found in Volume III, Chapter 1. Side slopes should not exceed 3:1. After determining the necessary volume, size the trap by adding an additional 1½ feet for sediment accumulation to the volume computed using the 2-year, 24-hour design storm.
- To complete the design of the temporary sediment trap:
  - a. Figures II-5.28 and II-5.29 may be useful in designing the sediment trap.
  - b. A 3:1 aspect ratio between the trap length and width of the trap is desirable. Length is defined as the average distance from the inlet to the outlet of the trap. This ratio is included in the computations for Figure II-5.28 for the surface area at the interface between the settling zone and sediment storage volume.
  - c. Determine the bottom and top surface area of the sediment storage volume to be provided (see Figure II-5.29) using 1½ feet in depth for sediment storage and 3:1 side slope from the bottom of the trap. Note the trap bottom should be level.
  - d. Determine the total trap dimensions by adding the depth required for the 2-year, 24-hour design storm above the surface of the sediment storage volume, while not exceeding 3:1 side slopes (see Figure II-5.29).

### Maintenance

- The key to having a functional sediment trap is continual monitoring and regular maintenance. The size of the trap is less important to its effectiveness than is regular sediment removal. Sediment should be removed from the trap when it reaches approximately one foot in depth (assuming a 1½ sediment accumulation depth). Regular inspections should be done and additional inspections made after each large runoff-producing storm.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

Figure II-5.27 ESC Structural Practices

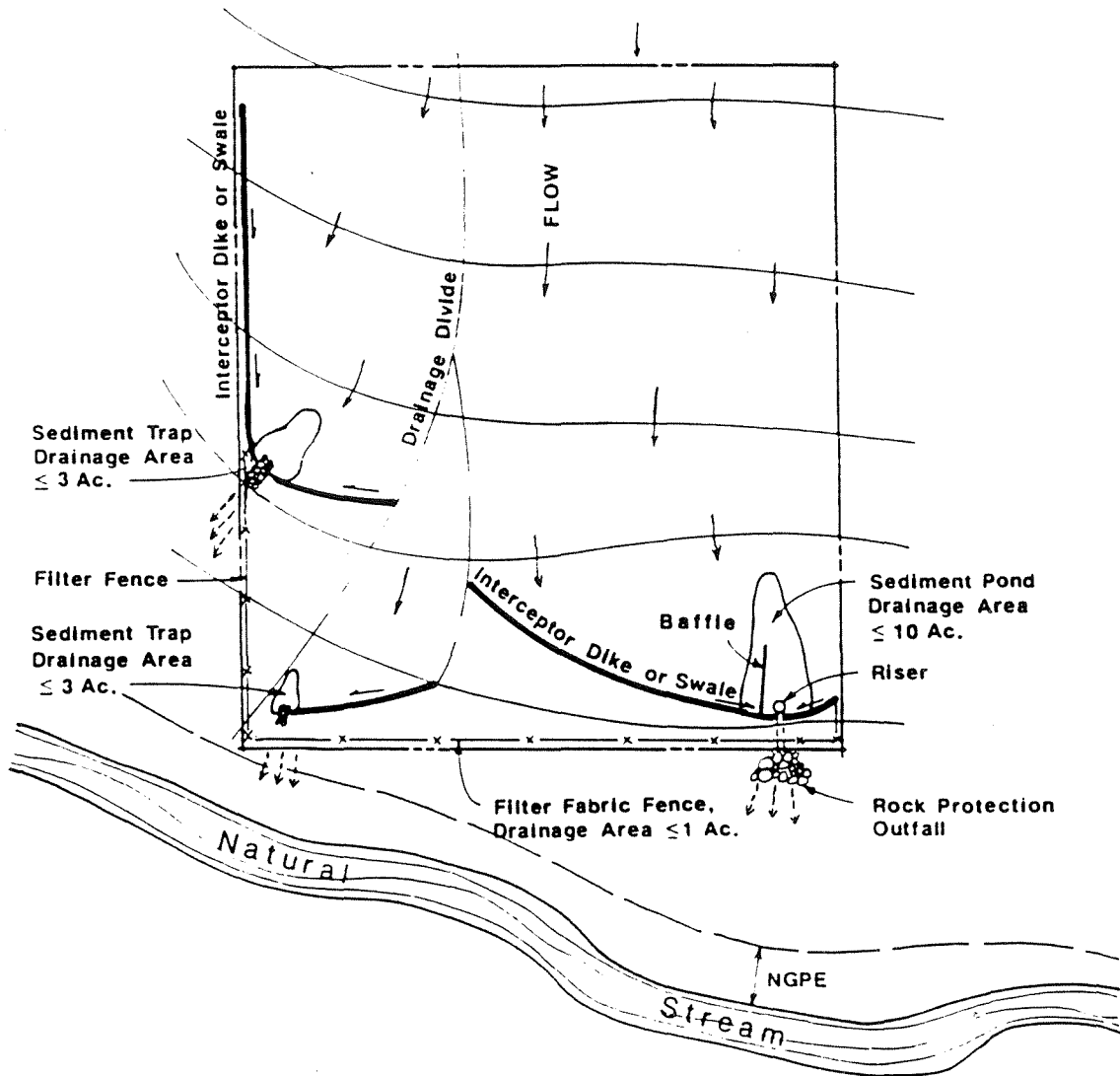
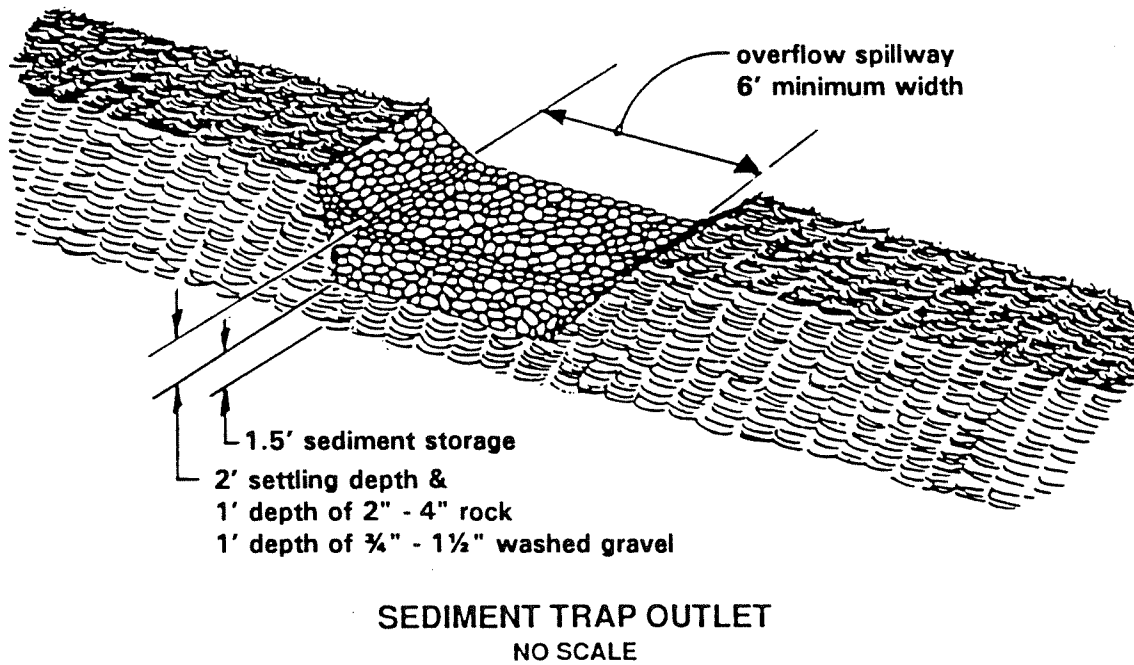
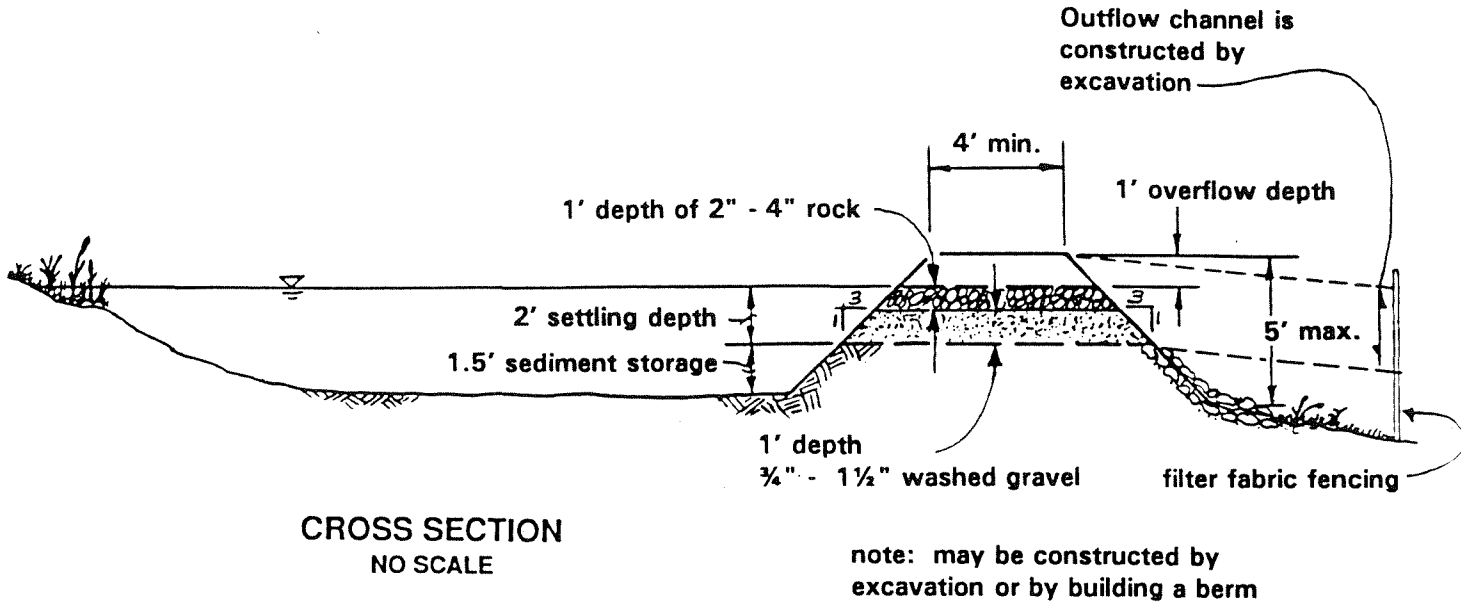


Figure II-5.28 Sediment Trap



II-5.8.7 BMP E3.40: Temporary Sediment Pond (or Basin)

Code:

SB

Symbol:



Editor's Note: Based on comments that were received during the technical review period of the manual, BMPs E3.35 (Sediment Trap) and E3.40 (Sediment Pond) were revised and the use of the Universal Soil Loss Equation to calculate the sediment storage volume was omitted. Instead, volume calculations are to be based on one of the methods found in Volume III, Runoff Control, and a constant depth for sediment storage.

It is important to understand that sizing is perhaps less important for these BMPs (because of their temporary nature) than is constant maintenance. Inspections must be made and sediment removed regularly for either of these BMPs to function well.

Definition A temporary basin with a controlled stormwater release structure formed by constructing an embankment of compacted soil across a drainageway, or other suitable locations.

Purpose

To collect and store sediment from sites cleared and/or graded during construction or for extended periods of time before reestablishment of permanent vegetation and/or construction of structures. It is intended to help prevent erosion on the site which results in silt-laden runoff. The basin is a temporary measure (with a design life less than 1 year) and is to be maintained until the site area is permanently protected against erosion.

Conditions Where Practice Applies

- Proposed construction sites where the tributary drainage is less than 10 acres.

Safety

Sediment traps and ponds must be installed only on sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities. Also, sediment traps and ponds are attractive to children and can be very dangerous. Local ordinances regarding health and safety must be adhered to. If fencing of the pond is required, the type of fence and its location shall be shown on the ESC plan.

Advantages

- Because of additional detention time, sediment ponds may be capable of trapping smaller sediment particles than traps. However, they are most effective when used in conjunction with other BMPs such as seeding or mulching.

Disadvantages/Problems

- Ponds may become an "attractive nuisance" and care must be taken to adhere to all safety practices.
- Sediment ponds are only practically effective in removing sediment down to about the medium silt size fraction. Sediment-laden runoff with smaller size fractions (fine silt and clay) will pass through untreated emphasizing the need to control erosion to the maximum extent first.

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## Planning Considerations

### Effectiveness

Sediment basins are at best only 70-80 percent effective in trapping sediment which flows into them. Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc. to reduce the amount of sediment flowing into the basin. Sediment basins are most effective when designed with a series of chambers.

### Location

To improve the effectiveness of the basin, it should be located so as to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally low areas below disturbed areas. Drainage into the basin can be improved by the use of diversion dikes and ditches. The basin must not be located in a stream but should be located to trap sediment-laden runoff before it enters the stream. The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.

### Multiple Use

Sediment basins may be designed as permanent structures to remain in place after construction is completed for use as stormwater detention ponds. Wherever these structures are to become permanent, or if they exceed the size limitations of the design criteria, they must be designed as permanent ponds by a professional engineer licensed in the State of Washington. Permanent ponds are dealt with in Volume III, Runoff Control.

### Design Criteria

The sediment pond may be formed by partial excavation and/or by construction of a compacted embankment. It may have one or more inflow points carrying polluted runoff. Baffles to spread the flow throughout the basin should be included (Figure II-5.30). A securely anchored riser pipe is the principal discharge mechanism along with an emergency overflow spillway. The riser pipe shall be solid with two 1-inch diameter dewatering holes located at the top of the sediment storage volume on opposite sides of the riser pipe as shown in Figure II-5.30. Outlet protection is provided to reduce erosion at the pipe outlet.

- The sediment pond volume is the sum of the sediment storage volume (3 feet in depth) plus a settling volume of not less than 2 feet in depth. The sediment depth is computed based on the basin surface area required to settle out the design particle at the design inflow rate.

Computing the settling zone volume: The settling zone volume may be approximated by assuming a 2 foot depth above the sediment storage volume and extending the 3:1 side slopes as necessary, or by computing the precise volume as outlined below. The maximum settling zone depth shall be 4 feet.

#### a. Pond surface area

The settling zone volume is determined by the pond surface area which is computed using the following equation:  $(SA) = 1.2Q_{10} / V_{sed}$

Where  $Q_{10}$  = design inflow based on the peak discharge from a 10-year, 24-hour duration design storm event from the tributary drainage area as computed using the methods described in Chapter III-1 of Volume III, Runoff Control.

$V_{sed}$  = the settling velocity of the design soil particle. The design particle chosen is medium silt (0.02 mm) (1) This has a settling velocity ( $V_{sed}$ ) of 0.00096 ft/sec. Note that for the relatively common sandy loam soils found in the Puget Sound basin, approximately 80 percent of the soil particles are larger than 0.02 mm. Thus, choosing a design particle size of 0.02 mm gives a theoretical trapping efficiency of approximately 80 percent. In practice, and for more finely textured soils, the trapping efficiency would be less. However, as a general rule, it will not be necessary to design for a particle of size less than 0.02 mm, especially since the surface area requirement increases dramatically for smaller particle sizes. For example, a design particle of 0.01 mm requires about three times the surface area of 0.02 mm. However, for sites with very finely textured soils, the local government may require a smaller design particle size than 0.02 mm. Note also that choosing a  $V_{sed}$  of 0.00096 ft/sec equates to a surface area (SA) of 1250 sq. ft. per cfs of inflow.

- b. Settling depth (SD) should not be less than 2 feet and is also governed by the sediment storage volume surface area and relationship to the basin length (L). The basin length is defined as the average distance from the inlet to the outlet of the pond.

The ratio of L/SD should be less than 200.

The settling volume is therefore the surface area (SA) times the required settling depth.

To complete the design of the sediment pond:

Total sediment pond volume and dimension are determined as outlined below:

- a. Determine pond geometry for the sediment storage volume calculated above using 3 feet in depth and 3:1 side slopes from the bottom of the basin. Note, the basin bottom is level.
- b. Extend the pond side slopes (at 3:1 max.) as necessary to obtain the settling zone volume at 2 foot depth minimum or as determined above, 4 foot maximum.

Figure II-5.29 Sedimentation Pond Baffles

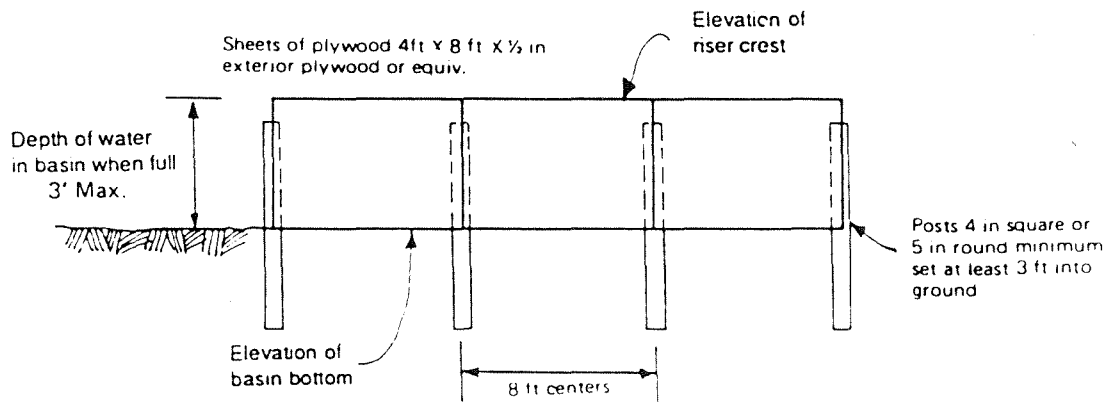
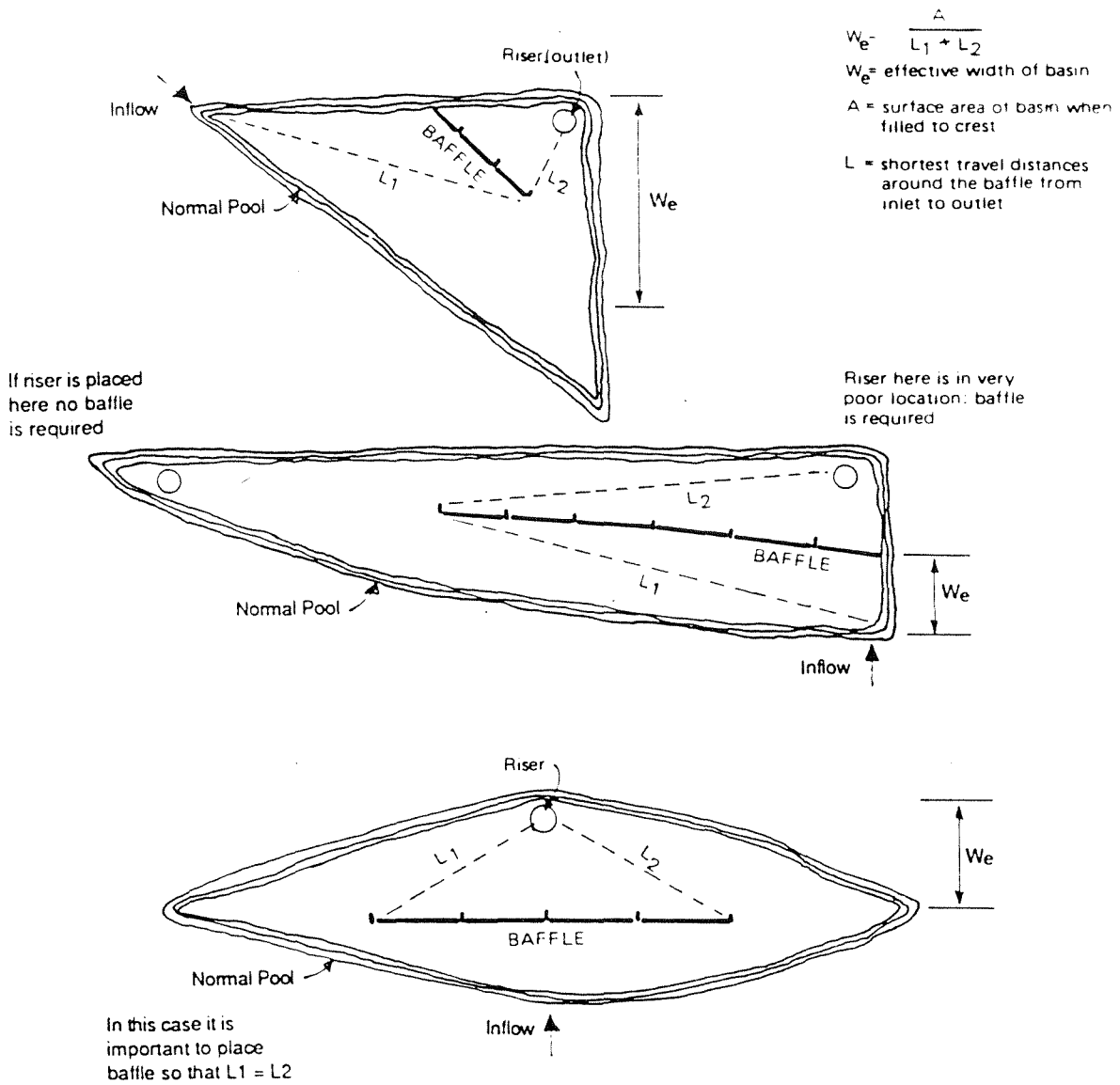
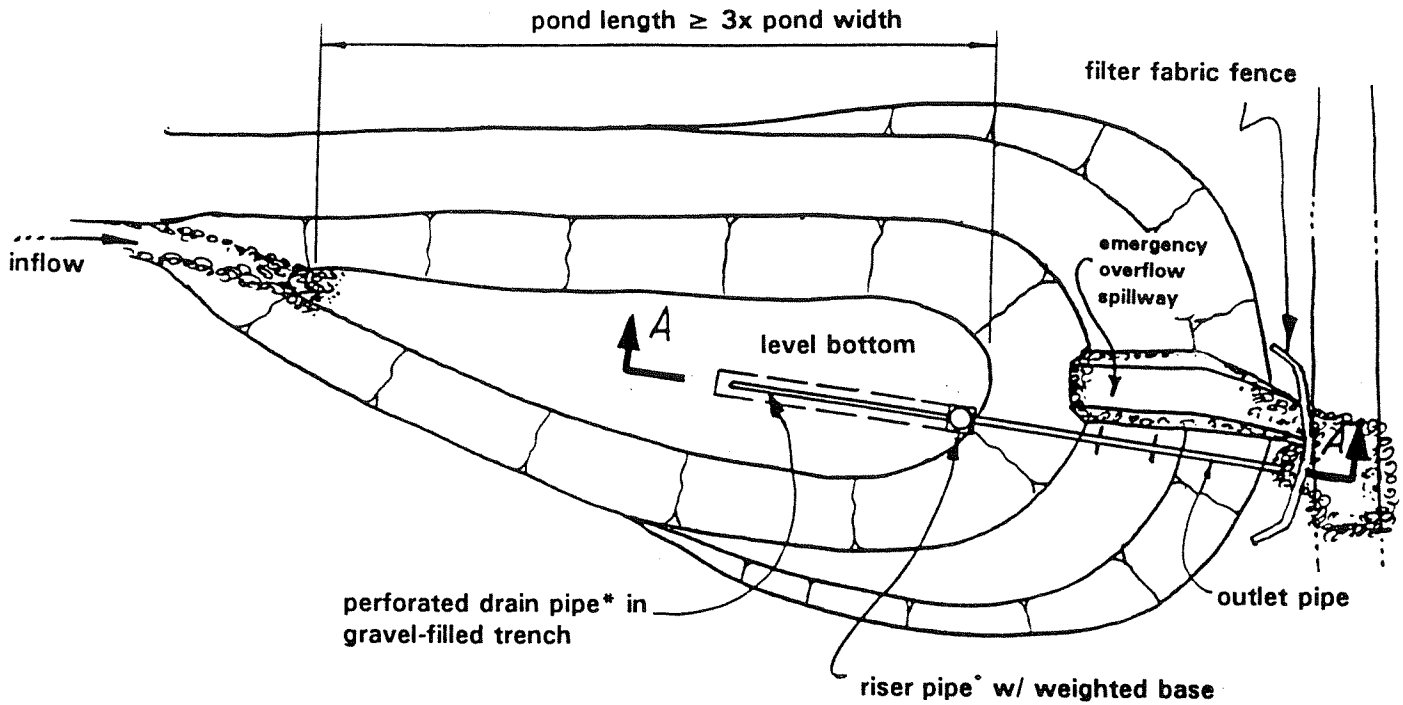
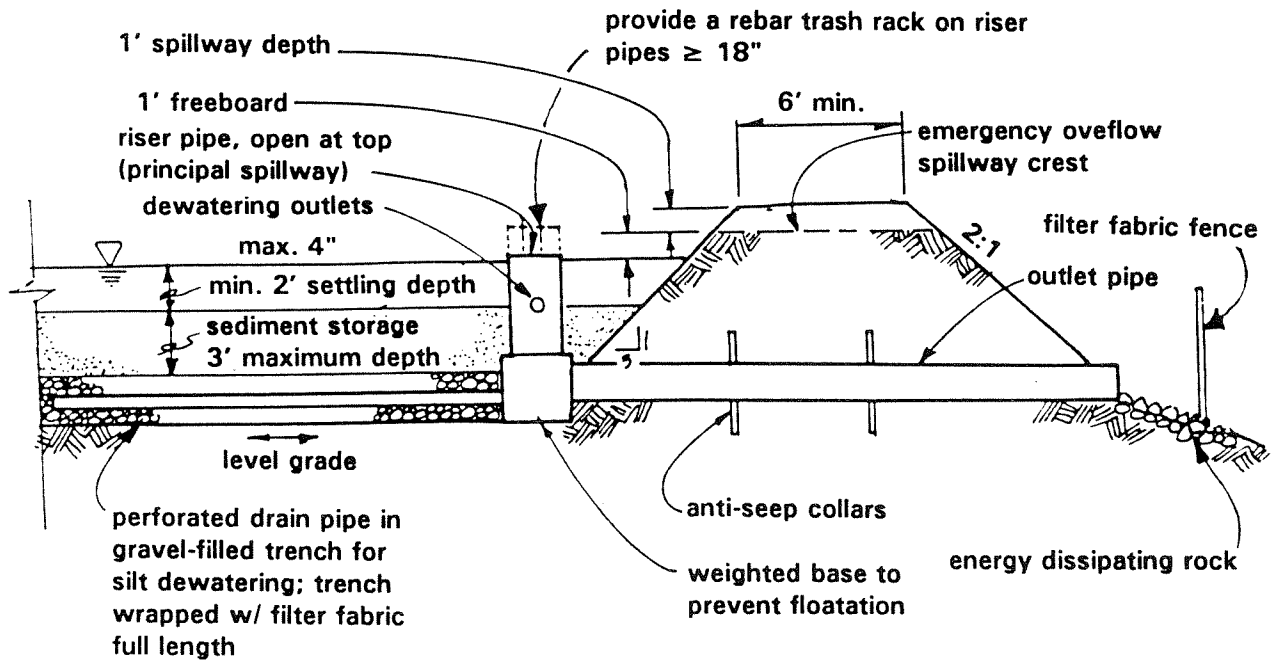


Figure II-5.30 Sediment Pond



\* Note: Sediment dewatering may be accomplished with perforated pipe in trench as shown or with a perforated riser pipe covered with filter fabric and a gravel "cone". A control structure may also be required; see Conditions Where Practice Applies



Section A-A



- 
- d. Adjust the geometry of the basin to effectively combine the settling zone volume and sediment storage volumes while preserving the depth and side slope criteria.

Provide baffles to prevent short-circuiting (see Figure II-5.30). A 6:1 aspect ratio between the basin length and width of the pond is desirable.

#### Maintenance

- Inspections should be made regularly, especially after large storm events. Sediment should be removed when it fills one half of the pond's total sediment storage area. The effectiveness of a sediment pond is based less on its size than on regular sediment removal.
- All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

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**II-5.9 EROSION AND SEDIMENT CONTROL ON INDIVIDUAL HOMESITES AND SMALL PARCELS****Background**

Construction of many small developments can cause large amounts of sediment to be transported to receiving waters. Many stormwater management professionals in the Puget Sound basin believe that construction of individual family residences and businesses on small parcels causes more than three-quarters of all erosion problems in the area.

The conclusion drawn by a Metro study of single family residential construction sites was that a minority of sites cause a majority of the problems. Only 26 percent of the sites had any BMPs in place and 10 percent of the total surveyed had water quality problems (mainly sedimentation). Fifteen of the 52 sites that had water quality problems were located within 50 feet of a water body (3).

The erosion-sedimentation process on smaller areas is similar to that on larger areas and is primarily influenced by four factors:

1. Climate - The frequency, intensity, and duration of precipitation influences the amount of runoff from a given area particularly when the ground surface is exposed or unprotected.
2. Soils - The texture, structure, and organic matter content (and thus the permeability and infiltration rate) of a soil largely determines its tendency to erode.
3. Topography - The size, shape, and slope characteristics (steepness, length, and profile) of a watershed or a small lot within the watershed influences the amount, duration, and intensity of runoff.
4. Vegetative Cover - The type, amount, and consistency of vegetation and ground litter are important in keeping erosion processes to a minimum. There are a number of characteristics of an effective vegetative cover:
  - a. Vegetative cover absorbs the energy of raindrops. Raindrops detach soil particles and destroy soil structure, and the splash of rain hitting the ground can transport soil particles. On an erodible soil, a very heavy rainfall may splash as much as 100 tong of soil per acre of exposed land and move each particle 4 to 5 feet (4).
  - b. Vegetative cover will reduce the volume and velocity of storm runoff. Vegetation absorbs water, and a thick mass of vegetation on the soil surface will also serve as a barrier to prevent high velocity surface runoff.
  - c. Roots aid in binding soil particles together giving the soil resistance to erosion.
  - d. Roots break up a heavy soil structure and increase its porosity. This increases the soils ability to absorb water. Undisturbed forest soils in the Pacific Northwest have only small amounts of surface runoff even during the largest storms.
  - e. Vegetation aids in removing surface and subsurface water through evapotranspiration. In a coniferous forest, evapotranspiration will release back to the air up to 40 percent of all precipitation over a years time.

The following are some of the damaging activities and conditions that may occur during development:

- Often, exposed and unprotected soil is left throughout the development. When runoff occurs, sediment is transported into the nearest stormwater facility or stream, eventually clogging it.
- Vehicles and heavy equipment track soil from the development onto the street. Gullies formed by tire tracks become channels for runoff flow.
- Vegetation bordering streams or lakes is often removed during construction. This increases the water temperature by removing shade. An increase in water temperature can contribute to algae blooms and may change the species composition of the lake or stream. Because the vegetation has been removed, there is no barrier to prevent sediment from entering the stream. This can clog spawning grounds and fishes' gills.

These problems may occur during work performed by subcontractors who are on-site for a very short time. Cooperation and communication between buyers (or developers), builders, and subcontractors are essential to minimize erosion and damage to the environment.

Some important design principles for controlling erosion and sedimentation in developing areas are as follows:

1. Plan the development to fit the particular topography, soils, waterways, and natural vegetation of a site.
  - a. Avoid wet areas. Wet areas can often be identified by the type of vegetation that grows there. Skunk cabbage, rushes, horsetail ferns, sedges, cattails, willows, and shrubby-looking stunted red alders may be found in moist or even saturated soil conditions. Check the area during the wet season, not in the middle of the summer.
  - b. Consider the effect of changes in topography. Wet areas are often found at the base of hills. Other wet areas are found along streams, in depressions where water can collect, and in natural drainageways.
  - c. Building on steep slopes without erosion BMPs can cause severe erosion problems because of uncontrolled, high velocity surface runoff.
2. Do not plan construction or other site disturbance activities during the rainy season.
3. Minimize the length and angles of graded slopes and fills.
4. Retain and/or properly manage runoff volume and velocity on areas subject to erosion. Divert runoff away from disturbed areas.
5. Save natural vegetation whenever possible to act as a buffer zone and help stabilize the soil.
6. Keep sediment on-site.
7. Stabilize disturbed areas immediately upon completion of earthmoving activities. Use temporary or permanent seeding, or mulches such as straw to provide immediate protection from erosion. The County Conservation District office or local Soil Conservation Service office can provide information on seeding mixtures and application rates.
8. Erosion and sediment control facilities must be maintained after they are installed. They must be inspected on a regular basis and repaired or replaced as necessary.

**II-5.10 BMPs FOR SMALL PARCELS**

A Small Parcel Stormwater Management Plan must be developed which satisfies the Small Parcel Minimum Requirements found in Volume II, Chapter II-2. These in turn may be satisfied by employing a suitable selection from the following list of BMPs.

**BMP ES.10 Planned Clearing and Grading.**

Plan and implement proper clearing and grading of the site. It is most important only to clear the areas needed, thus keeping exposed areas to a minimum. Phase clearing so that only those areas that are actively being worked are uncovered.

Note: Clearing limits should be flagged in the lot or area prior to initiating clearing.

**BMP ES.20 Excavated Basement Soil**

Locate excavated basement soil a reasonable distance behind the curb, such as in the backyard or side yard area. This will increase the distance eroded soil must travel to reach the storm sewer system. Soil piles should be covered until the soil is either used or removed. Piles should be situated so that sediment does not run into the street or adjoining yards.

**BMP ES.30 Backfilling**

Backfill basement walls as soon as possible and rough grade the lot. This will eliminate large soil mounds which are highly erodible and prepares the lot for temporary cover which will further reduce erosion potential.

**BMP ES.40 Removal of Excess Soil**

Remove excess soil from the site as soon as possible after backfilling. This will eliminate any sediment loss from surplus fill.

**BMP ES.50 Management of Soil Banks**

If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing a storage and settling area for stormwater.

**BMP ES.60 Construction Road Access**

Apply gravel or crushed rock to the driveway area and restrict truck traffic to this one route. Driveway paving can be installed directly over the gravel. This measure will eliminate soil from adhering to tires and stops soil from washing into the street. This measure requires periodic inspection and maintenance including washing, top-dressing with additional stone, reworking and compaction. (For further details see BMP E2.10, Chapter II-5.7.1).

**BMP ES.70 Soil Stabilization**

Stabilize denuded areas of the site by mulching, seeding, planting, or sodding. For further details on standards and specifications, see BMPs No. E1.10, E1.15, E1.35, E1.40 in Chapter II-5.

**BMP ES.80 Street Cleaning**

Provide for periodic street cleaning to remove any sediment that may have been tracked out. Sediment should be removed by shovelling or sweeping and carefully removed to a suitable disposal area where it will not be re-eroded.

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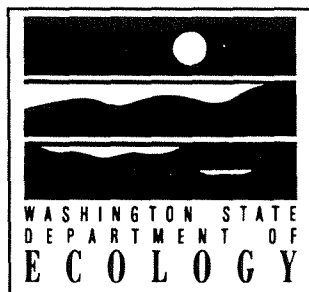


# **Stormwater Management Manual for the Puget Sound Basin**

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(The Technical Manual)

*Volume III - Runoff Control*



VOLUME III - RUNOFF CONTROL

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## Foreword

### Purpose of This Volume

The purpose of this volume of the stormwater manual is to provide technical assistance in the control of both stormwater runoff quality and quantity. Prior to the use of BMPs in this volume, Chapter I-2, "Minimum Requirements for All New Development and Redevelopment," Chapter I-3, "Preparation of Stormwater Site Plans," and Chapter I-4, "BMP Selection Process for Permanent Stormwater Quality Control Plans" should be read. These chapters provide an overview of the necessary requirements and the basis for the proper selection of BMPs to fit a particular site.

### Chapter Contents

Chapter III-1 reviews methods of hydrologic analysis, covers the use hydrograph methods for sites and provides an overview of various computerized modeling methods and analysis of closed depressions. The appendix at the end of the chapter by Bruce Barker et al. provides information on the latest efforts to produce a revised hydrologic analysis methods that will provide more accurate estimation of runoff for sites in western Washington. The appendix also includes a paper by Pat Powers of the Washington State Dept. of Fisheries which provides the rationale for a discharge rate of 50 percent of the preexisting 2-year, 24-hour design storm peak rate.

Chapter III-2 covers the design of conveyance systems including pipe systems, culverts, outfalls, open channels and floodplain/floodway analysis.

Chapter III-3 covers infiltration and filtration facilities. General limitations are listed to ensure that infiltration facilities are installed properly and to minimize ground water contamination. Infiltration basins, infiltration trenches, roof downspout systems, modular pavement, porous pavement, sand filtration basins, sand filtration trenches, and aquatards are covered.

Chapter III-4 covers detention facilities. Although infiltration systems are the preferred method for treatment of stormwater, detention systems are necessary in areas where infiltration is not possible. BMPs presented in this chapter include wet ponds, constructed wetlands, pre-settling basins, extended detention dry ponds, vaults and tanks.

Chapter III-5 provides information on natural and created wetlands. These wetlands are not considered to be BMPs but are to be managed to maintain their beneficial uses. While they serve a function in stormwater management they are not to be considered the primary facilities for providing runoff treatment or streambank erosion control. The role of natural wetlands in stormwater management is still open to question in many minds, but preliminary guidelines developed by Richard R. Horner, Coordinator of the Puget Sound Wetlands Research Committee, are provided for discussion purposes.

Chapter III-6 covers the design of biofiltration swales and vegetative filter strips.

Chapter III-7 covers oil/water separators, which have limited applications in controlling stormwater runoff.

Chapter III-8 covers stream stabilization BMPs. These BMPs are designed to correct existing streambank erosion problems by stabilizing eroding streambanks, preferably using vegetative techniques. These can augment BMPs which are designed to provide streambank erosion control using detention techniques.



## Acknowledgments

This volume of the manual was compiled by adapting from existing material and with the advice of a technical advisory group comprised of people representing local agencies and other interested parties within the Puget Sound basin. The major sources of material include:

- (i) King County Surface Water Management Manual, January, 1990
- (ii) Standards and Specifications for Infiltration Practices, Maryland Department of Natural Resources, February, 1984.
- (iii) Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Washington Council of Governments, prepared by Thomas R. Schueler, 1987.
- (iv) Guidelines for Constructing Wetland Stormwater Basins, Maryland Dept. of Natural Resources, March, 1987.

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Other sources that were used less extensively are referenced at the end of each section or chapter. Members of the technical advisory group include:

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Compilers and Editors

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## CHAPTER III-1

## HYDROLOGIC ANALYSIS

## III-1.1 INTRODUCTION

The broad definition of hydrology is "the science which studies the source, properties, distribution, and laws of water as it moves through its closed cycle on the earth (the hydrologic cycle)." As applied in this manual, however, the term "hydrologic analysis" addresses and quantifies only a small portion of this cycle. That portion is the relatively short-term movement of water over the land resulting directly from precipitation and called surface water or stormwater runoff. Localized and long-term ground water movement must also be of concern, but generally only as they affect or relate to the movement of water on or near the surface, such as stream base flow or infiltration systems.

The purpose of this chapter is to define the minimum computational standards required and also to outline how these may be applied, and to reference where more complete details may be found, should they be needed. The chapter also provides details on the hydrologic design process; that is what are the steps required in conducting a hydrologic analysis, including flow routing.

## III-1.2 DISCUSSION OF HYDROLOGIC ANALYSIS METHODS USED FOR DESIGNING BMPs

The use of SCS-based hydrologic models has limitations when designing streambank erosion control BMPs and efforts are underway to develop improved hydrologic analysis methods for the Puget Sound basin. Particularly promising is the Hydrologic Simulation Program Fortran (hereafter "HSPF"), a continuous simulation model as opposed to the single event SCS-type models. It is anticipated that HSPF will be available for use within the next year. In the interim, the use of SCS-based methods is recommended so long as appropriate correction factors are incorporated and design concerns are taken into account. This discussion will focus on the use of the Santa Barbara Urban Hydrograph method (hereafter "SBUH"). Note that the use of SCS-type models may continue to be acceptable for designing runoff treatment BMPs. Please note that to meet Minimum Requirement #3 Runoff Treatment, the 6-month, 24-hour water quality design storm must be treated.

Before utilizing the SBUH method, it is important to understand the different concerns for the runoff treatment storm as opposed to the streambank erosion control storms. The runoff treatment storm is the 6-month, 24-hour event and the major concern with using SBUH is the need to accurately model inflow hydrographs for infiltration, filtration, and detention-type BMPs. Recall that the 6-month, 24-hour storm volume is equal to 64 percent of the volume of the 2-year, 24-hour storm event. No correction factor to the BMP volume is necessary for the runoff treatment storm. The situation with the streambank erosion control storms (i.e., the 2, 10, and 100-year events) is quite different. For these events, BMPs are sized based on a comparison of the *existing condition* hydrograph with the *developed condition* hydrograph (for runoff treatment only the *developed condition* is modeled). There are two primary concerns with the use of SBUH when designing streambank erosion control BMPs. The first is how it estimates peak flow rates for pervious areas. The second concern is the use of a 24-hour duration storm, which is too short a duration in the Puget Sound basin for larger storms.

A summary of the concerns with SBUH is in order. While SBUH gives acceptable estimates of total runoff volumes, it tends to overestimate peak flow rates from pervious areas because it cannot adequately model subsurface flow (which is a dominant flow regime for pre-development conditions in the Puget Sound basin). One

reason SBUH overestimates the peak flow rate for pervious areas is because the actual time of concentration is typically greater than what is assumed. Better flow estimates could be made if a longer time of concentration was used. This would change both the peak flow rate (i.e., it would be lower) and the shape of the hydrograph (i.e., peak occurs somewhat later) such that the hydrograph would better reflect actual conditions. Note that it is not necessary to make corrections to the curve number ("CN") for modeling runoff from pervious areas when using SBUH.

The other major weakness of the current use of SBUH is that it is used to model a 24-hour storm event, which is too short to model larger storms in the Puget Sound basin. The use of a 7-day storm is a more correct choice for Puget Sound, in conjunction with the use of a continuous simulation model, such as HSPF. The SBUH model may not be adequate for modeling 7-day events and it is anticipated that it will be eventually replaced by the HSPF model. Note that the use of the 7-day duration storm will apply only to streambank erosion control BMPs and not to runoff treatment BMPs, as the 24-hour duration event is the correct one for runoff treatment purposes.

When designing a runoff treatment BMP, the primary concern with using SBUH is modeling of the inflow hydrograph to the BMP. SBUH tends to underestimate the time of concentration, thus the peak flow rate occurs too early. This can create problems for detention-type BMPs, such as pre-settling basins and dry vaults, because these BMPs are designed to achieve a 24-hour residence time. Calculation of the residence time is sensitive to the shape of the inflow hydrograph. The inflow hydrograph is also of fundamental importance when designing an infiltration or filtration BMP as these BMPs are sized based on a routing of the inflow hydrograph through the BMP. The best solution at this time is to try to account for subsurface flow when estimating the time of concentration. For sites with low impervious cover, this will increase the time of concentration, thus reducing the peak flow rate and shifting the peak rate to a somewhat later time. Note that for BMPs which maintain "permanent pools" (e.g., wet ponds) then none of the above concerns apply since the permanent pool volume is adequately predicted by SBUH.

When designing streambank erosion control BMPs, it will be necessary to apply a correction factor to the design volume of the BMP when using SBUH to model 24-hour storm events. Ecology currently recommends that correction factors of 20 percent and 50 percent apply to residential sites and commercial sites, respectively. Figure III-1.1 is provided which graphically illustrates the correction factor based on site impervious cover. This correction factor is to be applied to the volume of the BMP without changing its depth or the design of the outlet structure, thus an increase in surface area will result.

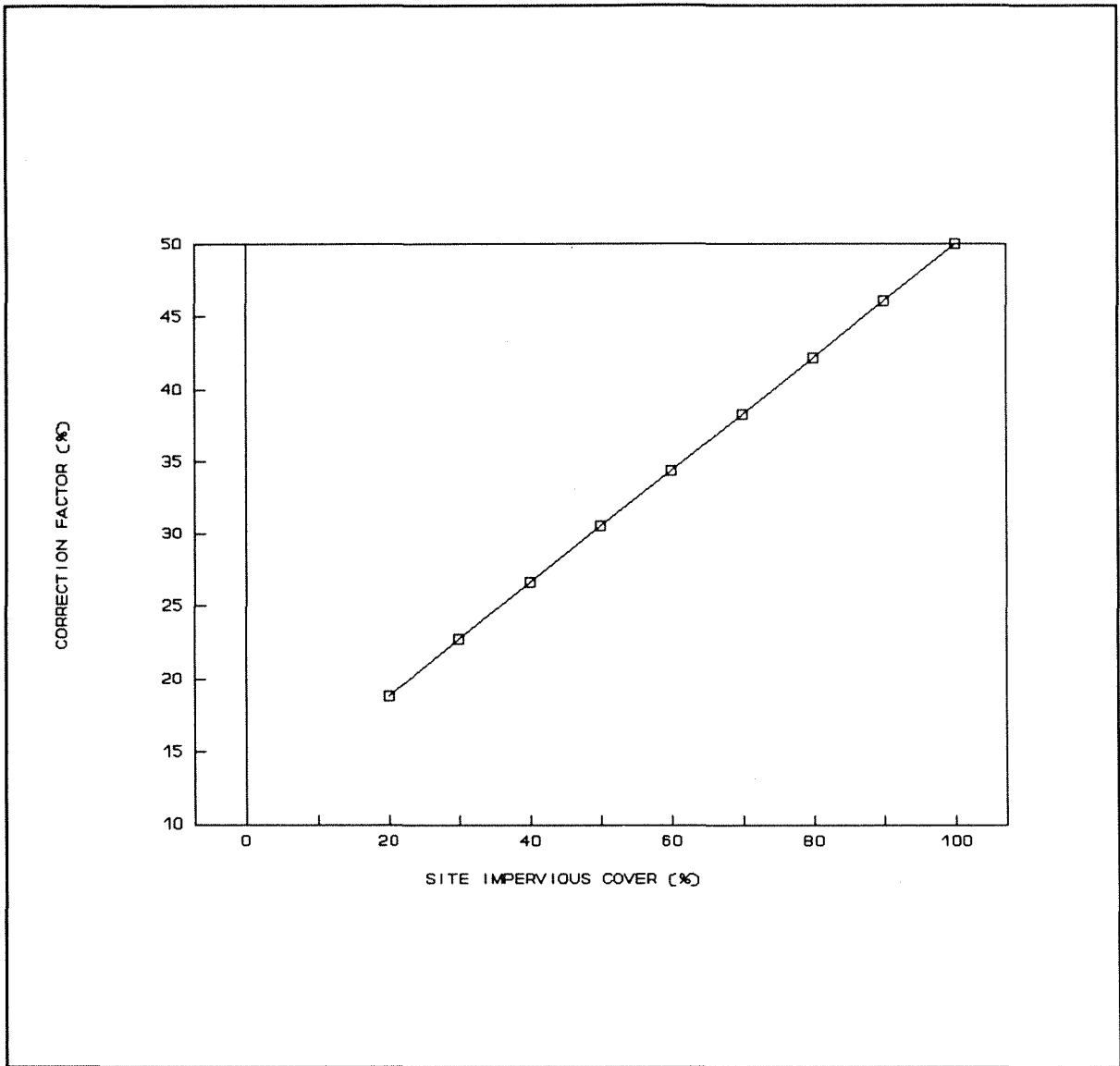
Appendix AIII-1.2 discusses this issue further. Also included in another appendix are the isopluvial maps for the 2, 10, and 100-year, 24-hour storm events.

### III-1.3 MINIMUM COMPUTATIONAL STANDARDS

The minimum computational standards required depend on the type of information required and the size of the drainage area to be analyzed, as follows:

1. For all computations, except for basin plans or equivalent, the minimum standard shall be the Soil Conservation Service Unit Hydrograph (SCSUH) method (1) with the level pool routing method, or equivalent hydrograph techniques, subject to approval of the local government. The Santa Barbara Urban Hydrograph (SBUH) method is also an acceptable method.
2. If a basin plan is being prepared, then the hydrologic analysis shall be performed using a continuous simulation model such as EPA's Hydrological Simulation Program - Fortran (HSPF) model (2), or EPA's Stormwater Model (SWM) (3), or equivalent, as approved by the local government.

FIGURE III-1.1  
Volume Correction Factor to be Applied to  
Streambank Erosion Control BMPs  
Based on Site Impervious Cover



Significant progress has been made by the United States Geological Survey (in cooperation with the counties of King, Snohomish, Pierce, and Thurston, and METRO) with the development of a local version of the HSPF model. This work has involved development of "runoff files" for various land types defined by vegetation, slope, and soil type (3). These runoff files will describe runoff characteristics of simulated runoff from a watershed with measured runoff. As a result, one will be able to simulate runoff from any other ungauged basin where only the distribution of land types is known. The model will be able to be applied on individual development sites of less than about 200 acres. This work is expected to be completed within the next year through a grant with the Center for Urban Water Resources Management at the University of Washington.

A continuous simulation model has a considerable advantage over the SCS and Rational Methods (and similar methods) that are single event-based. The single event model cannot take into account storm events that may occur just before or just after the single event (the design storm) that is under consideration. In addition, the runoff files generated for the HSPF model are the result of a considerable effort to introduce local parameters into the model and are therefore believed to result in better estimation of runoff than the SCS or Rational methods.

On the other hand, the HSPF model is relatively complex to use and is best suited for large scale applications such as basin plans or master drainage plans (see below).

#### III-1.4 HYDROGRAPH METHOD

Hydrograph analysis utilizes the standard plot of runoff flow versus time for a given design storm, thereby allowing the key characteristics of runoff such as peak, volume, and phasing to be considered in the design of drainage facilities.

The physical characteristics of the site and the design storm determine the magnitude, volume, and duration of the runoff hydrograph. Other factors such as the conveyance characteristics of channel or pipe, merging tributary flows, branching of channels, and flooding of lowlands can alter the shape and magnitude of the hydrograph. In the following sections, the key elements of hydrograph analysis are presented, namely:

- Design storm hyetograph
- Runoff parameters
- Hydrograph synthesis
- Hydrograph routing
- Hydrograph summation and phasing
- Computer applications

##### III-1.4.1 Design Storm Hyetograph

All storm event hydrograph methods require the input of a rainfall distribution or design storm hyetograph. The design storm hyetograph is essentially a plot of rainfall depth versus time for a given design storm frequency and duration. It is usually presented as a dimensionless plot of unit rainfall depth (increment rainfall depth for each time interval divided by the total rainfall depth) versus time.

The hyetograph provided in this section is to be used for all hydrograph analysis. See Figure III-1.2 and Table III-1.1. The hyetograph is the standard SCS Type 1A

rainfall distribution resolved to 10-minute time intervals for greater sensitivity in computing peak rates of runoff in urbanizing basins. The hyetograph was interpolated by Surface Water Management Division staff from King County from the SCS mass distribution and may differ slightly from the distribution used in other SCS-based computer models, particularly those which are not resolved to 10-minute time intervals.

The design storm hyetograph is constructed by multiplying the dimensionless hyetograph times the rainfall depth (in inches) for the design storm.

The total depth of rainfall (in tenths of an inch) for storms of 24-hour duration and 2, 5, 10, 25, 50, and 100-year recurrence intervals are published by the National Oceanic and Atmospheric Administration (NOAA). The information is presented in the form of "isopluvial" maps for each state. Isopluvial maps are maps where the contours represent total inches of rainfall for a specific duration. Isopluvial maps for the Puget Sound basin for the 2, 5, 10, 25, 50, and 100-year recurrence interval and 24-hour duration storm events can be found in the NOAA Atlas 2, "Precipitation - Frequency Atlas of the Western United States, Volume IX-Washington. Appendix III-Z-A provides the isopluvials for the 2, 10, and 100-year, 24-hour design storms for the Puget Sound basin.

For project sites with tributary drainage areas above elevation 1000 MSL, an additional total precipitation must be added to the total depth of rainfall, for the 25, 50, and 100-year design storm events, to account for the potential average snowmelt which occurs during major storm events.

This  $M_s$  factor is computed as follows:

$$M_s \text{ (in inches)} = 0.004 (MB_{ei} - 1000);$$

where:

$MB_{ei}$  = the mean tributary basin elevation above sea level (in feet).

Example:

Given: Project location: East of North Bend near 1-90.  $MB_{ei} = 1837$  feet.

Design Storm Event: 25-year (for culvert sizing);  $P_{25} = 7$  inches

$$\begin{aligned} \text{Compute: } M_s &= 0.004 (MB_{ei} - 1000) = (0.004) (1837 - 1000) \\ &= \underline{3.35 \text{ inches}} \end{aligned}$$

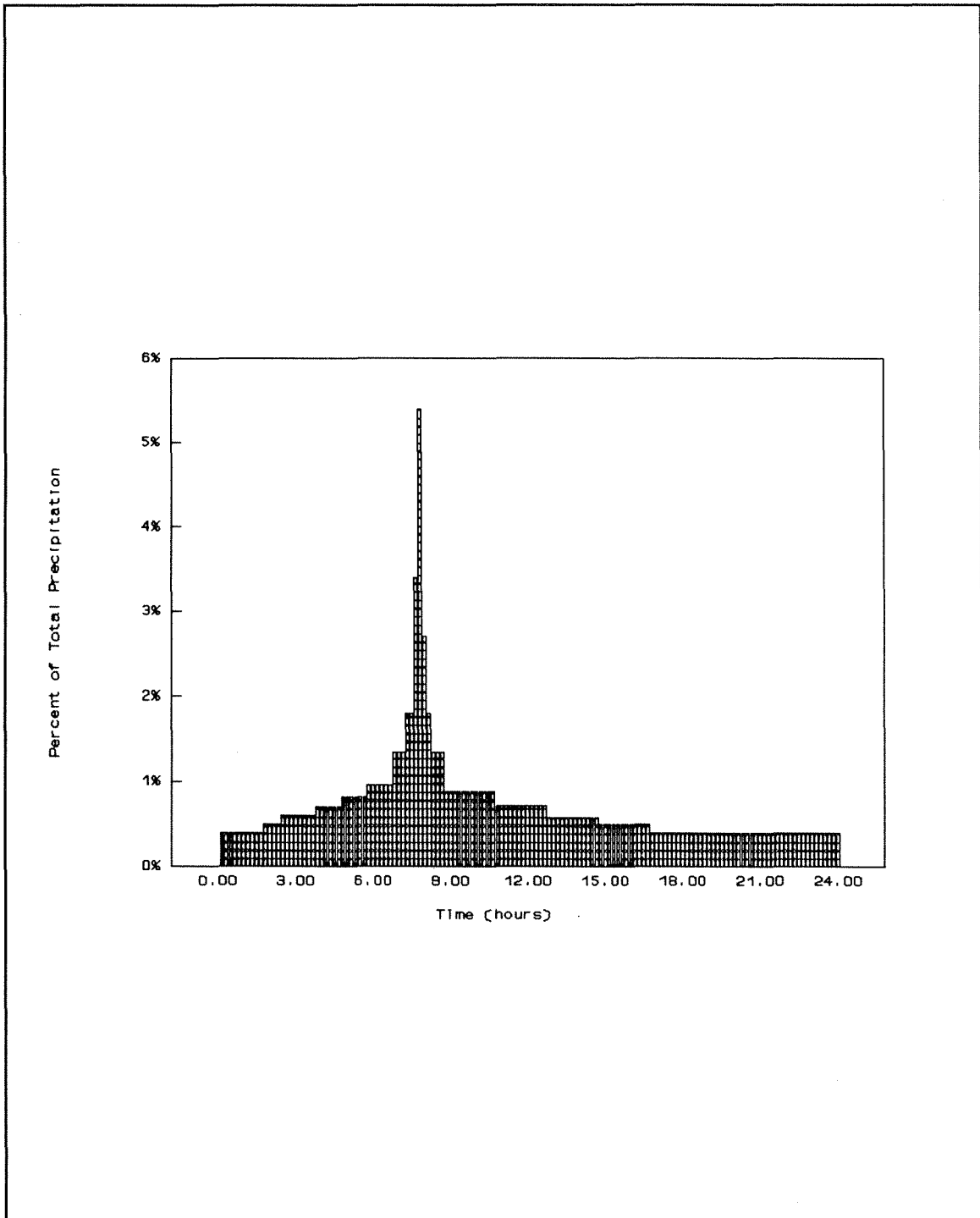
$$\begin{aligned} \text{Adjusted } P_{25} &= P_{25} + M_s \\ &= (7 \text{ inches}) + (3.35 \text{ inches}) \\ &= \underline{10.35 \text{ inches}} \end{aligned}$$



Table III-1.1 24-hour Design Storm Hyetograph Values

TIME FROM BEGINNING OF STORM	PERCENT RAINFALL	CUMUL. PERCENT RAINFALL	TIME FROM BEGINNING OF STORM	PERCENT RAINFALL	CUMUL. PERCENT RAINFALL	TIME FROM BEGINNING OF STORM	PERCENT RAINFALL	CUMUL. PERCENT RAINFALL
0	0.00	0.00	490	1.80	46.34	980	0.50	81.40
10	0.40	0.40	500	1.34	47.68	990	0.50	81.90
20	0.40	0.80	510	1.34	49.02	1000	0.50	82.40
30	0.40	1.20	520	1.34	50.36	1010	0.40	82.80
40	0.40	1.60	530	0.88	51.24	1020	0.40	83.20
50	0.40	2.00	540	0.88	52.12	1030	0.40	83.60
60	0.40	2.40	550	0.88	53.00	1040	0.40	84.00
70	0.40	2.80	560	0.88	53.88	1050	0.40	84.40
80	0.40	3.20	570	0.88	54.76	1060	0.40	84.80
90	0.40	3.60	580	0.88	55.64	1070	0.40	85.20
100	0.40	4.00	590	0.88	56.52	1080	0.40	85.60
110	0.50	4.50	600	0.88	57.40	1090	0.40	86.00
120	0.50	5.00	610	0.88	58.28	1100	0.40	86.40
130	0.50	5.50	620	0.88	59.16	1110	0.40	86.80
140	0.50	6.00	630	0.88	60.04	1120	0.40	87.20
150	0.50	6.50	640	0.88	60.92	1130	0.40	87.60
160	0.50	7.00	650	0.72	61.64	1140	0.40	88.00
170	0.60	7.60	660	0.72	62.36	1150	0.40	88.40
180	0.60	8.20	670	0.72	63.08	1160	0.40	88.80
190	0.60	8.80	680	0.72	63.80	1170	0.40	89.20
200	0.60	9.40	690	0.72	64.52	1180	0.40	89.60
210	0.60	10.00	700	0.72	65.24	1190	0.40	90.00
220	0.60	10.60	710	0.72	65.96	1200	0.40	90.40
230	0.70	11.30	720	0.72	66.68	1210	0.40	90.80
240	0.70	12.00	730	0.72	67.40	1220	0.40	91.20
250	0.70	12.70	740	0.72	68.12	1230	0.40	91.60
260	0.70	13.40	750	0.72	68.84	1240	0.40	92.00
270	0.70	14.10	760	0.72	69.56	1250	0.40	92.40
280	0.70	14.80	770	0.57	70.13	1260	0.40	92.80
290	0.82	15.62	780	0.57	70.70	1270	0.40	93.20
300	0.82	16.44	790	0.57	71.27	1280	0.40	93.60
310	0.82	17.26	800	0.57	71.84	1290	0.40	94.00
320	0.82	18.08	810	0.57	72.41	1300	0.40	94.40
330	0.82	18.90	820	0.57	72.98	1310	0.40	94.80
340	0.82	19.72	830	0.57	73.55	1320	0.40	95.20
350	0.95	20.67	840	0.57	74.12	1330	0.40	95.60
360	0.95	21.62	850	0.57	74.69	1340	0.40	96.00
370	0.95	22.57	860	0.57	75.26	1350	0.40	96.40
380	0.95	23.52	870	0.57	75.83	1360	0.40	96.80
390	0.95	24.47	880	0.57	76.40	1370	0.40	97.20
400	0.95	25.42	890	0.50	76.90	1380	0.40	97.60
410	1.34	26.76	900	0.50	77.40	1390	0.40	98.00
420	1.34	28.10	910	0.50	77.90	1400	0.40	98.40
430	1.34	29.44	920	0.50	78.40	1410	0.40	98.80
440	1.80	31.24	930	0.50	78.90	1420	0.40	99.20
450	1.80	33.04	940	0.50	79.40	1430	0.40	99.60
460	3.40	36.44	950	0.50	79.90	1440	0.40	100.00
470	5.40	41.84	960	0.50	80.40			
480	2.70	44.54	970	0.50	80.90			

Figure III-1.2  
24-hour Design Storm Hyetograph for  
Type 1A Rainfall Distribution



### III-1.4.2 Runoff Parameters

All storm event hydrograph methods require input of parameters which describe physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed. This section describes the 3 key parameters (area, curve number, and time of concentration) used to develop the hydrograph using the method of hydrograph synthesis discussed in Sec. III-1.4.3.

#### Area

The proper selection of homogeneous basin areas is required to obtain the highest degree of accuracy in hydrograph analysis. Significant differences in land use within a given drainage basin must be addressed by dividing the basin area into subbasin areas of similar land use and/or runoff characteristics. For example, a drainage basin consisting of a concentrated residential area and a large forested area should be divided into two subbasin areas accordingly. Hydrographs should then be computed for each subbasin area and summed to form the total runoff hydrograph for the basin.

To further enhance the accuracy of hydrograph analysis, all pervious and impervious areas within a given basin or subbasin shall be analyzed separately. This may be done by either computing separate hydrographs for each area and combining them to form the total runoff hydrograph or by computing the precipitation excess for each area and combining the two to obtain the total precipitation excess, which is then used to develop the runoff hydrograph. This procedure is explained further in Section III-1.4.3 "Hydrograph Synthesis". By analyzing pervious and impervious areas separately the errors associated with averaging these areas are avoided and the true shape of the runoff hydrograph is better approximated.

#### Curve Number

The Soil Conservation Service (SCS), has for many years, conducted studies into the runoff characteristics of various land types. After gathering and analyzing extensive data, SCS has developed relationships between land use, soil type, vegetation cover, interception, infiltration, surface storage, and runoff. The relationships have been characterized by a single runoff coefficient called a "curve number." The National Engineering Handbook - Section 4: Hydrology (NEH-4, SCS, August 1972) contains a detailed description of the development and use of the curve number method.

SCS has developed "curve number" (CN) values based on soil type and land use. The combination of these two factors is called the "soil-cover complex." The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics. SCS has classified over 4,000 soil types into these four soil groups. Table III-1.2 shows the hydrologic soil group of most soils in the Puget Sound basin and provides a brief description of the four groups.

Table III-1.3 shows the CNs, by land use description, for the four hydrologic soil groups. These numbers are for a 24-hour duration storm and typical antecedent soil moisture condition preceding 24-hour storms in Western Washington. Note these CNs are not, therefore, "average," but rather calibrated by the SCS for Western Washington and should not be used with "wet" or "dry" modifications. Modeling performed to calibrate to actual rainfall and/or runoff data should start with the original SCS CNs published in TR-55. (5)

The following are important criteria/considerations for selection of CN values:

1. Many factors may affect the CN value for a given land use. For example, the movement of heavy equipment over bare ground may compact the soil so that it has a lesser infiltration rate and greater runoff potential than would be indicated by strict application of the CN value based on pre-development conditions at the site.

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Table III-1.6 Hydrologic Soil Groups for Soils in the Puget Sound Basin

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Agnew	C	Colter	C
Ahl	B	Custer	ND
Aits	C	Dabob	ND
Alderwood	C	Delphi	D
Arents, Alderwood	B	Dick	ND
Arents, Everett	B	Dimal	D
Ashoe	B	Dupont	D
Baldhill	B	Earlmont	C
Barneston	C	Edgewick	C
Baumgard	B	Eld	B
Beausite	B	Elwell	B
Belfast	C	Esquatzel	B
Bellingham	D	Everett	A
Bellingham variant	C	Everson	D
Boistfort	B	Galvin	D
Bow	D	Getchell	A
Briscot	D	Giles	B
Buckley	C	Godfrey	D
Bunker	B	Greenwater	A
Cagey	C	Grove	C
Carlsborg	ND	Harstine	C
Casey	ND	Hartnit	ND
Cassolary	C	Hoh	ND
Cathcart	B	Hoko	ND
Centralia	B	Hoodsport	ND
Chehalis	B	Hoogdal	C
Chesaw	A	Hoypus	ND
Cinebar	B	Huel	ND
Clallam	C	Indianola	ND
Clayton	B	Jonas	B
Coastal beaches	variable	Jumpe	ND
Kapowsin	C/D	Kalaloch	C
Katula	C	Renton	D
Kilchis	C	Republic	B
Kitsap	C	Riverwash	variable
Klaus	ND	Rober	C
Klone	ND	Salal	C
Lates	C	Salkum	B
Lebam	B	Sammamish	D
Lummi	ND	San Juan	ND
Lynnwood	ND	Scamman	D
Lystair	ND	Schneider	B
Mal	C	Seattle	D
Manley	B	Sekiu	ND
Mashel	B	Semiahmoo	D
Maytown	C	Shalcar	D
McKenna	D	Shano	B
McMurray	ND	Shelton	C
Melbourne	B	Si	C
Menzel	ND	Sinclair	C
Mixed Alluvial	variable	Skipopa	D
Molson	B	Skykomish	B
Mukilteo	C/D	Snahopish	ND
Naff	B	Snohomish	D
Nargar	A	Solduc	B
National	ND	Solleks	ND
Neilton	A	Spana	D

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Newberg	B	Spanaway	A/B
Nisqually	B	Springdale	B
Nooksack	C	Sulsavar	B
Norma	C/D	Sultan	C
Ogarty	C	Sultan variant	B
Olete	ND	Sumas	C
Olomount	C	Swantown	ND
Olympic	B	Tacoma	D
Orcas	D	Tanwax	ND
Oridia	D	Tealwhit	ND
Orting	ND	Tenino	C
Oso	C	Tisch	D
Ovall	C	Tokul	ND
Pastik	C	Townsend	C
Pheeney	C	Triton	ND
Phelan	ND	Tukwila	D
Pilchuck	C	Tukey	ND
Potchub	C	Urban	variable
Poulsbo	C	Vailton	B
Prather	C	Verlot	C
Puget	D	Wapato	ND
Puyallup	B	Warden	B
Queets	ND	Whidbey	ND
Quilcene	ND	Wilkeson	B
Ragnar	B	Winston	A
Rainier	C	Woodinville	B
Raught	B	Yelm	C
Reed	ND	Zynbar	B

Hydrologic Soil Group Classifications

- A. (Low runoff potential). Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-to-excessively drained sands or gravels. These soils have a high rate of water transmission.
  - B. (Moderately low runoff potential). Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
  - C. (Moderately high runoff potential). Soils having slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
  - D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.
- ND Data not currently available for this soil type.

\*From SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form #5, September 1988 and various county soil surveys.

2. CN values can be area weighted when they apply to pervious areas of similar CNs (within 20 CN points). However, high CN areas should not be combined with low CN areas. In this case, separate hydrographs should be generated and summed to form one hydrograph unless the low CN areas are less than 15 percent of the subbasin.
3. Separate CN values must be selected for the pervious and impervious areas of an urban basin or subbasin. For single family residential areas the percent impervious given in Table III-1.3 shall be used to compute the respective pervious and impervious areas. For proposed commercial areas, PUDs etc., the percent impervious must be computed from the site plan. For all other land uses the percent impervious must be estimated from best available aerial topography and/or field reconnaissance. The pervious area CN value shall be a weighted average of all the pervious area CNs within the subbasin. The impervious area CN value shall be 98.
4. For storm duration other than 24 hours, an adjustment must be made to the CN values given in Table III-1.3. Based on information obtained from SCS, the following equation shall be used for adjusting these CNs for the seven-day design storm:

$$CN (7 \text{ day}) = 0.1549 CN + 0.8451 ((CN^{2.365} / 631.8) + 15)$$

Example: The following is an example of how CN values are selected for a sample project.

Select CNs for the following development:

Existing Land Use - forest (undisturbed)  
 Future Land Use - residential plat (3.6 DU/GA)  
 Basin Size - 10 acres  
 Soil Type - 80% Alderwood, 20% Ragnor

Table III-1.2 shows that Alderwood soil belongs to the "C" hydrologic soil group and Ragnor soil belongs to the "B" group. Therefore, for the existing condition, CNs of 76 and 64 are read from Table III-1.3 and areal weighted to obtain a CN value of 74. For the developed condition with 3.6 DU/GA the percent impervious of 39 percent is interpolated from Table III-1.3 and used to compute pervious and impervious areas of 6.1 acres and 3.9 acres, respectively. The 6.1 acres of pervious area consists of residential yards and lawns covering the same proportions of Alderwood and Everett soil (80 percent and 20 percent respectively). Therefore, CNs of 90 and 85 are read from Table III-1.3 and areal weighted to obtain a pervious area CN value of 89. The impervious area CN value is 98. The result of this example is summarized below:

<u>On-Site Condition</u>	<u>Existing</u>	<u>Developed</u>
Land use	Forest	Residential
Pervious area	10 ac.	6.1 ac.
CN of pervious area	74	89
Impervious area	0 ac.	3.9 ac.
CN of impervious area	---	98

#### SCS Curve Number Equations

The rainfall-runoff equations of the SCS curve number method relates a land area's runoff depth (precipitation excess) to the precipitation it receives and to its natural storage capacity, as follows:

Table III-1.3 SCS Western Washington Runoff Curve Numbers  
 (Published by SCS in 1982) Runoff curve numbers for selected agricultural, suburban and urban land use for Type 1A rainfall distribution, 24-hour storm duration.

LAND USE DESCRIPTION		CURVE NUMBERS BY HYDROLOGIC SOIL GROUP			
		A	B	C	D
Cultivated land(1):	winter condition	86	91	94	95
Mountain open areas:	low growing brush & grasslands	74	82	89	92
Meadow or pasture:		65	78	85	89
Wood or forest land:	undisturbed	42	64	76	81
Wood or forest land:	young second growth or brush	55	72	81	86
Orchard:	with cover crop	81	88	92	94
Open spaces, lawns, parks, golf courses, cemeteries, landscaping.					
Good condition:	grass cover on $\geq 75\%$ of the area	68	80	86	90
Fair condition:	grass cover on 50-75% of the area	77	85	90	92
Gravel roads & parking lots:		76	85	89	91
Dirt roads & parking lots:		72	82	87	89
Impervious surfaces, pavement, roofs etc.		98	98	98	98
Open water bodies:	lakes, wetlands, ponds etc.	100	100	100	100
Single family residential(2):					
Dwelling Unit/Gross Acre	%Impervious(3)	Separate curve number shall be selected for pervious & impervious portions of the site or basin			
1.0 DU/GA	15				
1.5 DU/GA	20				
2.0 DU/GA	25				
2.5 DU/GA	30				
3.0 DU/GA	34				
3.5 DU/GA	38				
4.0 DU/GA	42				
4.5 DU/GA	46				
5.0 DU/GA	48				
5.5 DU/GA	50				
6.0 DU/GA	52				
6.5 DU/GA	54				
7.0 DU/GA	56				
PUD's, condos, apartments, commercial businesses & industrial areas	%impervious must be computed				

- (1) For a more detailed description of agricultural land use curve numbers refer to National Engineering Handbook, Sec. 4, Hydrology, Chapter 9, August 1972.
- (2) Assumes roof and driveway runoff is directed into street/storm system.
- (3) The remaining pervious areas (lawn) are considered to be in good condition for these curve numbers.

$$\begin{aligned} \text{and } Q_d &= (P_R - 0.2S)^2 / (P_R + 0.8S) && \text{for } P_R \geq 0.2S \\ Q_d &= 0 && \text{for } P_R < 0.2S \end{aligned}$$

where:

- $Q_d$  = runoff depth in inches over the area,
- $P_R$  = precipitation depth in inches over the area, and
- $S$  = potential maximum natural detention, in inches over the area, due to infiltration, storage, etc.

The area's potential maximum detention,  $S$ , is related to its curve number, CN:

$$S = (1000 / CN) - 10$$

The combination of the above equations allows for estimation of the total runoff volume by computing total runoff depth,  $Q_d$ , given the total precipitation depth,  $P_R$ . For example, if the curve number of the area is 70, then the value of  $S$  is 4.29. With a total precipitation for the design event of 2.0 inches, the total runoff depth would be:

$$Q_d = [2.0 - 0.2 (4.29)]^2 / [2.0 + 0.8 (4.29)] = \underline{0.24 \text{ inches}}$$

This computed runoff represents inches over the tributary area. Therefore, the total volume of runoff is found by multiplying  $Q_d$  by the area (with necessary conversions):

$$\begin{aligned} \text{Total runoff} & & & \\ \text{Volume} & = & 3,630 & \times & Q_d & \times & A \\ \text{(cu. ft.)} & & \text{(cu. ft./ac. in.)} & & \text{(in)} & & \text{(ac)} \end{aligned}$$

If the area is 10 acres, the total runoff volume is:

$$3,630 \text{ cu. ft./ac. in.} \times 0.24 \text{ in.} \times 10 \text{ ac.} = \underline{8,712 \text{ cu. ft.}}$$

When developing the runoff hydrograph, the above equation for  $Q_d$  is used to compute the incremental runoff depth for each time interval from the incremental precipitation depth given by the design storm hyetograph. This time distribution of runoff depth is often referred to as the precipitation excess and provides the basis for synthesizing the runoff hydrograph.

Travel Time and Time of Concentration for Use in Hydrograph Analysis (based on the methods described in Chapter 3, SCS TR-55(5))

Travel time ( $T_t$ ) is the time it takes water to travel from one location to another in a watershed.  $T_t$  is a component of time of concentration ( $T_c$ ), which is the time it takes for runoff to travel from the hydraulically most distant point of the watershed.  $T_c$  is computed by summing all the travel times for consecutive components of the drainage conveyance system.  $T_c$  influences the shape and peak of the runoff hydrograph. Urbanization usually decreases  $T_c$ , thereby increasing peak discharge.  $T_c$  can be increased as a result of either ponding behind small or inadequate drainage systems (including storm drain inlets and road culverts) or by reduction of land slope through grading.

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow or some combination of these. The type of flow that occurs is best determined by field inspection.

Travel time ( $T_t$ ) is the ratio of flow length to flow velocity:

$$T_t = \frac{L}{60V}$$



where:

- $T_t$  = travel time (minutes)
- $L$  = flow length (feet)
- $V$  = average velocity (feet/sec) and
- 60 = conversion factor from seconds to minutes

Time of concentration ( $T_c$ ) is the sum of  $T_t$  values for the various consecutive flow segments.

$$T_c = T_{t_1} + T_{t_2} + \dots + T_{t_m}$$

where:

- $T_c$  = time of concentration (minutes) and
- $m$  = number of flow segments

Sheet Flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value ( $n_s$ ) (a modified Manning's effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges and rocks; and erosion and transportation of sediment) is used. These  $n_s$  values are for very shallow flow depths of about 0.1 foot and are only used for travel lengths up to 300 feet. Table III-1.4 gives Manning's  $n_s$  values for sheet flow for various surface conditions.

For sheet flow of up to 300 feet, use Manning's kinematic solution to directly compute  $T_t$ .

$$T_t = \frac{0.42 (n_s L)^{0.8}}{(P_2)^{0.527} (s_0)^{0.4}}$$

where:

- $T_t$  = travel time (min),
- $n_s$  = sheet flow Manning's effective roughness coefficient (from Table III-1.4).
- $L$  = flow length (ft),
- $P_2$  = 2-year, 24-hour rainfall (in), and
- $s_0$  = slope of hydraulic grade line (land slope, ft/ft)

Velocity Equation

A commonly used method of computing average velocity of flow, once it has measurable depth, is the following equation:

$$V = k \sqrt{s_0}$$

where:

- $V$  = velocity (ft/s)
- $k$  = time of concentration velocity factor (ft/s)
- $s_0$  = slope of flow path (ft/ft)

"k" is computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = (1.49 (R)^{0.667}) / n$$

where:

- $R$  = an assumed hydraulic radius
- $n$  = Manning's roughness coefficient for open channel flow

**Shallow Concentrated Flow:** After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. The average velocity for this flow can be calculated using the  $k_s$  values from Table III-1.4 in which average velocity is a function of watercourse slope and type of channel. After computing the average velocity using the Velocity Equation above, the travel time ( $T_t$ ) for the shallow concentrated flow segment can be computed using the Travel Time Equation described above.

**Open Channel Flow:** Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on United States Geological Survey (USGS) quadrangle sheets. The  $k_c$  values from Table III-1.4 used in the Velocity Equation above or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull conditions. After average velocity is computed the travel time ( $T_t$ ) for the channel segment can be computed using the Travel Time Equation above.

**Lakes or Wetlands:** Sometimes it is necessary to estimate the velocity of flow through a lake or wetland at the outlet of a watershed. This travel time is normally very small and can be assumed as zero. Where significant attenuation may occur due to storage effects, the flows should be routed using the "level pool routing" technique described in Section III-1.4.4.

**Limitations:** The following limitations apply in estimating travel time ( $T_t$ ).

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet.
- In watersheds with storm drains, carefully identify the appropriate hydraulic flow path to estimate  $T_c$ . Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. A hydrograph should be developed to this point and the "level pool routing" technique described in Section III-1.4.4 should be used to determine the outflow rating curve through the culvert or bridge.

**Example:** The following is an example of travel time and time of concentration calculations.

Given: An existing drainage basin having a selected flow route composed of the following five segments. Note: Drainage basin is in Federal Way and has a  $P_2 = 2.1$  inches.

Segment 1:	L	= 200 ft. Forest with dense brush (sheet flow)
	$s_o$	= 0.03 ft/ft, $n_s = 0.80$
Segment 2:	L	= 300 ft. Pasture (shallow concentrated flow)
	$s_o$	= 0.04 ft/ft, $k_s = 11$
Segment 3:	L	= 50 ft. Small pond (year around)
	$s_o$	= 0.00 ft/ft, $k_c = 0$
Segment 4:	L	= 300 ft. Grassed waterway (intermittent channel)
	$s_o$	= 0.05 ft/ft, $k_c = 17$
Segment 5:	L	= 500 ft. Grass-lined stream (continuous)
	$s_o$	= 0.02 ft/ft, $k_c = 27$

Table III-1.4 "n" AND "k" Values Used in Time Calculations for Hydrographs

"n," Sheet Flow Equation Manning's Values (for the initial 300 ft. of travel)	n <sub>s</sub>
Smooth surfaces (concrete, asphalt, gravel, or bare hand packed soil)	
0.011	
Fallow fields or loose soil surface (no residue)	0.05
Cultivated soil with residue cover (s ≤ 0.20 ft/ft)	0.06
Cultivated soil with residue cover (s > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grasses	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods or forest with light underbrush	0.40
Woods or forest with dense underbrush	0.80
*Manning values for sheet flow only, from Overton and Meadows 1976 (See TR-55, 1986)	
"k" Values Used in Travel Time/Time of Concentration Calculations	
Shallow Concentrated Flow (After the initial 300 ft. of sheet flow, R = 0.1)	k <sub>s</sub>
1. Forest with heavy ground litter and meadows (n = 0.10)	3
2. Brushy ground with some trees (n = 0.060)	5
3. Fallow or minimum tillage cultivation (n = 0.040)	8
4. High grass (n = 0.035)	9
5. Short grass, pasture and lawns (n = 0.030)	11
6. Nearly bare ground (n = 0.25)	13
7. Paved and gravel areas (n = 0.012)	27
Channel Flow (intermittent) (At the beginning of visible channels R = 0.2)	k <sub>c</sub>
1. Forested swale with heavy ground litter (n = 0.10)	5
2. Forested drainage course/ravine with defined channel bed (n = 0.050)	10
3. Rock-lined waterway (n = 0.035)	15
4. Grassed waterway (n = 0.030)	17
5. Earth-lined waterway (n = 0.025)	20
6. CMP pipe (n = 0.024)	21
7. Concrete pipe (0.012)	42
8. Other waterways and pipe 0.508/n	
Channel Flow (Continuous stream, R = 0.4)	k <sub>c</sub>
9. Meandering stream with some pools (n = 0.040)	20
10. Rock-lined stream (n = 0.035)	23
11. Grass-lined stream (n = 0.030)	27
12. Other streams, man-made channels and pipe 0.807/n**	

Table III-1.5 Values of the Roughness Coefficient, "n"

Type of Channel and Description	Manning's "n" (Normal)	Type of Channel and Description	Manning's "n" (Normal)
<b>A. Constructed Channels</b>		<b>6. Sluggish reaches, weedy deep pools</b>	0.070
<b>a. Earth, straight and uniform</b>		<b>7. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush</b>	0.100
1. Clean, recently completed	0.018		
2. Gravel, uniform section, clean	0.025		
3. With short grass, few weeds	0.027		
<b>b. Earth, winding and sluggish</b>	0.025	<b>b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages</b>	
1. No vegetation	0.025	1. Bottom: gravel, cobbles, and few boulders	0.040
2. Grass, some weeds	0.030	2. Bottom: cobbles with large boulders	0.050
3. Dense weeds or aquatic plants in deep channels	0.035		
4. Earth bottom and rubble sides	0.030	<b>B-2 Flood plains</b>	
5. Stony bottom and weedy banks	0.035	<b>a. Pasture, no brush</b>	
6. Cobble bottom and clean sides	0.040	1. Short grass	0.030
<b>c. Rock lined</b>		2. High grass	0.035
1. Smooth and uniform	0.035	<b>b. Cultivated areas</b>	
2. Jagged and irregular	0.040	1. No crop	0.030
<b>d. Channels not maintained, weeds and brush uncut</b>		2. Mature row crops	0.035
1. Dense weeds, high as flow depth	0.080	3. Mature field crops	0.040
2. Clean bottom, brush on sides	0.050	<b>c. Brush</b>	
3. Same, highest stage of flow	0.070	1. Scattered brush, heavy weeds	0.050
4. Dense brush, high stage	0.070	2. Light brush and trees	0.060
<b>B. Natural Streams</b>	0.100	3. Medium to dense brush	0.070
<b>B-1 Minor streams (top width at flood stage &lt; 100 ft.)</b>		4. Heavy, dense brush	0.100
<b>a. Streams on plain</b>		<b>d. Trees</b>	
1. Clean, straight, full stage no rifts or deep pools	0.030	1. Dense willows, straight	0.150
2. Same as above, but more stones and weeds	0.035	2. Cleared land with tree stumps, no sprouts	0.040
3. Clean, winding, some pools and shoals	0.040	3. Same as above, but with heavy growth of sprouts	0.060
4. Same as above, but some weeds	0.040	4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as 4, but more stones	0.050	5. Same as above, but with flood stage reaching branches	0.120

Calculate travel times ( $T_1$ 's) for each reach and then sum them to calculate the drainage basin time of concentration ( $T_c$ ).

$$\text{Segment 1: Sheet flow (L < 300 feet), } T_1 = \frac{0.42 (n_s L)^{0.8}}{(P_2)^{0.5} (s_0)^{0.4}}$$

$$T_1 = \frac{(0.42) [((0.80)(200))^{0.8}]}{(2.1)^{0.527} (0.03)^{0.4}} = \underline{68 \text{ minutes}}$$

$$\text{Segment 2: Shallow concentrated flow } V = k_s \sqrt{s_0}$$

$$V_2 = (11) \sqrt{(0.04)} = 2.2 \text{ ft/s}$$

$$T_2 = \frac{L}{60V} = \frac{(300)}{60(2.2)} = \underline{2 \text{ minutes}}$$

Segment 3: Flat water surface

$$T_3 = \underline{0 \text{ minutes}}$$

Segment 4: Intermittent channel flow

$$V_4 = (17) \sqrt{(0.05)} = 3.8 \text{ ft/s}$$

$$T_4 = \frac{(300)}{60(3.8)} = \underline{1 \text{ minute}}$$

Segment 5: Continuous stream

$$V_5 = (27) \sqrt{(0.02)} = 3.8 \text{ ft/s}$$

$$T_5 = \frac{(500)}{60(3.8)} = \underline{2 \text{ minutes}}$$

$$T_c = T_1 + T_2 + T_3 + T_4 + T_5$$

$$T_c = 68 + 2 + 0 + 1 + 2 = \underline{73 \text{ minutes}}$$

It is important to note how the initial sheet flow segment's travel time dominates the time of concentration computation. This will nearly always be the case for relatively small drainage basins and in particular the existing site conditions. This also illustrates the significant impact urbanization has on the surface runoff portion of the hydrologic process.

### III-1.4.3 Hydrograph Synthesis

This section presents a description of the Santa Barbara Urban Hydrograph (SBUH) method. It is given here as a guideline only, as it is only one of the many SCS-based hydrograph methods that are available for use. This particular method is favored by King County because staff there have found the SBUH method to be more consistent and better suited for analysis of small urban basins. Other local governments may favor other hydrograph-based methods such as the SCS TR-20 method (1), or, preferably, simplified versions of the HSPF model when they are developed.

#### The Santa Barbara Urban Hydrograph Method

The SBUH method, like the Soil Conservation Service Urban Hydrograph (SCSUH) method, is based on the curve number (CN) approach, and also uses SCS equations for

computing soil absorption and precipitation excess. The SCSUH method works by converting the incremental runoff depths (precipitation excess) for a given basin and design storm hydrographs of equal time base according to basin time of concentration and adds them to form the runoff hydrograph. The SBUH method, on the other hand, converts the incremental runoff depths into instantaneous hydrographs which are then routed through an imaginary reservoir with a time delay equal to the basin time of concentration.

The SBUH method was developed by the Santa Barbara County Flood Control and Water Conservation District, California. The SBUH method directly computes a runoff hydrograph without going through an intermediate process (unit hydrograph) as the SCSUH method does. By comparison, the calculation steps of the SBUH method are much simpler and can be programmed on a calculator or a spreadsheet program.

The SBUH method uses two steps to synthesize the runoff hydrograph:

Step one - computing the instantaneous hydrograph, and Step two - computing the runoff hydrograph.

The instantaneous hydrograph,  $I(t)$ , in cfs, at each time step,  $dt$ , is computed as follows:

$$I(t) = 60.5 R(t) A/dt$$

where:

$R(t)$  = total runoff depth (both impervious and pervious runoffs) at time increment  $dt$ , in inches (also known as precipitation excess)

$A$  = area in acres

$dt$  = time interval in minutes\*

\* NOTE: A maximum time interval of 10 minutes should be used for all design storms of 24-hour duration. A maximum time interval of 60 minutes should be used for the 100-year, 7-day design storm.

The runoff hydrograph,  $Q(t)$ , is then obtained by routing the instantaneous hydrograph  $I(t)$ , through an imaginary reservoir with a time delay equal to the time of concentration,  $T_c$ , of the drainage basin. The following equation estimates the routed flow,  $Q(t)$ :

$$Q(t+1) = Q(t) + w[I(t) + I(t+1) - 2Q(t)]$$

where:

$w$  =  $dt/(2T_c + dt)$

$dt$  = time interval in minutes

**Example:** To illustrate the SBUH method, Tables III-1.6 and III-1.7 show runoff hydrograph values computed by this method for both existing and developed conditions. Figure III-1.3 illustrates the hydrographs for existing and developed conditions. Note, this example was prepared using the LOTUS 123 spreadsheet program and illustrates how the method can be used with a personal computer. Copies of this program and a Fortran version are available (with minimal documentation) from King County Surface Water Management Division.

#### III-1.4.4 Hydrograph Routing

This section presents the methodology for routing a hydrograph through an existing retention/detention facility or closed depression, and for sizing a new retention/detention facility using hydrograph analysis.

## Storage Routing Technique

The "level pool routing" technique presented here is one of the simplest and most commonly used hydrograph routing methods. This method is described in "Handbook of Applied Hydrology," Chow, V. Te, 1964, (6) and elsewhere, and is based on the continuity equation:

Inflow - Outflow = Change in storage

$$\left[ \frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} \right] = \frac{\Delta S}{\Delta t} = S_2 - S_1$$

where:

I = Inflow at time 1 and time 2  
 O = Outflow at time 1 and time 2  
 S = Storage at time 1 and time 2  
 $\Delta t$  = Time interval, 2-1

The time interval,  $\Delta t$ , must be consistent with the time interval used in developing the inflow hydrograph. The time interval used for a 24-hour storm is 10 minutes while the time interval used for a 7-day storm is 60 minutes. The  $\Delta t$  variable can be eliminated by dividing it into the storage variables to obtain the following rearranged equation:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2$$

If the time interval,  $\Delta t$ , is in minutes, the units of storage (S) are now [cf/min] which can be converted to cfs by multiplying times 1 min/60 sec.

The terms on the left-hand side of the equation are known from the inflow hydrograph and from the storage and outflow values of the previous time step. The unknowns O and S can be solved interactively from the given stage-storage and stage-discharge curves.

The following section gives the specific hydrograph routing steps:

1. Develop stage-storage relationship

- For retention/detention facilities with vertical sides (vaults), the stored volume is simply the bottom area times the height.
- For ponds with 3:1 side slopes, the stored volume can be computed by averaging the pond surface area with the bottom area. The following equation was derived based on this assumption and for a square pond but provides a reasonable trial estimate for typical ponds of other shapes:

$$S(H) = 18H^3 + (6 \cdot H^2 \cdot (A_b)^{0.5}) + A_b H$$

where:

H = stage height (ft) or water depth above pond bottom  
 $A_b$  = area of pond bottom (sq. ft.)  
 S(H) = storage (cu. ft.) at stage height, H.

- For irregularly shaped areas the stage-storage curve may be developed as follows:
  - a. Obtain topographic contours of an existing or proposed retention/detention facility site and planimeter (or otherwise compute) the area enclosed by each contour. For example, see Figure III-1.4 in which each contour represents a one-foot interval. Contour 71 is the lowest portion of the site and represents

zero storage. Contour 76 represents a potential stage of 5 feet above the bottom of the facility.

- b. Calculate the average area between each contour. For the example given above, the average area between contours 71 and 72 would be:

$$\frac{600 + 4400}{2} = 2500 \text{ sq. ft.}$$

- c. Calculate the volume between contours by multiplying the average area between contours by the difference in elevation. To illustrate, the volume between contours 71 and 72 would be:

$$(2500)(1 \text{ foot}) = 2500 \text{ cu. ft.}$$

Similarly,

Area 72-73	-	6550 cu. ft.
Area 73-74	-	10050 cu. ft.
Area 74-75	-	12950 cu. ft.
Area 75-76	-	16750 cu. ft.

- d. Define the total storage below each contour. This is just the sum of the volumes computed in the previous step for the contour in question. For example, there is no storage below contour 71, 2500 cu. ft. below Contour 72, and (6550 + 2500 = 9050 cu. ft. below Contour 73).

In summary,

<u>Contours</u>	<u>Stage</u>	<u>Sum of Volumes</u>	<u>Total Volume</u>
Contours 71-72	1	0 + 2500	= 2500 cu. ft.
Contours 72-73	2	2500 + 6500	= 9050 cu. ft.
Contours 73-74	3	9050 + 10050	= 19100 cu. ft.
Contours 74-75	4	19100 + 12950	= 32050 cu. ft.
Contours 75-76	5	32050 + 16750	= 48800 cu. ft.



TABLE III-1.6  
SBUH HYDROGRAPH VALUES FOR EXISTING SITE CONDITION

Given: Area = 10 acres. Pt = 2.9 inches (10-year, 24-hour event). dt = 10 minutes. Tc = 73 minutes  
 PERVIOUS AREA: Area = 10 acres CN = 74 S = 3.51 0.2S = 0.70  
 IMPERVIOUS AREA Area = 0 acres CN = 98 S = 0.20 0.2S = 0.04

Column (3) = SCS Type 1A rainfall distribution  
 Column (4) = Column (3) \* Pt  
 Column (5) = Accumulated sum of Column (4)  
 Column (6) = (If P ≤ 0.2S) = 0; (If P > 0.2S) = ((Column (5) - 0.2S)^2)/(Column(5) + 0.8S) where the PERVIOUS AREA S value is used  
 Column (7) = Column (6) of present time step - Column (6) of previous time step  
 Column (8) = Same as Column (6) except use IMPERVIOUS AREA S value  
 Column (9) = Column (8) of present time step - Column (8) of previous time step  
 Column (10) = ((PERVIOUS AREA/TOTAL AREA) \* Column (7)) + ((IMPERVIOUS AREA/TOTAL AREA) \* Column (9))  
 Column (11) = (60.5 \* Column (10) \* TOTAL AREA)/dt where dt = 10 minutes  
 Column (12) = Column (12) of previous time step + w \* [(Column (11) of previous time step + Column (11) of present time step) - (2 \* Column (12) of previous time step)] where w = routing constant = dt/(2Tc + dt) = 0.0641

(1) Time Increment	(2) Time (min)	(3) Rainfall Distrib. (fraction)	(4) Incre. Rainfall (inches)	(5) Accumul. Rainfall (inches)	(6) PERVIOUS AREA Accum. Runoff (inches)	(7) Incre. Runoff (inches)	(8) IMPERVIOUS AREA Accum. Runoff (inches)	(9) Incre. Runoff (inches)	(10) Total Runoff (inches)	(11) Instant Flowrate (cfs)	(12) Design Flowrate (cfs)
1	0	0	0	0	0	0	0	0	0	0.0	0.0
2	10	0.004	0.0116	0.012	0.000	0.000	0.000	0.000	0.000	0.0	0.0
3	20	0.004	0.0116	0.023	0.000	0.000	0.000	0.000	0.000	0.0	0.0
4	30	0.004	0.0116	0.035	0.000	0.000	0.000	0.000	0.000	0.0	0.0
5	40	0.004	0.0116	0.046	0.000	0.000	0.000	0.000	0.000	0.0	0.0
6	50	0.004	0.0116	0.058	0.000	0.000	0.001	0.001	0.000	0.0	0.0
7	60	0.004	0.0116	0.070	0.000	0.000	0.004	0.002	0.000	0.0	0.0
8	70	0.004	0.0116	0.081	0.000	0.000	0.007	0.003	0.000	0.0	0.0
9	80	0.004	0.0116	0.093	0.000	0.000	0.011	0.004	0.000	0.0	0.0
10	90	0.004	0.0116	0.104	0.000	0.000	0.015	0.005	0.000	0.0	0.0
11	100	0.004	0.0116	0.116	0.000	0.000	0.020	0.005	0.000	0.0	0.0
12	110	0.005	0.0145	0.131	0.000	0.000	0.027	0.007	0.000	0.0	0.0
13	120	0.005	0.0145	0.145	0.000	0.000	0.035	0.008	0.000	0.0	0.0
14	130	0.005	0.0145	0.160	0.000	0.000	0.044	0.008	0.000	0.0	0.0
15	140	0.005	0.0145	0.174	0.000	0.000	0.053	0.009	0.000	0.0	0.0
16	150	0.005	0.0145	0.189	0.000	0.000	0.062	0.009	0.000	0.0	0.0
17	160	0.005	0.0145	0.203	0.000	0.000	0.072	0.010	0.000	0.0	0.0
18	170	0.006	0.0174	0.220	0.000	0.000	0.084	0.012	0.000	0.0	0.0
19	180	0.006	0.0174	0.238	0.000	0.000	0.097	0.013	0.000	0.0	0.0
20	190	0.006	0.0174	0.255	0.000	0.000	0.110	0.013	0.000	0.0	0.0
21	200	0.006	0.0174	0.273	0.000	0.000	0.123	0.013	0.000	0.0	0.0
22	210	0.006	0.0174	0.290	0.000	0.000	0.137	0.014	0.000	0.0	0.0
23	220	0.006	0.0174	0.307	0.000	0.000	0.151	0.014	0.000	0.0	0.0
24	230	0.007	0.0203	0.328	0.000	0.000	0.168	0.017	0.000	0.0	0.0
25	240	0.007	0.0203	0.348	0.000	0.000	0.185	0.017	0.000	0.0	0.0
26	250	0.007	0.0203	0.368	0.000	0.000	0.202	0.017	0.000	0.0	0.0
27	260	0.007	0.0203	0.389	0.000	0.000	0.219	0.017	0.000	0.0	0.0
28	270	0.007	0.0203	0.409	0.000	0.000	0.237	0.018	0.000	0.0	0.0
29	280	0.007	0.0203	0.429	0.000	0.000	0.255	0.018	0.000	0.0	0.0
30	290	0.0082	0.0238	0.453	0.000	0.000	0.276	0.021	0.000	0.0	0.0
31	300	0.0082	0.0238	0.477	0.000	0.000	0.297	0.021	0.000	0.0	0.0
32	310	0.0082	0.0238	0.501	0.000	0.000	0.318	0.021	0.000	0.0	0.0
33	320	0.0082	0.0238	0.524	0.000	0.000	0.340	0.022	0.000	0.0	0.0
34	330	0.0082	0.0238	0.548	0.000	0.000	0.362	0.022	0.000	0.0	0.0
35	340	0.0082	0.0238	0.572	0.000	0.000	0.384	0.022	0.000	0.0	0.0
36	350	0.0095	0.0276	0.599	0.000	0.000	0.409	0.026	0.000	0.0	0.0
37	360	0.0095	0.0276	0.627	0.000	0.000	0.435	0.026	0.000	0.0	0.0
38	370	0.0095	0.0276	0.655	0.000	0.000	0.461	0.026	0.000	0.0	0.0
39	380	0.0095	0.0276	0.682	0.000	0.000	0.486	0.026	0.000	0.0	0.0
40	390	0.0095	0.0276	0.710	0.000	0.000	0.512	0.026	0.000	0.0	0.0
41	400	0.0095	0.0276	0.737	0.000	0.000	0.539	0.026	0.000	0.0	0.0
42	410	0.0134	0.0389	0.776	0.001	0.001	0.575	0.037	0.001	0.1	0.0
43	420	0.0134	0.0389	0.815	0.003	0.002	0.613	0.037	0.002	0.1	0.0
44	430	0.0134	0.0389	0.854	0.006	0.003	0.650	0.037	0.003	0.2	0.0
45	440	0.018	0.0522	0.906	0.011	0.005	0.700	0.050	0.005	0.3	0.1
46	450	0.018	0.0522	0.958	0.017	0.006	0.750	0.050	0.006	0.4	0.1
47	460	0.034	0.0986	1.057	0.032	0.015	0.846	0.096	0.015	0.9	0.2
48	470	0.054	0.1566	1.213	0.065	0.032	0.999	0.153	0.032	2.0	0.3
49	480	0.027	0.0783	1.292	0.085	0.020	1.075	0.077	0.020	1.2	0.5
50	490	0.018	0.0522	1.344	0.099	0.014	1.127	0.051	0.014	0.9	0.6
51	500	0.0134	0.0389	1.383	0.110	0.011	1.165	0.038	0.011	0.7	0.6

TABLE III-1.6  
 SBUH HYDROGRAPH VALUES FOR EXISTING SITE CONDITION (continued)

(1) Time Increment	(2) Time (min)	(3) Rainfall Distrib. (fraction)	(4) Incre. Rainfall (inches)	(5) Accumul. Rainfall (inches)	(6) PERVIOUS AREA Accum. Runoff	(7) Incre. Runoff	(8) IMPERVIOUS AREA Accum. Runoff (inches)	(9) Incre. Runoff (inches)	(10) Total Runoff (inches)	(11) Instant Flowrate (cfs)	(12) Design Flowrate (cfs)
52	510	0.0134	0.0389	1.422	0.122	0.012	1.203	0.038	0.012	0.7	0.6
53	520	0.0134	0.0389	1.460	0.134	0.012	1.241	0.038	0.012	0.7	0.6
54	530	0.0088	0.0255	1.486	0.143	0.008	1.266	0.025	0.008	0.5	0.6
55	540	0.0088	0.0255	1.511	0.151	0.009	1.291	0.025	0.009	0.5	0.6
56	550	0.0088	0.0255	1.537	0.160	0.009	1.317	0.025	0.009	0.5	0.6
57	560	0.0088	0.0255	1.563	0.169	0.009	1.342	0.025	0.009	0.5	0.6
58	570	0.0088	0.0255	1.588	0.178	0.009	1.367	0.025	0.009	0.6	0.6
59	580	0.0088	0.0255	1.614	0.188	0.009	1.392	0.025	0.009	0.6	0.6
60	590	0.0088	0.0255	1.639	0.197	0.010	1.417	0.025	0.010	0.6	0.6
61	600	0.0088	0.0255	1.665	0.207	0.010	1.442	0.025	0.010	0.6	0.6
62	610	0.0088	0.0255	1.690	0.217	0.010	1.468	0.025	0.010	0.6	0.6
63	620	0.0088	0.0255	1.716	0.227	0.010	1.493	0.025	0.010	0.6	0.6
64	630	0.0088	0.0255	1.741	0.237	0.010	1.518	0.025	0.010	0.6	0.6
65	640	0.0088	0.0255	1.767	0.247	0.010	1.543	0.025	0.010	0.6	0.6
66	650	0.0072	0.0209	1.788	0.256	0.009	1.564	0.021	0.009	0.5	0.6
67	660	0.0072	0.0209	1.808	0.265	0.009	1.585	0.021	0.009	0.5	0.6
68	670	0.0072	0.0209	1.829	0.274	0.009	1.605	0.021	0.009	0.5	0.6
69	680	0.0072	0.0209	1.850	0.283	0.009	1.626	0.021	0.009	0.5	0.6
70	690	0.0072	0.0209	1.871	0.292	0.009	1.647	0.021	0.009	0.5	0.6
71	700	0.0072	0.0209	1.892	0.301	0.009	1.667	0.021	0.009	0.6	0.6
72	710	0.0072	0.0209	1.913	0.310	0.009	1.688	0.021	0.009	0.6	0.6
73	720	0.0072	0.0209	1.934	0.319	0.009	1.709	0.021	0.009	0.6	0.6
74	730	0.0072	0.0209	1.955	0.329	0.009	1.729	0.021	0.009	0.6	0.6
75	740	0.0072	0.0209	1.975	0.338	0.010	1.750	0.021	0.010	0.6	0.6
76	750	0.0072	0.0209	1.996	0.348	0.010	1.771	0.021	0.010	0.6	0.6
77	760	0.0072	0.0209	2.017	0.358	0.010	1.791	0.021	0.010	0.6	0.6
78	770	0.0057	0.0165	2.034	0.366	0.008	1.808	0.016	0.008	0.5	0.6
79	780	0.0057	0.0165	2.050	0.374	0.008	1.824	0.016	0.008	0.5	0.6
80	790	0.0057	0.0165	2.067	0.382	0.008	1.841	0.016	0.008	0.5	0.5
81	800	0.0057	0.0165	2.083	0.389	0.008	1.857	0.016	0.008	0.5	0.5
82	810	0.0057	0.0165	2.100	0.398	0.008	1.873	0.016	0.008	0.5	0.5
83	820	0.0057	0.0165	2.116	0.406	0.008	1.890	0.016	0.008	0.5	0.5
84	830	0.0057	0.0165	2.133	0.414	0.008	1.906	0.016	0.008	0.5	0.5
85	840	0.0057	0.0165	2.149	0.422	0.008	1.923	0.016	0.008	0.5	0.5
86	850	0.0057	0.0165	2.166	0.430	0.008	1.939	0.016	0.008	0.5	0.5
87	860	0.0057	0.0165	2.183	0.439	0.008	1.955	0.016	0.008	0.5	0.5
88	870	0.0057	0.0165	2.199	0.447	0.008	1.972	0.016	0.008	0.5	0.5
89	880	0.0057	0.0165	2.216	0.455	0.008	1.988	0.016	0.008	0.5	0.5
90	890	0.005	0.0145	2.230	0.463	0.007	2.003	0.014	0.007	0.4	0.5
91	900	0.005	0.0145	2.245	0.470	0.007	2.017	0.014	0.007	0.5	0.5
92	910	0.005	0.0145	2.259	0.478	0.008	2.031	0.014	0.008	0.5	0.5
93	920	0.005	0.0145	2.274	0.485	0.008	2.046	0.014	0.008	0.5	0.5
94	930	0.005	0.0145	2.288	0.493	0.008	2.060	0.014	0.008	0.5	0.5
95	940	0.005	0.0145	2.303	0.501	0.008	2.075	0.014	0.008	0.5	0.5
96	950	0.005	0.0145	2.317	0.508	0.008	2.089	0.014	0.008	0.5	0.5
97	960	0.005	0.0145	2.332	0.516	0.008	2.103	0.014	0.008	0.5	0.5
98	970	0.005	0.0145	2.346	0.524	0.008	2.118	0.014	0.008	0.5	0.5
99	980	0.005	0.0145	2.361	0.532	0.008	2.132	0.014	0.008	0.5	0.5
100	990	0.005	0.0145	2.375	0.539	0.008	2.147	0.014	0.008	0.5	0.5
101	1000	0.005	0.0145	2.390	0.547	0.008	2.161	0.014	0.008	0.5	0.5
102	1010	0.004	0.0116	2.401	0.554	0.006	2.173	0.012	0.006	0.4	0.5
103	1020	0.004	0.0116	2.413	0.560	0.006	2.184	0.012	0.006	0.4	0.5
104	1030	0.004	0.0116	2.424	0.566	0.006	2.196	0.012	0.006	0.4	0.4
105	1040	0.004	0.0116	2.436	0.573	0.006	2.207	0.012	0.006	0.4	0.4
106	1050	0.004	0.0116	2.448	0.579	0.006	2.219	0.012	0.006	0.4	0.4
107	1060	0.004	0.0116	2.459	0.585	0.006	2.230	0.012	0.006	0.4	0.4
108	1070	0.004	0.0116	2.471	0.592	0.006	2.242	0.012	0.006	0.4	0.4
109	1080	0.004	0.0116	2.482	0.598	0.006	2.253	0.012	0.006	0.4	0.4
110	1090	0.004	0.0116	2.494	0.605	0.007	2.265	0.012	0.007	0.4	0.4
111	1100	0.004	0.0116	2.506	0.611	0.007	2.276	0.012	0.007	0.4	0.4
112	1110	0.004	0.0116	2.517	0.618	0.007	2.288	0.012	0.007	0.4	0.4
113	1120	0.004	0.0116	2.529	0.625	0.007	2.299	0.012	0.007	0.4	0.4
114	1130	0.004	0.0116	2.540	0.631	0.007	2.311	0.012	0.007	0.4	0.4
115	1140	0.004	0.0116	2.552	0.638	0.007	2.322	0.012	0.007	0.4	0.4
116	1150	0.004	0.0116	2.564	0.644	0.007	2.334	0.012	0.007	0.4	0.4
117	1160	0.004	0.0116	2.575	0.651	0.007	2.346	0.012	0.007	0.4	0.4
118	1170	0.004	0.0116	2.587	0.658	0.007	2.357	0.012	0.007	0.4	0.4

TABLE III-1.6  
 SBUH HYDROGRAPH VALUES FOR EXISTING SITE CONDITION (continued)

(1) Time Increment	(2) Time (min)	(3) Rainfall Distrib. (fraction)	(4) Incre. Rainfall (inches)	(5) Accumul. Rainfall (inches)	(6) PERVIOUS AREA Accum. Runoff	(7) INCREASING AREA Incre. Runoff	(8) IMPERVIOUS AREA Accum. Runoff (inches)	(9) IMPERVIOUS AREA Incre. Runoff (inches)	(10) Total Runoff (inches)	(11) Instant Flowrate (cfs)	(12) Design Flowrate (cfs)
119	1180	0.004	0.0116	2.598	0.664	0.007	2.369	0.012	0.007	0.4	0.4
120	1190	0.004	0.0116	2.610	0.671	0.007	2.380	0.012	0.007	0.4	0.4
121	1200	0.004	0.0116	2.622	0.678	0.007	2.392	0.012	0.007	0.4	0.4
122	1210	0.004	0.0116	2.633	0.685	0.007	2.403	0.012	0.007	0.4	0.4
123	1220	0.004	0.0116	2.645	0.691	0.007	2.415	0.012	0.007	0.4	0.4
124	1230	0.004	0.0116	2.656	0.698	0.007	2.426	0.012	0.007	0.4	0.4
125	1240	0.004	0.0116	2.668	0.705	0.007	2.438	0.012	0.007	0.4	0.4
126	1250	0.004	0.0116	2.680	0.712	0.007	2.449	0.012	0.007	0.4	0.4
127	1260	0.004	0.0116	2.691	0.719	0.007	2.461	0.012	0.007	0.4	0.4
128	1270	0.004	0.0116	2.703	0.726	0.007	2.472	0.012	0.007	0.4	0.4
129	1280	0.004	0.0116	2.714	0.732	0.007	2.484	0.012	0.007	0.4	0.4
130	1290	0.004	0.0116	2.726	0.739	0.007	2.496	0.012	0.007	0.4	0.4
131	1300	0.004	0.0116	2.738	0.746	0.007	2.507	0.012	0.007	0.4	0.4
132	1310	0.004	0.0116	2.749	0.753	0.007	2.519	0.012	0.007	0.4	0.4
133	1320	0.004	0.0116	2.761	0.760	0.007	2.530	0.012	0.007	0.4	0.4
134	1330	0.004	0.0116	2.772	0.767	0.007	2.542	0.012	0.007	0.4	0.4
135	1340	0.004	0.0116	2.784	0.774	0.007	2.553	0.012	0.007	0.4	0.4
136	1350	0.004	0.0116	2.796	0.781	0.007	2.565	0.012	0.007	0.4	0.4
137	1360	0.004	0.0116	2.807	0.788	0.007	2.576	0.012	0.007	0.4	0.4
138	1370	0.004	0.0116	2.819	0.795	0.007	2.588	0.012	0.007	0.4	0.4
139	1380	0.004	0.0116	2.830	0.803	0.007	2.599	0.012	0.007	0.4	0.4
140	1390	0.004	0.0116	2.842	0.810	0.007	2.611	0.012	0.007	0.4	0.4
141	1400	0.004	0.0116	2.854	0.817	0.007	2.623	0.012	0.007	0.4	0.4
142	1410	0.004	0.0116	2.865	0.824	0.007	2.634	0.012	0.007	0.4	0.4
143	1420	0.004	0.0116	2.877	0.831	0.007	2.646	0.012	0.007	0.4	0.4
144	1430	0.004	0.0116	2.888	0.838	0.007	2.657	0.012	0.007	0.4	0.4
145	1440	0.004	0.0116	2.900	0.845	0.007	2.669	0.012	0.007	0.4	0.4

TABLE III-1.7  
SBUH HYDROGRAPH VALUES FOR DEVELOPED SITE CONDITION

Given: Area = 10 acres. Pt = 2.9 inches (10-year, 24-hour event). dt = 10 minutes. Tc = 73 minutes  
 PERVIOUS AREA: Area = 6.1 acres CN = 89 S = 1.24 0.2S = 0.25  
 IMPERVIOUS AREA Area = 3.9 acres CN = 98 S = 0.20 0.2S = 0.04

Given: Area = 10 acres. Pt = 2.9 inches (10-year, 24-hour event). dt = 10 minutes. Tc = 28 minutes

- Column (3) = SCS Type 1A rainfall distribution
- Column (4) = Column (3) \* Pt
- Column (5) = Accumulated sum of Column (4)
- Column (6) = (If P ≤ 0.2S) = 0; (If P > 0.2S) = ((Column (5) - 0.2S)<sup>2</sup>)/(Column(5) + 0.8S) where the PERVIOUS AREA S value is used
- Column (7) = Column (6) of present time step - Column (6) of previous time step
- Column (8) = Same as Column (6) except use IMPERVIOUS AREA S value
- Column (9) = Column (8) of present time step - Column (8) of previous time step
- Column (10) = ((PERVIOUS AREA/TOTAL AREA) \* Column (7)) + ((IMPERVIOUS AREA/TOTAL AREA) \* Column (9))
- Column (11) = (60.5 \* Column (10) \* TOTAL AREA)/dt where dt = 10 minutes
- Column (12) = Column (11) of previous time step + w \* [(Column (11) of previous time step + Column (11) of present time step) - (2 \* Column (12) of previous time step)] where w = routing constant = dt/(2Tc + dt) = 0.1515

(1) Time Increment	(2) Time (min)	(3) Rainfall Distrib. (fraction)	(4) Incre. Rainfall (inches)	(5) Accumul. Rainfall (inches)	(6) PERVIOUS Accum. Runoff (inches)	(7) PERVIOUS Incre. Runoff (inches)	(8) IMPERVIOUS Accum. Runoff (inches)	(9) IMPERVIOUS Incre. Runoff (inches)	(10) Total Runoff (inches)	(11) Instant Flowrate (cfs)	(12) Design Flowrate (cfs)
1	0	0	0	0	0	0	0	0	0	0.0	0.0
2	10	0.004	0.0116	0.012	0.000	0.000	0.000	0.000	0.000	0.0	0.0
3	20	0.004	0.0116	0.023	0.000	0.000	0.000	0.000	0.000	0.0	0.0
4	30	0.004	0.0116	0.035	0.000	0.000	0.000	0.000	0.000	0.0	0.0
5	40	0.004	0.0116	0.046	0.000	0.000	0.000	0.000	0.000	0.0	0.0
6	50	0.004	0.0116	0.058	0.000	0.000	0.001	0.001	0.000	0.0	0.0
7	60	0.004	0.0116	0.070	0.000	0.000	0.004	0.002	0.001	0.1	0.0
8	70	0.004	0.0116	0.081	0.000	0.000	0.007	0.003	0.001	0.1	0.0
9	80	0.004	0.0116	0.093	0.000	0.000	0.011	0.004	0.002	0.1	0.0
10	90	0.004	0.0116	0.104	0.000	0.000	0.015	0.005	0.002	0.1	0.1
11	100	0.004	0.0116	0.116	0.000	0.000	0.020	0.005	0.002	0.1	0.1
12	110	0.005	0.0145	0.131	0.000	0.000	0.027	0.007	0.003	0.2	0.1
13	120	0.005	0.0145	0.145	0.000	0.000	0.035	0.008	0.003	0.2	0.1
14	130	0.005	0.0145	0.160	0.000	0.000	0.044	0.008	0.003	0.2	0.1
15	140	0.005	0.0145	0.174	0.000	0.000	0.053	0.009	0.003	0.2	0.2
16	150	0.005	0.0145	0.189	0.000	0.000	0.062	0.009	0.004	0.2	0.2
17	160	0.005	0.0145	0.203	0.000	0.000	0.072	0.010	0.004	0.2	0.2
18	170	0.006	0.0174	0.220	0.000	0.000	0.084	0.012	0.005	0.3	0.2
19	180	0.006	0.0174	0.238	0.000	0.000	0.097	0.013	0.005	0.3	0.2
20	190	0.006	0.0174	0.255	0.000	0.000	0.110	0.013	0.005	0.3	0.3
21	200	0.006	0.0174	0.273	0.001	0.000	0.123	0.013	0.006	0.3	0.3
22	210	0.006	0.0174	0.290	0.001	0.001	0.137	0.014	0.006	0.4	0.3
23	220	0.006	0.0174	0.307	0.003	0.001	0.151	0.014	0.006	0.4	0.3
24	230	0.007	0.0203	0.328	0.005	0.002	0.168	0.017	0.008	0.5	0.4
25	240	0.007	0.0203	0.348	0.008	0.003	0.185	0.017	0.008	0.5	0.4
26	250	0.007	0.0203	0.368	0.011	0.003	0.202	0.017	0.009	0.5	0.4
27	260	0.007	0.0203	0.389	0.015	0.004	0.219	0.017	0.009	0.5	0.5
28	270	0.007	0.0203	0.409	0.019	0.004	0.237	0.018	0.009	0.6	0.5
29	280	0.007	0.0203	0.429	0.023	0.005	0.255	0.018	0.010	0.6	0.5
30	290	0.0082	0.0238	0.453	0.029	0.006	0.276	0.021	0.012	0.7	0.6
31	300	0.0082	0.0238	0.477	0.036	0.007	0.297	0.021	0.012	0.7	0.6
32	310	0.0082	0.0238	0.501	0.043	0.007	0.318	0.021	0.013	0.8	0.7
33	320	0.0082	0.0238	0.524	0.051	0.008	0.340	0.022	0.013	0.8	0.7
34	330	0.0082	0.0238	0.548	0.059	0.008	0.362	0.022	0.013	0.8	0.7
35	340	0.0082	0.0238	0.572	0.068	0.009	0.384	0.022	0.014	0.8	0.8
36	350	0.0095	0.0276	0.599	0.078	0.011	0.409	0.026	0.016	1.0	0.8
37	360	0.0095	0.0276	0.627	0.089	0.011	0.435	0.026	0.017	1.0	0.9
38	370	0.0095	0.0276	0.655	0.101	0.012	0.461	0.026	0.017	1.0	0.9
39	380	0.0095	0.0276	0.682	0.113	0.012	0.486	0.026	0.018	1.1	1.0
40	390	0.0095	0.0276	0.710	0.126	0.013	0.512	0.026	0.018	1.1	1.0
41	400	0.0095	0.0276	0.737	0.139	0.013	0.539	0.026	0.018	1.1	1.0
42	410	0.0134	0.0389	0.776	0.158	0.019	0.575	0.037	0.026	1.6	1.1
43	420	0.0134	0.0389	0.815	0.179	0.020	0.613	0.037	0.027	1.6	1.3
44	430	0.0134	0.0389	0.854	0.200	0.021	0.650	0.037	0.027	1.7	1.4
45	440	0.018	0.0522	0.906	0.229	0.029	0.700	0.050	0.037	2.3	1.6
46	450	0.018	0.0522	0.958	0.260	0.031	0.750	0.050	0.038	2.3	1.8
47	460	0.034	0.0986	1.057	0.320	0.061	0.846	0.096	0.074	4.5	2.3
48	470	0.054	0.1566	1.213	0.424	0.103	0.999	0.153	0.123	7.4	3.4
49	480	0.027	0.0783	1.292	0.478	0.054	1.075	0.077	0.063	3.8	4.1
50	490	0.018	0.0522	1.344	0.516	0.037	1.127	0.051	0.043	2.6	3.8

TABLE III-1.7  
 SBUH HYDROGRAPH VALUES FOR DEVELOPED SITE CONDITION (continued)

(1) Time Increment	(2) Time (min)	(3) Rainfall Distrib. (fraction)	(4) Incre. Rainfall (inches)	(5) Accumul. Rainfall (inches)	(6) PERVIOUS AREA Runoff Accum. (inches)	(7) Runoff Incre. (inches)	(8) IMPERVIOUS AREA Runoff Accum. (inches)	(9) Runoff Incre. (inches)	(10) Total Runoff (inches)	(11) Instant Flowrate (cfs)	(12) Design Flowrate (cfs)
51	500	0.0134	0.0389	1.383	0.544	0.028	1.165	0.038	0.032	1.9	3.3
52	510	0.0134	0.0389	1.422	0.572	0.028	1.203	0.038	0.032	2.0	2.9
53	520	0.0134	0.0389	1.460	0.601	0.029	1.241	0.038	0.032	2.0	2.6
54	530	0.0088	0.0255	1.486	0.620	0.019	1.266	0.025	0.021	1.3	2.3
55	540	0.0088	0.0255	1.511	0.639	0.019	1.291	0.025	0.022	1.3	2.0
57	560	0.0088	0.0255	1.563	0.678	0.019	1.342	0.025	0.022	1.3	1.7
58	570	0.0088	0.0255	1.588	0.698	0.020	1.367	0.025	0.022	1.3	1.5
59	580	0.0088	0.0255	1.614	0.717	0.020	1.392	0.025	0.022	1.3	1.5
60	590	0.0088	0.0255	1.639	0.737	0.020	1.417	0.025	0.022	1.3	1.4
61	600	0.0088	0.0255	1.665	0.757	0.020	1.442	0.025	0.022	1.3	1.4
62	610	0.0088	0.0255	1.690	0.777	0.020	1.468	0.025	0.022	1.3	1.4
63	620	0.0088	0.0255	1.716	0.797	0.020	1.493	0.025	0.022	1.3	1.4
64	630	0.0088	0.0255	1.741	0.818	0.020	1.518	0.025	0.022	1.3	1.4
65	640	0.0088	0.0255	1.767	0.838	0.020	1.543	0.025	0.022	1.3	1.4
66	650	0.0072	0.0209	1.788	0.855	0.017	1.564	0.021	0.018	1.1	1.3
67	660	0.0072	0.0209	1.808	0.871	0.017	1.585	0.021	0.018	1.1	1.3
68	670	0.0072	0.0209	1.829	0.888	0.017	1.605	0.021	0.018	1.1	1.2
69	680	0.0072	0.0209	1.850	0.905	0.017	1.626	0.021	0.018	1.1	1.2
70	690	0.0072	0.0209	1.871	0.922	0.017	1.647	0.021	0.018	1.1	1.2
71	700	0.0072	0.0209	1.892	0.939	0.017	1.667	0.021	0.018	1.1	1.1
72	710	0.0072	0.0209	1.913	0.956	0.017	1.688	0.021	0.018	1.1	1.1
73	720	0.0072	0.0209	1.934	0.973	0.017	1.709	0.021	0.019	1.1	1.1
74	730	0.0072	0.0209	1.955	0.990	0.017	1.729	0.021	0.019	1.1	1.1
75	740	0.0072	0.0209	1.975	1.008	0.017	1.750	0.021	0.019	1.1	1.1
76	750	0.0072	0.0209	1.996	1.025	0.017	1.771	0.021	0.019	1.1	1.1
77	760	0.0072	0.0209	2.017	1.042	0.017	1.791	0.021	0.019	1.1	1.1
78	770	0.0057	0.0165	2.034	1.056	0.014	1.808	0.016	0.015	0.9	1.1
79	780	0.0057	0.0165	2.050	1.070	0.014	1.824	0.016	0.015	0.9	1.0
80	790	0.0057	0.0165	2.067	1.084	0.014	1.841	0.016	0.015	0.9	1.0
81	800	0.0057	0.0165	2.083	1.097	0.014	1.857	0.016	0.015	0.9	1.0
82	810	0.0057	0.0165	2.100	1.111	0.014	1.873	0.016	0.015	0.9	0.9
83	820	0.0057	0.0165	2.116	1.125	0.014	1.890	0.016	0.015	0.9	0.9
84	830	0.0057	0.0165	2.133	1.139	0.014	1.906	0.016	0.015	0.9	0.9
85	840	0.0057	0.0165	2.149	1.153	0.014	1.923	0.016	0.015	0.9	0.9
86	850	0.0057	0.0165	2.166	1.167	0.014	1.939	0.016	0.015	0.9	0.9
87	860	0.0057	0.0165	2.183	1.181	0.014	1.955	0.016	0.015	0.9	0.9
88	870	0.0057	0.0165	2.199	1.195	0.014	1.972	0.016	0.015	0.9	0.9
89	880	0.0057	0.0165	2.216	1.209	0.014	1.988	0.016	0.015	0.9	0.9
90	890	0.005	0.0145	2.230	1.222	0.012	2.003	0.014	0.013	0.8	0.9
91	900	0.005	0.0145	2.245	1.234	0.012	2.017	0.014	0.013	0.8	0.9
92	910	0.005	0.0145	2.259	1.246	0.012	2.031	0.014	0.013	0.8	0.8
93	920	0.005	0.0145	2.274	1.259	0.012	2.046	0.014	0.013	0.8	0.8
94	930	0.005	0.0145	2.288	1.271	0.012	2.060	0.014	0.013	0.8	0.8
95	940	0.005	0.0145	2.303	1.284	0.012	2.075	0.014	0.013	0.8	0.8
96	950	0.005	0.0145	2.317	1.296	0.012	2.089	0.014	0.013	0.8	0.8
97	960	0.005	0.0145	2.332	1.309	0.012	2.103	0.014	0.013	0.8	0.8
98	970	0.005	0.0145	2.346	1.321	0.012	2.118	0.014	0.013	0.8	0.8
99	980	0.005	0.0145	2.361	1.334	0.013	2.132	0.014	0.013	0.8	0.8
100	990	0.005	0.0145	2.375	1.346	0.013	2.147	0.014	0.013	0.8	0.8
101	1000	0.005	0.0145	2.390	1.359	0.013	2.161	0.014	0.013	0.8	0.8
102	1010	0.004	0.0116	2.401	1.369	0.010	2.173	0.012	0.011	0.6	0.8
103	1020	0.004	0.0116	2.413	1.379	0.010	2.184	0.012	0.011	0.6	0.7
104	1030	0.004	0.0116	2.424	1.389	0.010	2.196	0.012	0.011	0.6	0.7
105	1040	0.004	0.0116	2.436	1.399	0.010	2.207	0.012	0.011	0.6	0.7
106	1050	0.004	0.0116	2.448	1.409	0.010	2.219	0.012	0.011	0.6	0.7
107	1060	0.004	0.0116	2.459	1.419	0.010	2.230	0.012	0.011	0.6	0.7
108	1070	0.004	0.0116	2.471	1.429	0.010	2.242	0.012	0.011	0.6	0.7
109	1080	0.004	0.0116	2.482	1.439	0.010	2.253	0.012	0.011	0.6	0.7
110	1090	0.004	0.0116	2.494	1.449	0.010	2.265	0.012	0.011	0.6	0.7
111	1100	0.004	0.0116	2.506	1.460	0.010	2.276	0.012	0.011	0.6	0.7
112	1110	0.004	0.0116	2.517	1.470	0.010	2.288	0.012	0.011	0.6	0.6
113	1120	0.004	0.0116	2.529	1.480	0.010	2.299	0.012	0.011	0.6	0.6
114	1130	0.004	0.0116	2.540	1.490	0.010	2.311	0.012	0.011	0.6	0.6
115	1140	0.004	0.0116	2.552	1.500	0.010	2.322	0.012	0.011	0.6	0.6
116	1150	0.004	0.0116	2.564	1.510	0.010	2.334	0.012	0.011	0.6	0.6

TABLE III-1.7  
 SBUH HYDROGRAPH VALUES FOR DEVELOPED SITE CONDITION (continued)

(1) Time Increment	(2) Time (min)	(3) Rainfall Distrib. (fraction)	(4) Incre. Rainfall (inches)	(5) Accumul. Rainfall (inches)	(6) PERVIOUS AREA Accum. Runoff (inches)	(7) Incre. Runoff (inches)	(8) IMPERVIOUS AREA Accum. Runoff (inches)	(9) Incre. Runoff (inches)	(10) Total Runoff (inches)	(11) Instant Flowrate (cfs)	(12) Design Flowrate (cfs)
117	1160	0.004	0.0116	2.575	1.521	0.010	2.346	0.012	0.011	0.6	0.6
118	1170	0.004	0.0116	2.587	1.531	0.010	2.357	0.012	0.011	0.6	0.6
119	1180	0.004	0.0116	2.598	1.541	0.010	2.369	0.012	0.011	0.6	0.6
120	1190	0.004	0.0116	2.610	1.551	0.010	2.380	0.012	0.011	0.6	0.6
121	1200	0.004	0.0116	2.622	1.562	0.010	2.392	0.012	0.011	0.6	0.6
122	1210	0.004	0.0116	2.633	1.572	0.010	2.403	0.012	0.011	0.7	0.6
123	1220	0.004	0.0116	2.645	1.582	0.010	2.415	0.012	0.011	0.7	0.6
124	1230	0.004	0.0116	2.656	1.592	0.010	2.426	0.012	0.011	0.7	0.7
125	1240	0.004	0.0116	2.668	1.603	0.010	2.438	0.012	0.011	0.7	0.7
126	1250	0.004	0.0116	2.680	1.613	0.010	2.449	0.012	0.011	0.7	0.7
127	1260	0.004	0.0116	2.691	1.623	0.010	2.461	0.012	0.011	0.7	0.7
128	1270	0.004	0.0116	2.703	1.633	0.010	2.472	0.012	0.011	0.7	0.7
129	1280	0.004	0.0116	2.714	1.644	0.010	2.484	0.012	0.011	0.7	0.7
130	1290	0.004	0.0116	2.726	1.654	0.010	2.496	0.012	0.011	0.7	0.7
131	1300	0.004	0.0116	2.738	1.664	0.010	2.507	0.012	0.011	0.7	0.7
132	1310	0.004	0.0116	2.749	1.675	0.010	2.519	0.012	0.011	0.7	0.7
133	1320	0.004	0.0116	2.761	1.685	0.010	2.530	0.012	0.011	0.7	0.7
134	1330	0.004	0.0116	2.772	1.695	0.010	2.542	0.012	0.011	0.7	0.7
135	1340	0.004	0.0116	2.784	1.706	0.010	2.553	0.012	0.011	0.7	0.7
136	1350	0.004	0.0116	2.796	1.716	0.010	2.565	0.012	0.011	0.7	0.7
137	1360	0.004	0.0116	2.807	1.726	0.010	2.576	0.012	0.011	0.7	0.7
138	1370	0.004	0.0116	2.819	1.737	0.010	2.588	0.012	0.011	0.7	0.7
139	1380	0.004	0.0116	2.830	1.747	0.010	2.599	0.012	0.011	0.7	0.7
140	1390	0.004	0.0116	2.842	1.758	0.010	2.611	0.012	0.011	0.7	0.7
141	1400	0.004	0.0116	2.854	1.768	0.010	2.623	0.012	0.011	0.7	0.7
142	1410	0.004	0.0116	2.865	1.778	0.010	2.634	0.012	0.011	0.7	0.7
143	1420	0.004	0.0116	2.877	1.789	0.010	2.646	0.012	0.011	0.7	0.7
144	1430	0.004	0.0116	2.888	1.799	0.010	2.657	0.012	0.011	0.7	0.7
145	1440	0.004	0.0116	2.900	1.810	0.010	2.669	0.012	0.011	0.7	0.7

FIGURE III-1.3  
Example SBUH Hydrographs for Existing and Developed Site Conditions

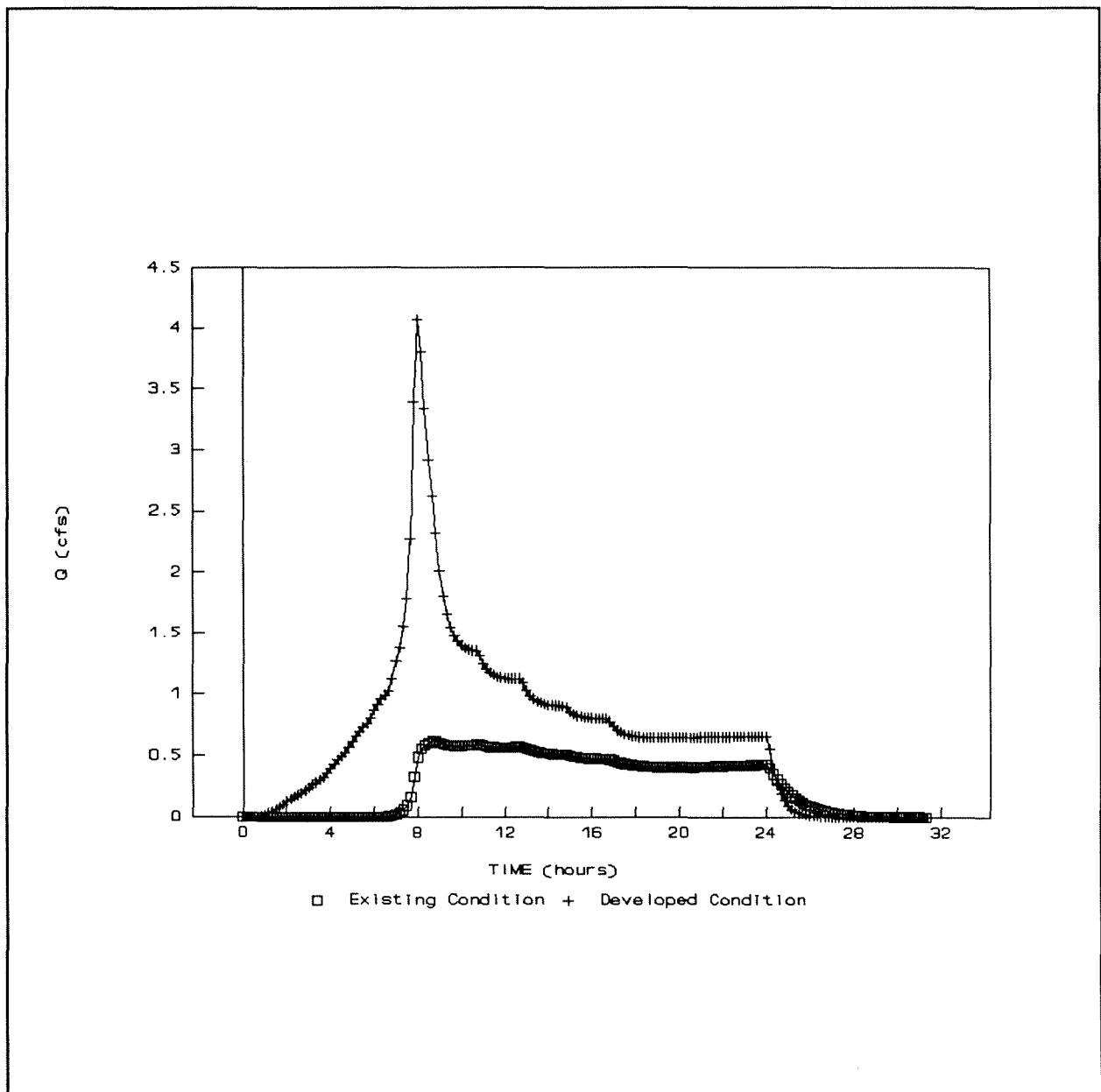


Figure III-1.4 Proposed Retention/Detention Facility Site Contours At 1 Foot Intervals

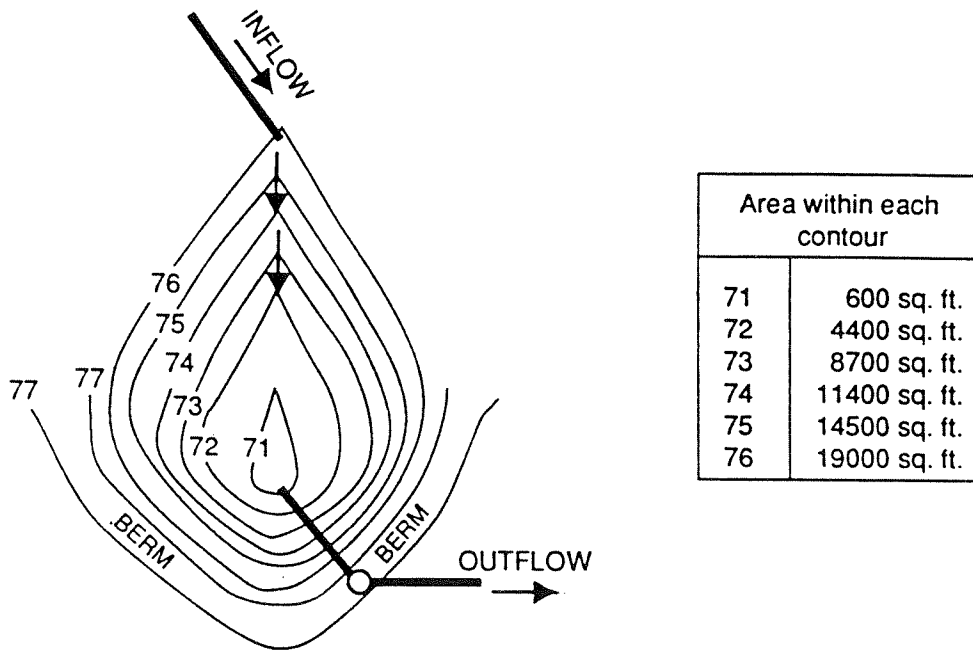


Figure III-1.5 Stage-Storage Relationship

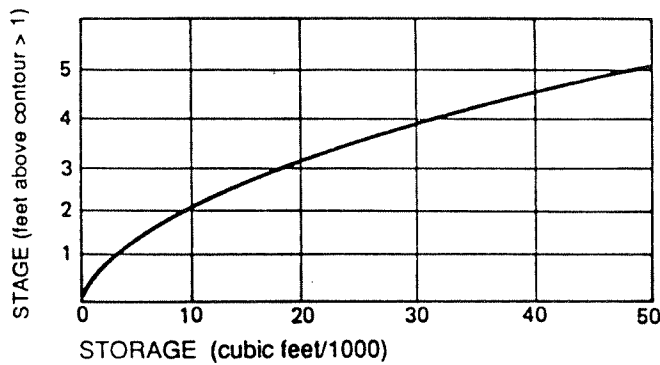


Figure III-1.6 Routing Curve for t = 60 minutes

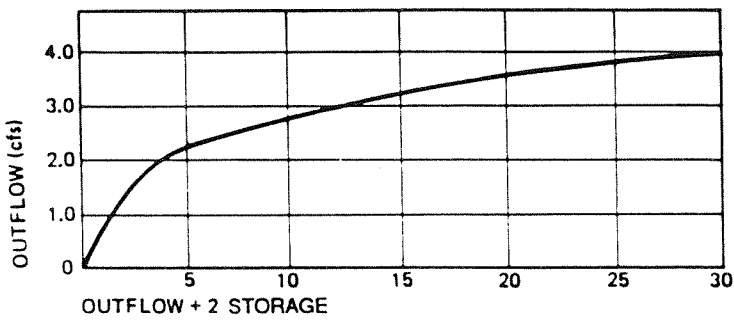
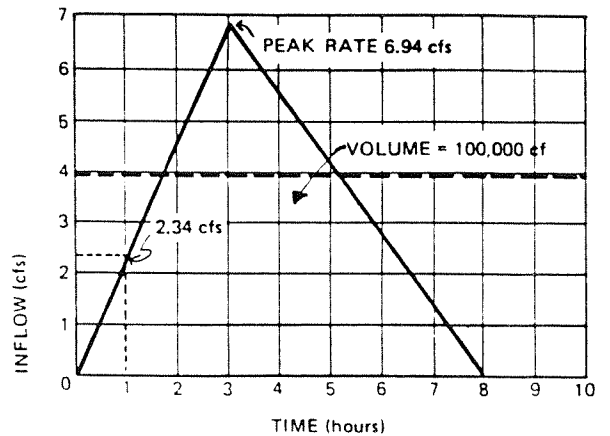


Figure III-1.7 Simplified Example of Inflow Hydrograph



$Q_{ALLOWABLE} = 4.0$  cfs  
(maximum outflow desired)



2. Develop a curve called the "routing curve" which is simply a plot of outflow for a given stage versus a term,  $O + 2S$ , for the same stage. This curve may be easily plotted by setting up a table like Table III-1.8. The units for the expression of outflow,  $O$ , are cubic-feet per second for the time period of interest. For this example, the time period,  $\Delta t$ , of 60 minutes will be used for illustrative purposes. (Usually  $\Delta t$  will be 10 minutes to correspond to the time steps used in preparing the hydrographs.) Therefore, all variables in the rearranged continuity equation must have the units of cfs. This means that the storage which was plotted in cubic feet must be converted from  $\text{ft}^3$  to cfs by dividing it by the time interval,  $\Delta t$ . For the storage below Contour 2 this would be:

$$\frac{S}{\Delta t} = \frac{2500 \text{ ft}^3}{(60 \text{ min})} \frac{1 \text{ min}}{60 \text{ sec}} = 0.694 \text{ cfs}$$

Table III-1.8 Tabulation of Data for Routing Curve

Elevation Feet	Stage Feet	Outflow* O cfs	Storage S cfs**	2S cfs	O + 2S cfs
72	1	1.76	0.694	1.388	3.15
73	2	2.49	2.514	5.028	7.52
74	3	3.05	5.306	10.612	13.66
75	4	3.52	8.903	17.806	21.33
76	5	3.94	13.556	27.112	31.05

\* from 8" orifice, stage-discharge relationship  
 $[Q = (\text{orifice area})(0.62) \sqrt{2gh}$ , where  $h = \text{stage}$ ]

\*\* from stage-storage curve, Figure III-1.5, volume converted to cfs for 60-minute time intervals.

For this example, the maximum allowable outflow was arbitrarily selected to be 4.0 cfs (this value is normally the pre-developed runoff rate from the site) and the maximum stage in the pond of 5 feet.

The "Outflow" column in Table III-1.8 is the stage-discharge relationship for an 8-inch orifice outlet pipe. The 8-inch pipe size was chosen because the maximum allowable outflow is approximately 4.0 cfs at the maximum desired storage depth of 5 feet. From Table III-1.8 the routing curve is plotted as shown in Figure III-1.6.

3. The final step is to route the inflow hydrograph through the proposed storage facility by completing successive columns of Table III-1.9 for each time period. For illustrative purposes a simple triangular shaped inflow hydrograph will be assumed as shown in Figure III-1.7. The routing table is completed by the following steps. Keep in mind the equation used:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2 \text{ (For each time period, } \Delta t)$$

Step

1. Initial inflow,  $I_1$ , is the inflow at the beginning of each time period and is read from the inflow hydrograph for each time period. For period 1,  $I_1$  in this example is zero, and this is entered in Row (1) of the routing table.

Table III-1.9 Tabular Calculation of Outflow Using Level Pool Routing

Row	Variables	Time Periods ( $\Delta t = 60$ min/usually $\Delta t = 10$ min.)											
		1	2	3	4	5	6	7	8	9	10	11	12
(1)	$I_1$	0	2.34	4.64	6.94	5.55	4.18	2.79	1.39	0	0	0	0
(2)	$I_2$	2.34	4.64	6.94	5.55	4.18	2.79	1.39	0	0	0	0	0
(3)	$2S_1$	0	0.84	3.97	10.17	16.23	18.96	18.76	15.97	10.86	5.21	1.11	0
(4)	$I_1 + I_2 + 2S_1$	2.34	7.82	15.55	22.66	25.96	25.93	22.94	17.36	10.86	5.21	1.11	0
(5)	$O_1$	0	1.50	2.35	3.03	3.40	3.60	3.57	3.40	3.10	2.55	1.55	0
(6)	$O_2 + 2S_2$	2.34	6.32	13.20	19.63	22.56	22.33	19.37	13.96	7.76	2.66	-	0
(7)	Stage <sub>1</sub> (ft)	0	0.7	2.31	2.90	3.77	4.12	4.10	3.75	3.05	2.65	0.80	0
(8)	Elevation (ft)	71.0	71.7	73.31	73.90	74.77	75.12*	75.10	74.75	74.05	73.65	71.80	71.0

\* Maximum floodplain elevation

2.  $I_2$ , inflow at the end of the time period, is read from the inflow hydrograph, and entered in Row (2) for each time period. This same value is the initial inflow for the next time period. For our example,  $I_2$ , for time period 1 is 2.34 cfs; this is also entered in Row (1) of time period 2 as  $I_1$ .
3. Two times the initial storage,  $2S_1$ , is entered in Row (3). For the example, initial storage for time period 1 is zero. Subsequent values entered as  $2S_1$  are calculated after the remaining values for the preceding time period are filled in. This is explained below.
4. Enter in Row (4) the sum of Rows (1), (2), and (3), for the appropriate time period. In this case, the sum for time period 1 is 2.34.
5.  $O_1$ , outflow initially for the time period, is entered in Row (5). For time period 1,  $O_1$  is zero in this case. Subsequent values are read from the routing curve after Row (6) has been calculated. This is explained below.
6. From the routing equation, the entry in Row (6),  $O_2 + 2S_2$ , is the difference between Row (4),  $I_1 + I_2 + 2S_1$ , and Row (5),  $O_1$ . For time period 1, this value is 2.34. This is entered and the process repeated.
7. The value of  $O_1$  for the next time period is read from the routing curve (Figure III-1.6) for the previous value of  $O_2 + 2S_2$ . In this case, a value of 1.50 is obtained for  $O_1$  for time period 2, corresponding to ( $O_2 + 2S_2 = 2.34$ ). Therefore, 1.50 is entered in Row (5) for time period 2.
8. The value of  $2S_1$  for the next time period is the difference between the previous value of ( $O_2 + 2S_2$ ) and the corresponding value of  $O_1$  read from the routing curve as in Step 7, above. For this example,

$$\begin{aligned}
 O_2 + 2S_2 &= 2.34 \text{ (for time period 1)} \\
 O_1 &= 1.50 \text{ (for time period 2)} \\
 2S_1 &= (O_2 + 2S_2) - O_1 = 0.84 \text{ (for time period 2)}
 \end{aligned}$$

Therefore, enter 0.84 in Row (3) for time period 2.

9. Find the sum of Rows (1), (2), and (3) and enter value in Row (4).
10. Subtract value in Row (5) from Row (4) and enter result in Row (6).
11. Refer to routing curve for next value of  $O_1$ , corresponding to result of Step 10.

Continue this process until the outflow hydrograph, as represented by the tabulated values of  $O_1$ , returns to zero.

Row (7) of entries in the Table III-1.8 (stage at the beginning of each time period) is obtained by dividing each value of  $2S_1$  by 2, and referring to the stage-storage curve, Figure III-1.8. For example, for time period 3,  $2S_1$  equals 3.97 cfs-min, half of which is 1.98 cfs-min. Referring to stage-storage curve for storage 1.98 cfs-min. (or  $1.98 \times 3600 = 7,128$  cu. ft.), a stage of 1.6 feet is obtained. Adding these stages to the elevation of the first contour (71) allows floodplain or maximum water surface (Row (8)) for each time period to be computed.

Finally, plot the values of  $O_1$  for each time period to plot the complete outflow hydrograph, as shown in Figure III-1.8. The volume which must be stored is represented by the dark shaded area, and may be obtained through graphical techniques. The volume may also be closely estimated from the largest tabulated value of  $2S_1$ , divided by 2, and converted to cubic feet. This will exactly coincide with the true peak only if two hydrographs cross exactly at the end of a time interval. However, this inaccuracy in volume would be very small, and for practical purposes may be neglected.

In summary, the characteristics of the sample detention facility and the selected eight-inch orifice outlet are such that the peak runoff rate will be reduced below the required 4.0 cfs. Furthermore, the full five feet of available storage is not used and the maximum floodplain elevation generated in the pond is 75.12 feet. This indicates that additional trials or iterations could be performed to optimize the size and outlet control of this sample detention pond.

#### Sizing a Detention Facility for Multiple Design Storm Events

To design a storage facility to meet performance requirements of 2, 10, and 100-year storm control, it is usually necessary to perform many iterative routings to arrive at a minimum facility size with the proper outlet (orifice) control. Each iterative routing requires that the facility size (stage-storage curve) and/or outlet configuration (stage-discharge curve) be adjusted and tested for performance. Such iteration can be cumbersome, even with the use of a computer. To minimize the number of iterations, a graphical evaluation of the developed inflow hydrographs is useful in approximating the storage volume and outlet configuration of a hypothetical detention pond that meets the performance requirements, prior to beginning the iteration process to finalize the design of a detention facility.

The following simplified example presents a graphical approach to approximating storage volume and outlet configuration.

1. Assume the following performance requirements (allowable release rates) and developed peak inflow rates have been noted from hydrographs generated for the purposes of sizing a standard on-site detention pond:

<u>Design Storm</u>	<u>Allowable Release</u>	<u>Developed Inflows</u>
2-year, 24-hour	$P_2Q_{rel} = 0.23$ cfs	$P_2Q_{dev} = 1.65$ cfs
10-year, 24-hour	$P_{10}Q_{rel} = 1.40$ cfs	$P_{10}Q_{dev} = 3.46$ cfs
100-year, 24-hour	$P_{100}Q_{rel} = 3.47$ cfs	$P_{100}Q_{dev} = 5.89$ cfs

Note: This example illustrates detaining the peak flows for the 2, 10, and 100-year, 24-hour duration design storms. The required performance for the 100-year

Figure III-1.8 Simplified Example of Inflow and Outflow Hydrograph

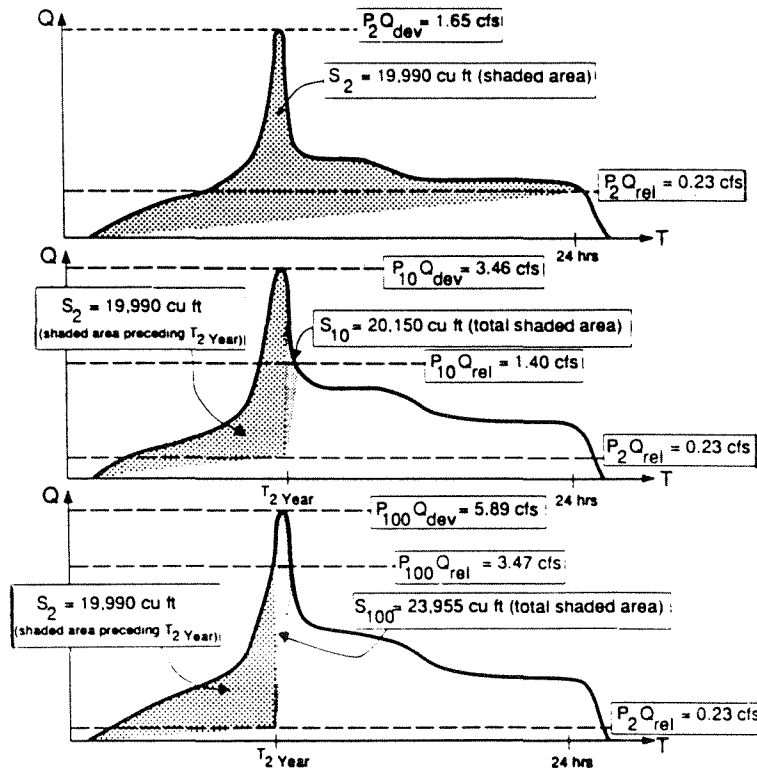
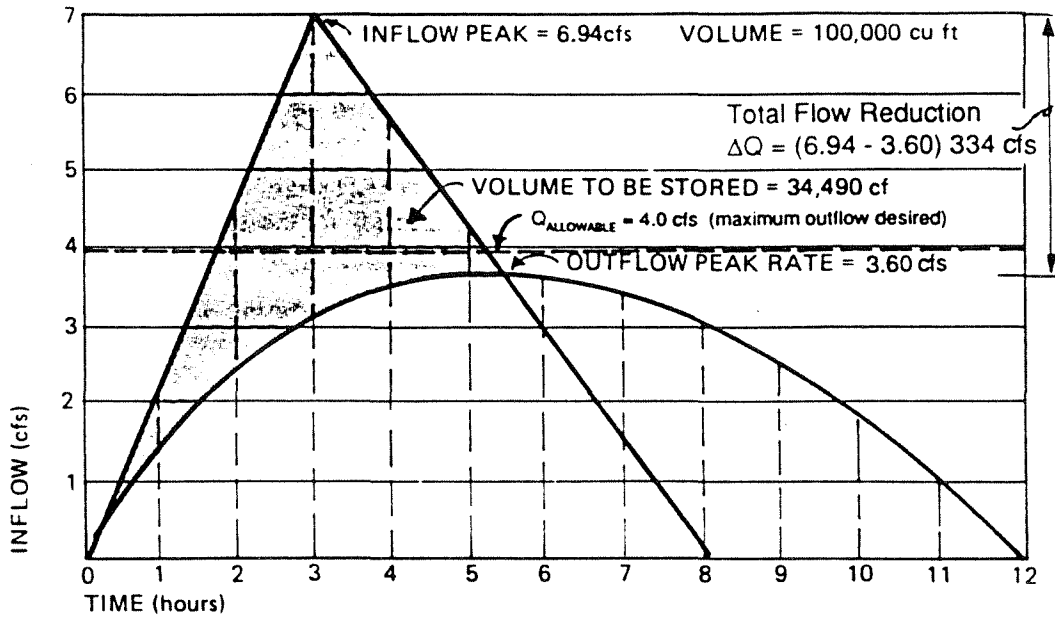


Figure III-1.9 Plots of the Developed Condition Inflow Hydrographs for the 2, 10, and 100-Year Design Storms

design storm may in some cases be more than the pre-developed flow rate depending on downstream conditions.

2. Plots of the developed inflow hydrographs are used to graphically approximate the detention storage required to achieve the performance.
3. Starting with the 2-year hydrograph, the 2-year allowable release rate ( $P_2Q_{rel}$ ) (which must not be exceeded) is plotted as a horizontal line extending from time zero to the point where it intercepts the falling limb of the hydrograph. A line is drawn from the beginning of the inflow hydrograph to this point. This line approximates the outflow rating curve of a control structure of a hypothetical detention facility which would restrict outflow to not exceed  $P_2Q_{rel}$  and thus approximates the rising limb of a hypothetical outflow hydrograph.
4. As in standard inflow-outflow hydrograph analysis, the area under the inflow hydrograph, less the area under the rising limb of the hypothetical outflow hydrograph, graphically approximates the amount of inflow which must be stored, detained and released once the inflow hydrograph falls below the allowable release rate. This volume of storage for the 2-year storm (as shaded) is termed  $S_2$  and can thus be approximated by measuring the area with a planimeter. In this example, the vertical scale is 1 inch = 0.936 cfs and the horizontal scale is: 1 inch = 5.65 hours, then for a planimetered area measurement of 1.05 sq. in.:  $S_2 = (1.05 \text{ sq. in.})(0.936 \text{ cfs/in.})(5.65 \text{ hrs./in.})(3600 \text{ sec./hr.})$  19,990 cu. ft.
5. The 10 and 100-year developed inflow hydrographs must now each be examined to determine which will require the most storage volume in addition to the 19,900 cu. ft. approximated for the 2-year storm. Note, the amount of storage volume needed to control the 10-year storm may exceed that of the 100-year when using this method. This occurs because the peak flows for the 10- and 100-year inflow hydrographs are similar in magnitude, and the difference between 10-year allowable release and developed peak rates can be substantially greater than for the 100-year. The interception point with the  $P_{10}Q_{rel}$  thus occurs further down the falling limb than for the 100-year, resulting in a larger storage volume required.

The 10 or 100-year allowable release rate ( $P_{10}Q_{rel}$  or  $P_{100}Q_{rel}$ ) (which must not be exceeded) is plotted as a horizontal line extending from time zero to the point where it intercepts the falling limb of the corresponding hydrograph.

By trial and error, the time ( $T_{2\text{-year}}$ ) at which the  $S_2$  volume occurs, while maintaining  $P_2Q_{rel}$ , is determined by planimeter. From this point, a line is drawn to connect to the  $P_{10}Q_{rel}$  or  $P_{100}Q_{rel}$  point on the falling limb. The area from time  $T_{2\text{-year}}$  under the inflow hydrograph to this point, less the area under the rising limb of the hypothetical outflow hydrograph (shown as the slender shaded triangle(s)), represents the additional storage volume needed to meet the required performance. The total storage volume  $S_{10}$  or  $S_{100}$  can then be computed by adding the additional storage volume to  $S_2$ .

6. From the storage volumes computed above, choose the largest of the three volumes for the initial pond sizing. In this case the 100-year volume,  $S_{100}$ , is the largest. Therefore, call it  $S_d$ .

$$S_d = 23,955 \text{ cu. ft.}$$

7. Estimate the bottom area,  $A_b$ , of the pond assuming 3:1 side slopes and a design depth,  $H_d$ , of 4 feet. The following equation may be used:

$$A_b = \left( \frac{(4(S_d/H_d) - 36H_d^2)}{2} - 3H_d \right)^2$$

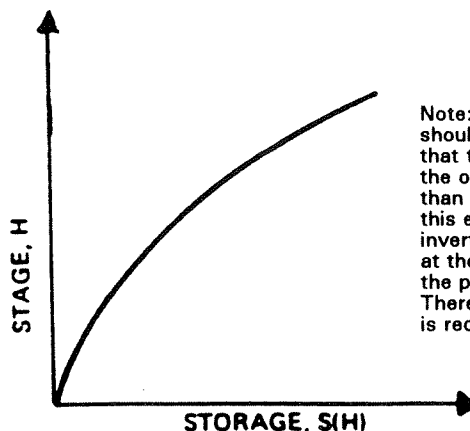
= 4154 sq. ft.

8. Compute the stage-storage curve using the following equation for ponds with 3:1 side slopes.

$$S(H) = 18H^3 + 6H^2 \sqrt{A_b} + A_b H$$

Figure III-1.10  
Stage - Storage Curve

Stage, H*	Storage, S(H)
0.0	0.0
0.5	2,176
1.0	4,559
1.5	7,162
2.0	9,999
2.5	13,083
3.0	16,428
3.5	20,048
4.0	23,955



Note: Stage Heights, H should be adjusted so that they measure from the outlet invert rather than the pond bottom. In this example, the outlet invert is assumed to be at the same elevation as the pond bottom. Therefore no adjustment is required.

**\*Note:** Stage heights, H, should be adjusted so that they measure from the outlet invert rather than the pond bottom. In this example, the outlet invert is assumed to be at the same elevation as the pond bottom. Therefore, no adjustment is required.

9. From the stage-storage curve, determine the depth, H, required for the 2-year storage volume.

For  $S_2 = 19,990$  cu. ft.;  $H_2 = 3.49$  feet

**Special Note:** It has been found through experience that usually only two orifices are necessary to meet 2, 10 and 100-year performance requirements. The bottom orifice is therefore sized to meet the 2-year performance requirement, while the top orifice is located above the 2-year water surface and is sized and situated such that both the 10-year and 100-year performance requirements are met. This is further illustrated as the example continues.

10. Size the bottom orifice for the 2-year allowable release,  $P_2 Q_{rel} = 0.23$  cfs, using the following derivation of the orifice equation:

$$Q = C a \sqrt{2g H} \quad \text{Standard orifice equation}$$

where:

- C = entrance loss coefficient = 0.62 (typ.)
- a = area of orifice =  $\pi d^2/4$ , where d = diameter of orifice
- g = acceleration of gravity = 32.2 ft/s<sup>2</sup>
- H = head on orifice

For 2-year allowable release:

$$P_2 Q_{rel} = 0.23 \text{ cfs}; \quad H_2 = 3.49 \text{ feet}$$

$$P_2 Q_{rel} = C a \sqrt{2g H_2}$$

rearranging to solve for a:

$$a = P_2 Q_{rel} / C \sqrt{2g H_2}$$

substituting for diameter:

$$d_b^2 / 4 = P_2 Q_{rel} / C \sqrt{2g H_2}$$

$$d_b^2 = 4 P_2 Q_{rel} / C \sqrt{2g H_2}$$

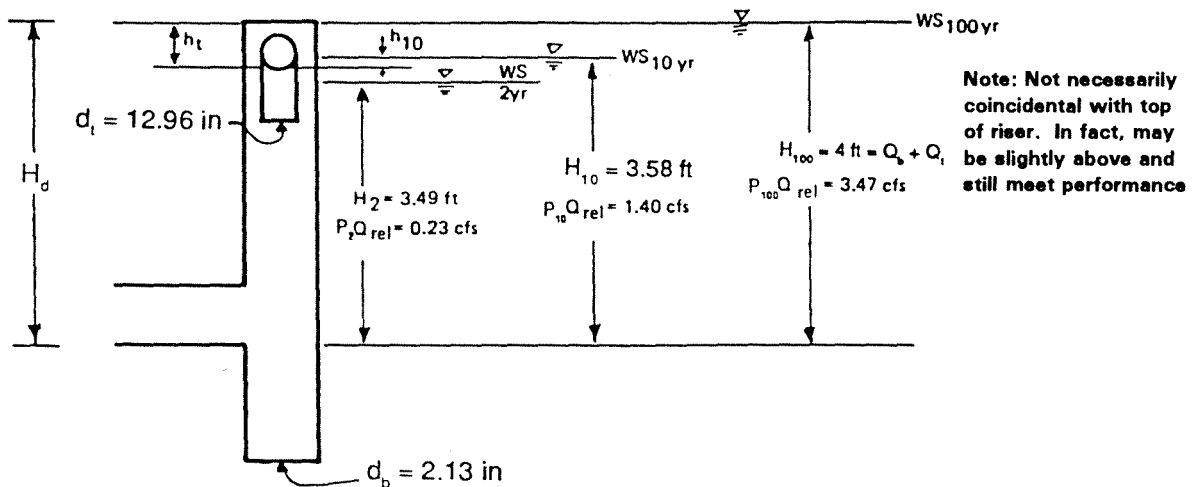
$$d_b = \sqrt{4 P_2 Q_{rel} / \pi C \sqrt{2g H_2}}$$

$$d_b = \sqrt{4(0.23) / (\pi)(0.62) \sqrt{2(32.2)(3.49)}}$$

$$d_b = 0.18 \text{ feet } (= 2.13 \text{ inches})$$

11. Sketch and consider the following flow control restrictor schematic:

Figure III-1.11 Flow Control Restrictor Schematic



12. Size and situate the top orifice at or above the 2-year water surface (WS 2-year). This may require some trial and error. The release rate for this orifice is:

$$Q_t = Q_{total} - Q_b, \text{ where } Q_{total} = 3.47 \text{ cfs (total flow at maximum head)}$$

$$Q_b = C A_o \sqrt{2gh} \quad \text{where } A_o = \pi d^2 / 4$$

$$d = 0.18 \text{ feet, thus } A_o = \pi (.18)^2 / 4 = 0.025 \text{ ft.}$$

$$h = 4 \text{ feet}$$

$$\therefore Q_b = 0.62(0.025) \sqrt{2(32.2)4} = 0.25 \text{ cfs}$$

$$Q_t = 3.47 \text{ cfs} - 0.25 \text{ cfs} = 3.22 \text{ cfs}$$

The size of this orifice will depend on its vertical location as specified by its head,  $h_t$ .  $h_t$  in this example, must be less than 0.51 feet so that the top orifice is above the 2-year water surface. Therefore, try  $h_t = 0.5$  feet:

$$\begin{aligned} \text{Top Orifice Diameter, } d_t &= \sqrt{\frac{4Qt}{\pi C \sqrt{2gh_t}}} \\ d_t &= \sqrt{\frac{4(3.22)}{\pi(0.62)\sqrt{2(32.2)(0.5)}}} \\ &= \underline{1.08 \text{ feet}} (= 12.96 \text{ inches}) \end{aligned}$$

13. Check for 10-year volume by:

a. Computing  $h_{10}$  (see Figure III-1.11)

$$\begin{aligned} h_{10} &= \left[ \frac{Q_{10} - Q_2}{CA_0} \right]^2 \cdot (2g)^{-1} \\ A_0 &= \pi d^2/4 \text{ where } d = 1.08 \text{ ft.}; A_0 = 0.92 \text{ ft.}^2 \\ h_{10} &= \left[ \frac{1.40 - 0.23}{0.62(0.92)} \right]^2 \cdot [2(32.2)]^{-1} = 0.07 \text{ ft.} \end{aligned}$$

b. Computing  $H_{10} = 3.49 \text{ feet} + 0.07 \text{ feet} = 3.56 \text{ feet}$

c. Check the stage-storage curve to see if there is sufficient volume at  $H_{10} = 3.56 \text{ feet}$ :

For  $H_{10} = 3.56 \text{ feet}$ :  $S(H) = 20,501 \text{ cu. ft.}$

Recalling  $s_{10} = 20,150 \text{ cu. ft.}$

20,501 cu. ft. > 20,150 cu. ft. okay

Note: Since the top-orifice size of 12.96 inches is too large to feasibly install in the upper 0.5 feet of the riser pipe, a notch weir must be substituted per details and equations given in Chapter III-2, Control Structures. Also, the 100-year water surface in this example is shown at the same elevation as the top of the riser. This will not necessarily be the case. In fact, it may be slightly above the riser and still meet performance.

The stage/storage/discharge information for a hypothetical detention facility developed above can then be used as a guide to design the actual detention facility. The design is checked using the "level pool routing" technique described at the beginning of this section. The stage/storage/discharge data from the actual facility design is used with each of the developed inflow hydrographs routed through the facility in order to demonstrate that the required performance is met.

The practical limits of orifice sizing may be between  $\frac{1}{2}$  inch and 1 inch in diameter. This could restrict the ability of small sites to satisfy some detention requirements. Local governments should pursue alternative detention requirements, such as the use of regional facilities (for a group of small lots, for example), for small sites. This is the point in the process where a number of iterations may be required in order to calibrate and optimize the actual facility design to meet performance with the minimal amount of storage volume. With experience and over time, techniques and methods will be developed that may assist the design engineer in this process. Ecology and local governments will inform the engineering community of these techniques and methods as they become available.

#### III-1.4.5 Hydrograph Summation and Phasing

One of the key advantages of hydrograph analysis is the ability to accurately describe the cumulative effect of runoff from several basins and/or subbasins having different runoff characteristics and travel times. This cumulative effect is best characterized



by a single hydrograph which is obtained by summing the individual hydrographs from tributary basins at a particular "discharge point of interest." The general procedure for performing a hydrograph summation is described below:

**Hydrograph Summation**

1. Select the "discharge point of interest" at which the hydrographs will be summed.
2. Estimate the time required for each hydrograph to travel from its point discharge to the "discharge point of interest." This travel time can be estimated using the methods presented in Section III-1.4.3 under "Travel Time and Time of Concentration."
3. Shift each hydrograph according to its travel time to the "discharge point of interest" as shown below in Figure III-1.12.
4. Sum the shifted hydrographs by adding the ordinate flow values at each time interval as shown below in Figure III-1.13.

Figure III-1.12 Shifting the Hydrographs Using Travel Time

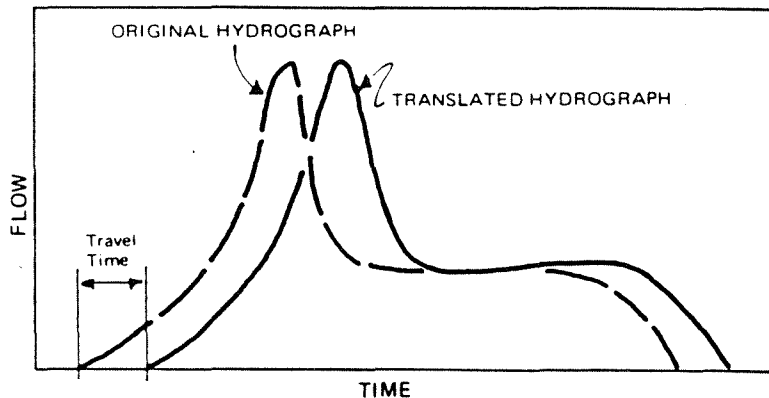
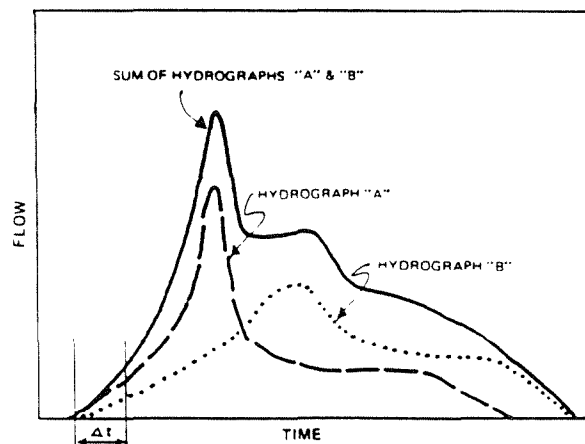


Figure III-1.13 Summing the Shifted Hydrographs



Note:  $\Delta t$  has been previously defined as 10 minutes or less for a 24-hour duration storm and 60 minutes for a 7-day duration storm.

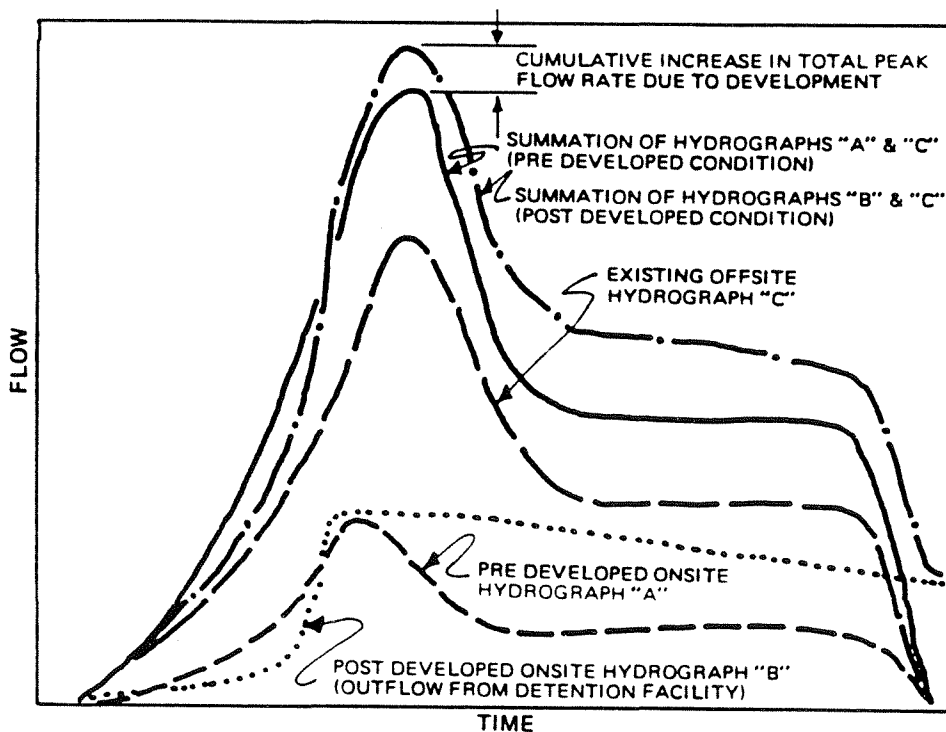
### Hydrograph Phasing Analysis

The ability to characterize cumulative effects through the summation of hydrographs provides a valuable tool for analyzing the interaction of on-site and off-site hydrographs both before and after development. This interaction of hydrographs is generally referred to as "hydrograph phasing" due to the similarity with compound wave-shapes. This hydrograph phasing analysis is required in order to determine the effect of the compound hydrograph shape on the downstream system.

The general procedure for performing a hydrograph phasing analysis is as follows:

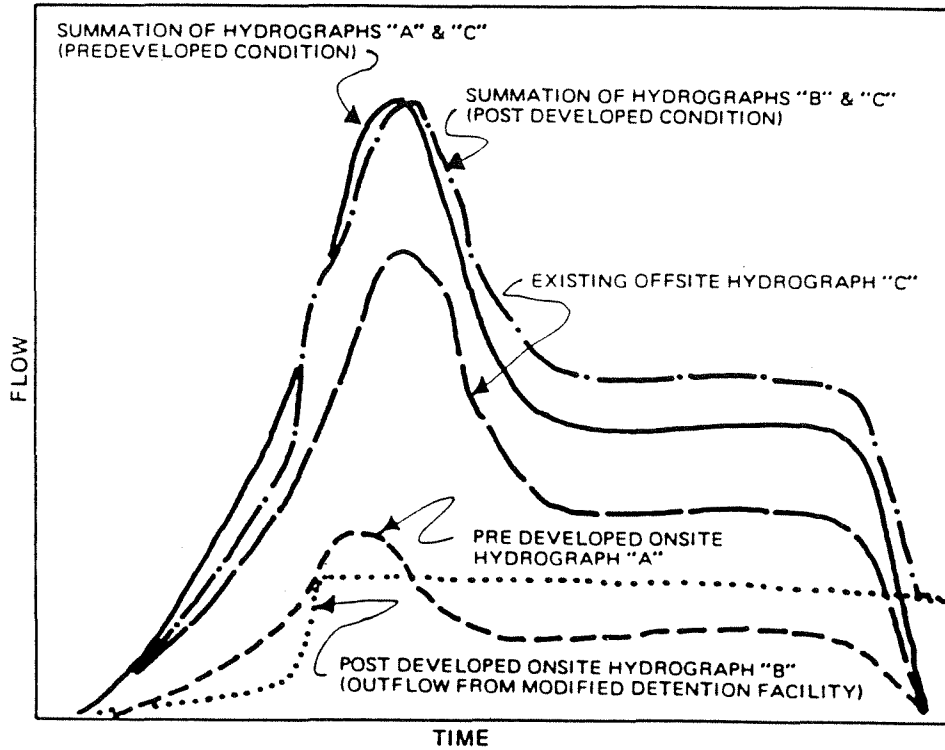
1. Select the "discharge point of interest" at which the on-site and off-site runoff hydrographs will be summed and compute travel times as explained under "Hydrograph Summation."
2. Compute the pre-developed on-site hydrograph and the existing off-site hydrograph for the design storm of interest. Shift and sum these hydrographs as explained under "Hydrograph Summation."
3. Compute the post-developed on-site hydrograph. If on-site detention is provided, this hydrograph will be the outflow hydrograph from the facility. Shift and sum this hydrograph with the existing off-site hydrograph.
4. Plot the above two summations as shown below to obtain a comparison of cumulative effects:

Figure III-1.14 Hydrograph Phasing Analysis



The above example plot illustrates how a development with standard on-site detention can cause an increase in peak flow at some point downstream. If this is the case, the local government shall require this condition be addressed by reducing the release rate from the detention facility such that the cumulative effect downstream is negligible as shown in the plot below:

Figure III-1.15 Reducing the Release Rate to Decrease Downstream Effects



III-1.4.6 Computer Applications

SBUH Method and Level Pool Routing

The computations required to generate the runoff hydrographs and perform the level pool routing techniques presented in this chapter can be performed manually. However, due to their volume and repetitive nature, a programmable calculator and/or a personal computer will perform these computations much quicker and with a likely higher degree of accuracy. Because of the familiarity that practicing engineers have with either a programmable calculator or a personal computer, they are encouraged to write their own routines to perform the hydrograph analysis.

## Computer Models

Local governments may make available programs and application templates developed in-house. These will likely be available on a "make-your-own-copy basis" and will be provided with minimal documentation and no formal support. Software developers are preparing programs that they plan to market and support. Local governments will maintain a list of these programs as they are approved by them for use.

### III-1.5 CLOSED DEPRESSION ANALYSIS

The analysis of closed depressions requires careful assessment of the existing hydrologic performance in order to evaluate the impacts a proposed project will have. The applicable requirements, (see Minimum Requirement #7) and the local government's Sensitive Areas Ordinance and Rules (if applicable) should be thoroughly reviewed prior to proceeding with the analysis.

#### Analysis and Design Criteria

The infiltration rates used in the analysis of closed depressions shall be determined according to the procedures in Chapter III-3. A minimum of four surface tests shall be performed to prepare an average surface infiltration rate based on the following criteria:

1. For closed depressions containing standing water, soil texture tests shall be performed on dry land adjacent to, and on opposite sides of the standing water (as is feasible), such that the elevation of the testing surface at the bottom of the test pit is one foot above the standing water elevation.
2. For closed depressions without standing water, infiltration rate tests shall be performed in the bottom of the closed depression at locations of similar elevation, and on opposite sides of the bottom area (as is feasible), such that the elevation of the testing surface at the bottom of the test pits is at least one foot above any observed ground water table.

Projects proposing to modify or compensate for replacement storage in a closed depression shall meet the design criteria for detention ponds as described in Chapter III-4.

#### Method of Analysis

Closed depressions are analyzed using hydrographs routed as described in Section III-1.4.4 "Hydrograph Routing." Infiltration shall be addressed where appropriate. In assessing the impacts of a proposed project on the performance of a closed depression there are three cases that dictate different applications of the performance standard as follows:

##### 1. CASE 1:

The 100-year, 7-day duration design storm flow from the drainage basin tributary to the closed depression is routed into the closed depression using only infiltration as outflow. If runoff does not overflow the closed depression, then no runoff may leave the closed depression for the 100-year, 7-day duration design storm following development of a proposed project. This may be accomplished by excavating additional storage volume in the closed depression (subject to all applicable requirements, for example providing a defined overflow system).

##### 2. CASE 2:

The 100-year, 7-day duration design storm flow from the drainage basin tributary to the closed depression is routed into the closed depression using only infiltration as

outflow. If runoff does overflow the closed depression, then the 100-year, 24-hour duration design storm flow from the drainage basin tributary to the closed depression is routed into the closed depression using only infiltration as outflow. If this does not cause outflow, then the allowable release rate is that which occurred for the 100-year, 7-day duration design storm. This performance can be met by excavating additional storage volume in the closed depression (subject to all applicable requirements, for example providing a defined overflow system).

### 3. CASE 3:

The 100-year, 7-day duration design storm flow and the 100-year, 24-hour duration design storm flow from the drainage basin tributary to the closed depression are routed into the closed depression using only infiltration as outflow, and both cause overflow to occur. Then the closed depression shall be analyzed as a detention/infiltration pond. The required performance, therefore, is to not exceed the existing runoff rates for the 2, 10, and 100-year, 24-hour duration and 100-year, 7-day duration design storms. This will require that a control structure, emergency overflow spillway, access road, and other design criteria described in Chapter III-4 be met and, if it is to be maintained by the local government, the closed depression placed in a tract dedicated to the local government. If it is to be privately maintained, it must be located in a drainage easement dedicated to the public.

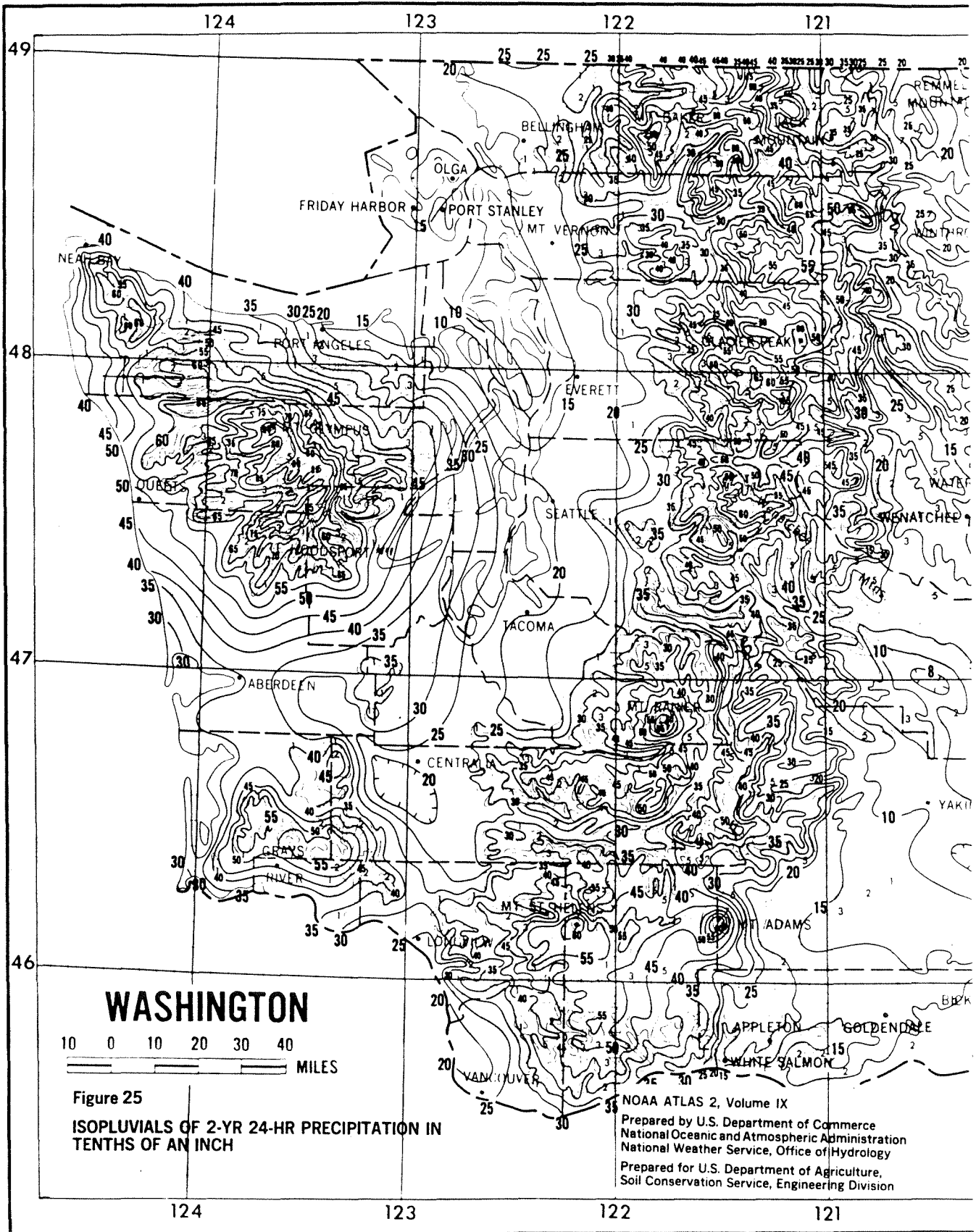
### III-1.6 REFERENCES

- (1) USDA-SCS, Technical Release No. 20 (TR-20) Model Project Formulation, 1982.
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- (3) Huber, Wayne, and Robert Dickinson, Stormwater Management Model Version 4 Part A: User's Manual, Environmental Research Laboratory, Athens, GA, 1988.
- (4) Dinacola, R.S., Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington, USGS Water Resources Investigations Report 89-4052, 1989.
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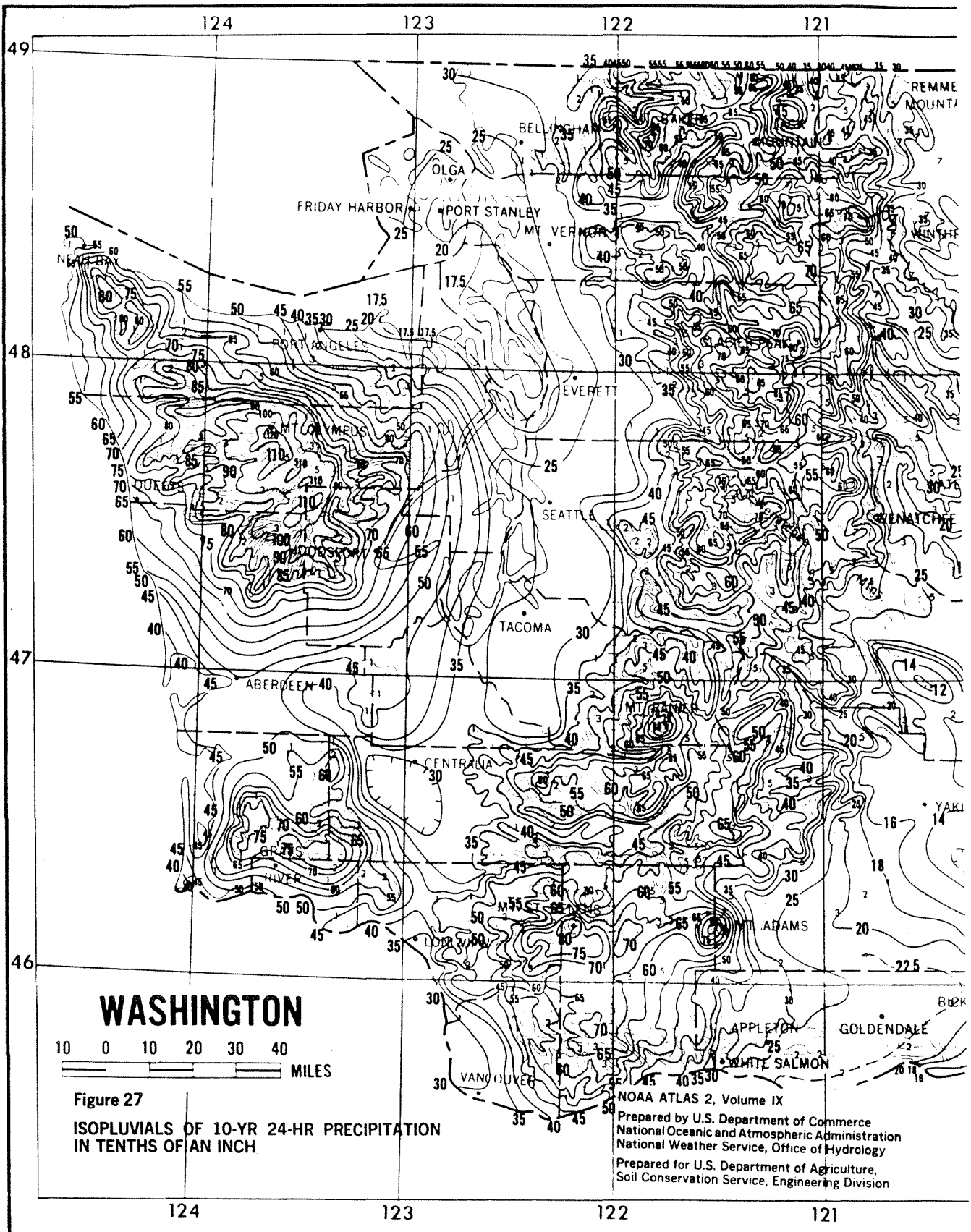
APPENDIX AIII-1.1

ISOPLUVIAL MAPS FOR DESIGN STORMS

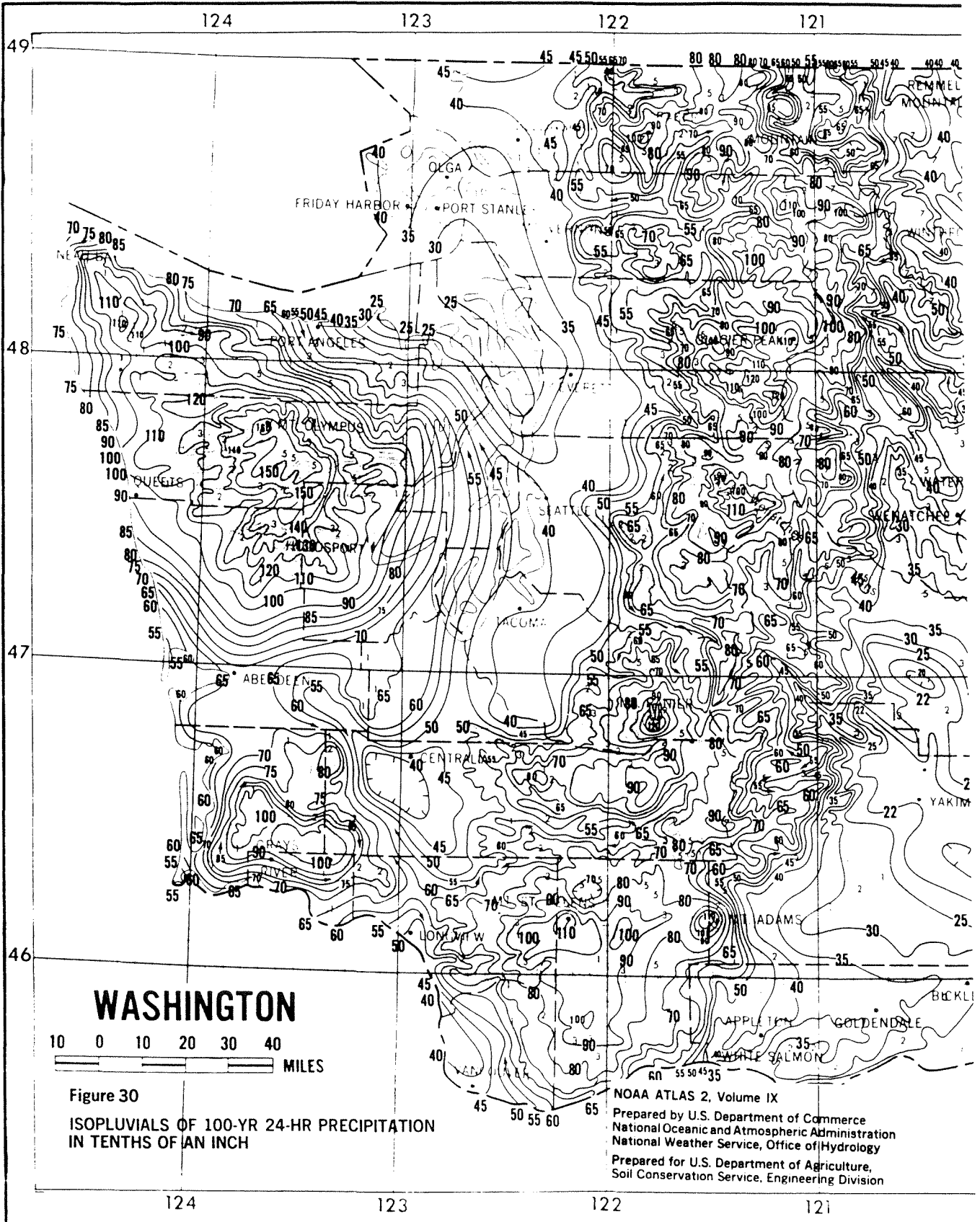
Included in this appendix are the 2, 10 and 100-year, 24-hour design storm and mean annual precipitation isopluvial maps for the Puget Sound basin. These have been taken from NOAA Atlas 2 "Precipitation - Frequency Atlas of the Western United States, Volume IX, Washington.

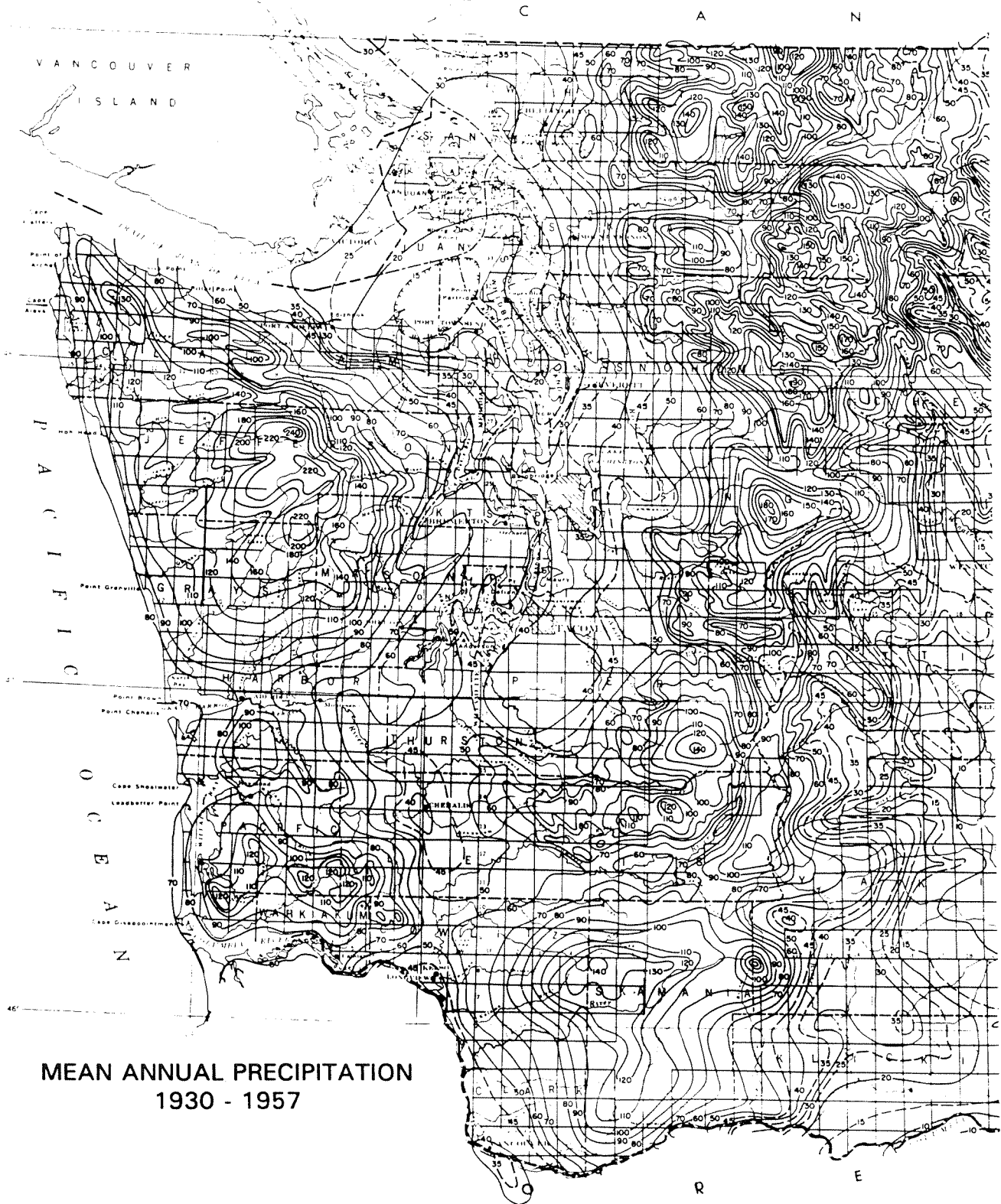


STORMWATER MANAGEMENT MANUAL FOR THE PUGET SOUND BASIN









MEAN ANNUAL PRECIPITATION  
1930 - 1957

APPENDIX AIII-1.2

PERFORMANCE OF DETENTION PONDS DESIGNED ACCORDING TO CURRENT STANDARDS

Bruce L. Barker, Ralph D. Nelson P.E., and Mark S. Wigmosta

Introduction

On-site detention has been widely adopted as a means to control the increased rate of runoff from urbanized areas. When an area is developed, a detention pond or vault is constructed to reduce the increased flows with urbanization. Past detention standards and design methods have not been adequate to mitigate these increased flows in King County. The sediment and pollutants associated with higher flows are ultimately deposited in Puget Sound. Thus, the proper functioning of detention ponds in urban areas is critical to the protection of stream systems and the water quality in Puget Sound.

Recent field data and new computer modeling suggest that the existing methods of detention pond design are not adequate for the hydrologic conditions found in the Puget Sound area. Peak flow releases from detention ponds designed under current standards were found to increase substantially over undeveloped conditions. This indicates that mitigation for development has not been adequate to date, and furthermore, the volume to fully mitigate peak flows with detention is actually much greater than the current methods estimate.

Detention Standards and Methods in King County

Rational Methods

In King County, the detention of stormwater runoff was first mandated by the Storm Drainage Control Manual (King County, 1979). The requirements in the manual focused on flood control. Ponds were typically designed such that post-developed 10-year flows were reduced to pre-developed 10-year flow levels (10-year standard). The method recommended for design was the Yrjanainen and Warren (Y&W) method with peak runoff rates based on the rational method. In 1985, an amendment was made requiring multiple orifices with the intent to control a greater range of flows.

In 1987, King County conducted a field survey (King County, 1987) of the streams in urbanizing areas and found substantial damage in urban areas with on-site detention ponds designed according to 1979 standards. The cause of damage was three-fold. First, drainage facilities were not being maintained properly; second, inspection during construction was inadequate; and third, the methods of design did not adequately protect the stream systems from erosion.

While many of these facilities were not functioning properly because of poor design and maintenance, the ponds having better design and maintenance failed to protect the stream system from flooding and most notably, erosion.

Single Event Methods

Recently, more stringent detention standards have been adopted in an attempt to prevent further degradation of streams. The King County Surface Water Design Manual (King County, 1989) requires that post-developed 2 and 10-year flows be reduced to pre-developed 2 and 10-year levels respectively with the resulting pond volume increased by a 30% safety factor (1.3(2-10 year)standard). The inclusion of more frequent events (2-year) in addition to the 10-year events was intended to reduce the amount of erosion by the more frequent storms. The approved design event methodology is the single event approach. The manual recommends the use of the Santa Barbara Urban Hydrograph (SBUH) method (Stubchaer, 1975), which incorporates much of the Soil Conservation Service (SCS, 1972) approach.

Other standards required by King County have sought to address, for example, the increased flow volume in addition to the peak flow. A standards recommended by the Bear Creek Basin Plan (King County, 1990) recommends that the 2, 10 and 100-year flows be reduced to pre-developed  $\frac{1}{2}$  of the 2, 2 and 10-year flows respectively (the "stream protection standard").

Use of a Continuous Simulation Model to Quantify Pond Performance

The performance of detention ponds designed to existing standards was tested using the Hydrological Simulation Program - Fortran (HSPF) (U.S. EPA, 1984). This model uses mathematical relationships to describe the physical processes controlling the hydrology of the watershed. Using inputs of precipitation and evaporation, HSPF computes the amount of discharge to the creek continuously through time from surface, shallow sub-surface, and ground water flow.

The HSPF model was calibrated to stream systems in urbanizing King and Snohomish Counties by the USGS (USGS, 1990). Using the calibrated model, a 39-year continuous record of rainfall collected at the Seattle-Tacoma Airport station was used to create a 39-year series of flows from hypothetical but typical site developments. The flows computed by HSPF were then routed through the detention ponds designed according to current methods and the resulting performance assessed. Return periods for the discharge from each pond tested were computed using a Log-Pearson analysis (WRC, 1977).

A total of 12 different detention ponds representing six different methods and standards, and two different land uses were evaluated in the tests. The design methods included the Y&W and SBUH methods. Pond release standards and design methods are summarized in Table A1.

Table A1  
Detention Pond Designs Tested

Detention Pond	Design Method	Release Standard
1979 Design Manual	Y&W	10-year single orifice
1979 Design Manual	Y&W	10-year multiple orifice
1989 Design Manual	SBUH 24-hour event	1.3 (2-10-year)
1990 Bear Creek Standard	SBUH 24-hour event	Stream protection

The ponds were sized for 25 and 50 acre site conversions of forest to commercial and residential land uses on till soils. The commercial site is assumed to be 100% impervious and the residential site is assumed to be 23% impervious with the remaining area covered by grass.

Simulated Pond Performance

Existing Methods and Standards

The different methods and standards evaluated for the tests produced a wide range of pond volumes (Table 2). It is clear that the 1989 Design Manual Standard provides substantially more detention volume than past standards. This increased volume is reflected in the performance of each detention pond.

Figure AIII-2.1

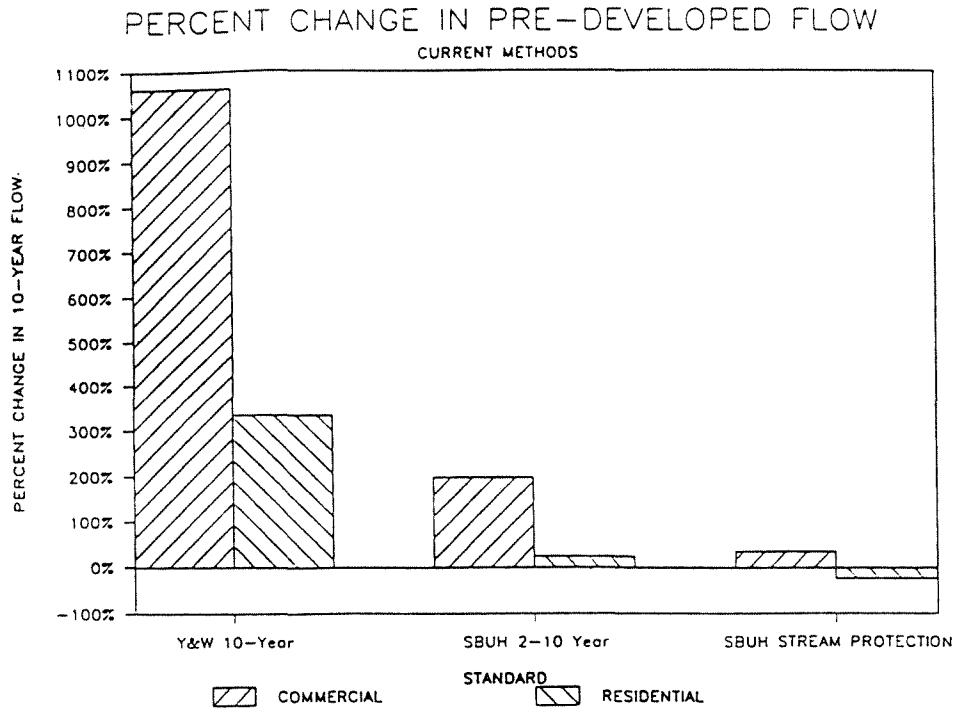


FIGURE 2

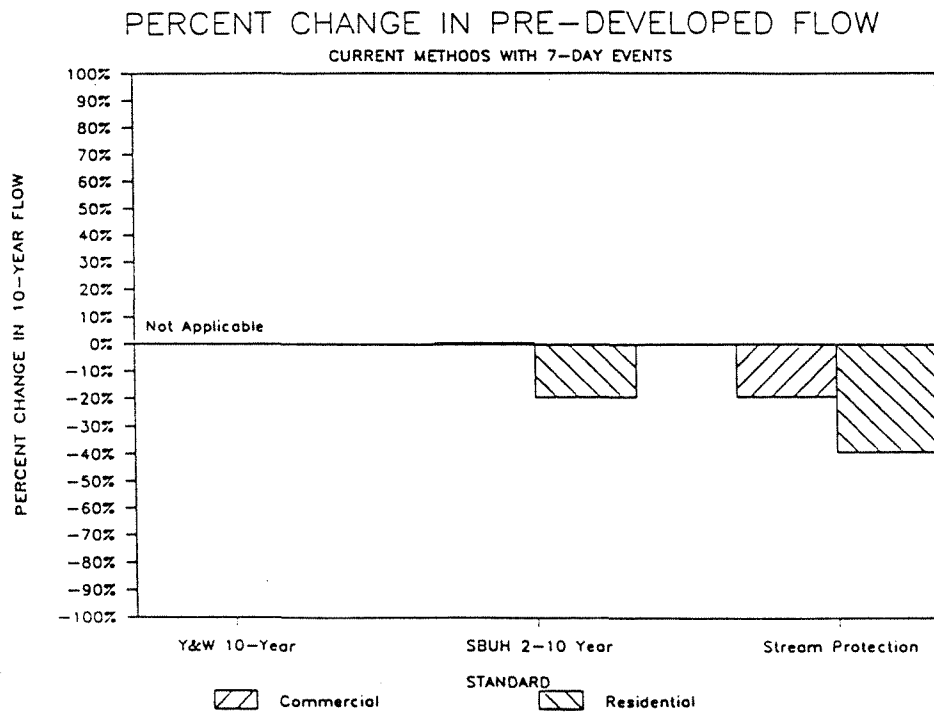


Figure AIII-2.2

Table A2  
Detention Volumes From Current Design Methods

Detention Pond	Volume (Inches)	
	Commercial	Residential
1979 Design Manual	0.51	0.19
1989 Design Manual	1.99	1.19
Bear Creek Standard	3.69	2.72

Figure 1 compares the performance of the detention ponds tested for a forested site converted to commercial and residential land uses. The ponds designed according to the 1979 manual performed the worst with 10-year flows from the commercial site pond increasing by a factor of 10 over pre-developed levels. Ponds designed according to the 1989 Design Manual performed substantially better with the 10-year flows from the commercial site increasing by a factor of 2 over pre-developed levels. Flows from the pond designed to the Bear Creek stream protection standard, which is intended to control 10-year flows to a 2-year pre-developed flow level, also increased by 30% over pre-developed 10-year levels. Overall, ponds designed for residential development densities performed better than the commercial sites. Flows from the 1979 manual, 1989 manual, and Stream Protection ponds changes by 350%, 20% and -10% respectively.

The generally poor performance is the result of the ponds filling and overtopping at a frequency greater than the design storm. The reason for this is the inherent assumption in any event-based design that the pond is empty when an event begins. Because pre-developed runoff rates in the Puget Sound area are low relative to post-developed rates, the ponds drain slowly and contain water for many consecutive days during the winter. Thus, when a large event occurs, the full pond volume is not available and the pond overtops. When a detention pond is full, pond inflows are not detained, and the pond outflow nearly equals the inflow, increasing the potential for downstream flooding and erosion.

The multiple orifice configuration tended to increase the time for the pond to drain, thus making it more susceptible to overtopping than the ponds designed with a single orifice.

Additional Volume Required to Control Peak Flows

Examination of discharge hydrographs from the ponds designed according to the SBUH method indicates that it takes from five to ten days to reach maximum discharge during a storm event. Therefore, the design storm event, or design series of events, should be of similar length.

The simulated ponds designed by the SBUH method were redesigned using a 7-day event in an effort to improve pond performance. A 7-day duration design storm based on a modified distribution developed by Schaefer (1990) was used. The performance of ponds designed with this 7-day storm are shown in Figure 2 for two design standards. The pond designed to the 2-10 standard matches the pre-developed peak flow, and the pond designed with the stream protection standard did not overtop during the simulation period. This indicates the ponds were performing as designed.

The ponds sized with the 7-day event produce detention ponds that are larger than the volumes determined by existing standards having obvious implications for development costs. For example, a commercial development pond requires 50% more detention with a 2-10 release standard, and 57% more storage with a stream protection release standard over existing design methodology. The increased detention storage is considerably less with residential developments. The increase

is approximately 23% with a pond release rate of 2-10, and 14% with a stream protection standard.

#### Summary

Past on-site design methodology has not been effective at controlling increased flows associated with urbanization. Increased flows have caused flooding and erosion damage to stream systems. These increased flows transport sediment and pollutants to Puget Sound, which is the final receiving body for streams in King County.

The performance of detention ponds designed according to various standards indicates that none of the methods or standards that have been used in King County to date reduce flows to the design level. The underlying cause of this is the assumption that the ponds are empty when the storm event begins. The continuous model shows this not to be the case, with the ponds designed according to event methods operating partially full for periods of several consecutive days at a time throughout the winter.

The pond performance was improved by designing the ponds using a longer design storm. This storm was chosen to be 7 days to match the apparent length of time ponds drain in the winter. The ponds designed with the 7-day event matched the design goals. However, they were considerably larger than ponds designed by current standards, 50% for commercial ponds and 20% for residential ponds.

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CHAPTER III-2  
CONVEYANCE SYSTEMS

**III-2.1 PURPOSE AND SCOPE**

This chapter presents acceptable methods for the analysis and design of conveyance systems. It also includes a section on control structures, or catchbasins, which link the conveyance system to the runoff treatment and streambank erosion control BMPs. The reader is referenced also to Chapter III-1, which provides details on hydrologic analysis methods, and to Chapters III-3 through III-8, which present acceptable methods for analysis and design of infiltration systems, detention facilities, and other water quality facilities. Before proceeding with analysis and design of these systems and facilities, and drainage plan and design, the design engineer should thoroughly review the site specific stormwater management plan requirements as set forth in Chapters I-2 and I-3.

Each of the sections in this chapter contain the methods of analysis, design criteria, and standard details for the various systems or facilities. They are organized with basically similar formats to provide consistency and quick reference to information. They may include:

- An Overview of topic and purpose.
- Design Guidelines and criteria for system design and alternative system applications.
- Site Constraints such as easement requirements, building setbacks, etc.
- Subsections with most containing the following information:
  - An introduction to the topic.
  - Specific Design Criteria such as acceptable materials, maximum slopes, geometrics, etc.
  - Methods of Analysis for hydraulic system design including standard charts, nomographs, tables, etc. and reference to applicable material.
  - Standard Details are provided or referenced in other publications.

**III-2.2 GENERAL DESIGN CRITERIA**

This manual and the local government's Road Standards provide established standards for engineering design, suitability of purpose, and method of analysis. The Washington State Department of Transportation/APWA (WSDOT/APWA) Standard Specifications for Road, Bridge, and Municipal Construction, most recent edition, also provides approved specifications and standards for design and construction.

**III-2.3 CONVEYANCE SYSTEM DESIGN AND ANALYSIS**

III-2.3.1 Overview

A conveyance system includes all portions of the surface water system, either natural or man-made, that transport storm and surface water runoff. The purpose of the conveyance system is to drain surface water from properties, up to a specific design flow, so as to provide protection to property and the environment.

A properly designed pipe system will maximize hydraulic efficiency by utilizing proper material, slope, and pipe size. An ideal channel section will be sized to provide adequate capacity for design flows while minimizing erosion and allowing for aesthetics, habitat preservation, and enhancement of water quality.

A man-made conveyance system should emulate the natural conveyance system to the extent feasible. Inflow to the system and discharge from the system should occur at the natural drainage points as determined by topography and existing drainage patterns.

Conveyance systems can be separated into the following five categories:

- Pipe systems
- Culverts
- Outfalls
- Open channels
- Floodplains/floodways

Open, vegetated channels are the preferred method of conveyance. The vegetation will help keep the channel from eroding, and can provide some amount of water quality treatment. Open channels also simplify tracing illegal dumping when it occurs.

#### III-2.3.2 Analysis and Route Design Requirements

##### Analysis

- All existing and proposed conveyance systems shall be analyzed and designed using the peak flows from the hydrographs developed using the procedures described in Chapter III-1.

##### Route Design

- The most efficient route selected for new conveyance systems will result from careful consideration of the topography of the area to be traversed and the legal property boundaries.
- Unless topography prohibits, new conveyance system alignments on private property must be located in drainage easements that are adjacent and parallel to property lines and are not split between adjacent properties.

**Exception:** Streams and natural drainage channels will not be relocated strictly to meet this requirement.

- Aesthetic considerations and traffic routes may dictate the placement and alignment of open channels. Appropriate vehicular and pedestrian traffic crossings must be provided in the design.

##### Easements and Building Setback Lines

- All public and privately maintained conveyance systems shall be located in drainage easements in accordance with requirements of the local government.

**Exception:** Roof downspout, minor yard and footing drains unless they serve other adjacent properties.

### III-2.3.3 Pipe Systems

Pipe systems are networks of storm drain pipes, catchbasins, manholes, inlets, and outfalls designed and constructed to convey storm and surface water. The hydraulic analysis of flow in storm drain pipes typically is limited to "gravity flow"; however, in analyzing existing systems it may be necessary to address pressurized conditions. Pump systems shall be designed using the hydraulic methods which apply to sanitary sewer pump systems.

#### Design Criteria for Pipe Systems

- (1) Pipe material, joints, and protective treatment shall be in accordance with WSDOT/APWA Standard Specifications Section 9.05 and AASHTO and ASTM treatment standards. Galvanized pipe is not recommended because of its tendency to leach zinc to the environment.
- (2) Pipe Sizes, Slopes, and Velocities
  - Pipe sizes and lengths, minimum slopes and velocities and design flow by structure shall be according to Washington Department of Ecology "Criteria for Sewage Works Design" or local government standards, whichever is the more stringent.
  - Change of Pipe Size (does not apply to detention tanks):
    - Changes of pipe size (increase or decrease) are allowed only at junctions, and structures must be located at all junctions. (Exceptions may be allowed by the local government's Road Standards.)
    - Downsizing of pipes is not a recommended practice and should only be allowed under special conditions (i.e. no hydraulic jump can occur; downstream pipe slope is significantly greater than the upstream slope; significant cost savings can be realized; velocities remain in the 3 - 8 fps range, etc.)
- (3) Structures
  - Table III-2.1 presents the allowable structures and pipe sizes allowed by size of structure.
  - The methods described in Chapter 5, Sections 4 and 5, of the Washington State Department of Transportation (WSDOT) Hydraulics Manual can be used in determining the capacity of inlet grates when capacity is of concern with the following exceptions:
    - Use design peak flows as required in Chapter III-1 of this manual.
    - Assume grate areas on slopes are 80 percent free of debris. "Vaned" grates, 95%.
    - Assume grate areas in sags or low spots are 50 percent free of debris. "Vaned" grates, 75%.
  - Catchbasin (or manhole) diameter shall be determined by pipe orientation at the junction structure. A plan view of the junction structure, drawn to scale, will be required when more than four pipes enter the structure on the same plane, or if angles of approach and clearance between pipes is of concern. The plan view (and sections if necessary) must insure a minimum distance (of solid concrete wall) between pipe openings of 8 inches for

48 inch and 54 inch catchbasins and 12 inches for 72 inch and 96 inch catchbasins.

Catchbasin evaluation of structural integrity for H-20 loading may be required for multiple junction catchbasins and other structures.

- Catchbasins shall be provided within 50 feet of the entrance to a pipe system to provide for silt and debris removal.
- HDPP pipe systems longer than 100 feet must be secured at the upstream end and the downstream end placed in a 4 foot section of the next larger pipe size. This sliding sleeve connection allows for the high thermal expansion/contraction coefficient of this pipe material.
- The maximum slope of the ground surface for a radius of 5 feet around a catchbasin grate shall be 3:1.

Table III-2.1 Allowable Structures and Pipe Sizes

Catchbasin Type(1)	Maximum Pipe Diameter	
	(2)CMP, Spiral Rib CPEP, HDPP, PVC (Inches)	Concrete and Ductile Iron (Inches)
Inlet(4)	12	12
Type 1(3)	18	12
Type 1L(3)	24	18
Type 2-48-inch dia.	30	24
Type 2-54-inch dia.	36	30
Type 2-72-inch dia.	54	48
Type 2-96-inch dia.	72	72

- (1) Catchbasins, including manhole steps, ladder, and handholds shall conform to the local government's Road Standards.
- (2) Generally these pipe materials will be one size larger than concrete due to smaller wall thickness. However, for angled connections or those with several pipes on the same plane, this will not apply.
- (3) Maximum 5 vertical feet allowed between grate and invert elevation.
- (4) Normally allowed only for use in privately maintained drainage systems and must discharge to a C.B. immediately downstream.

(4) Pipe Alignment/Connections/Cover

- Pipes must be laid true to line and grade with no curves, bends, or deflections in any direction [except for HDPP and Ductile Iron with flanged restrained

mechanical joint bends (not greater than 30°) on steep slopes].

- A break in grade or alignment or changes in pipe material shall occur only at catchbasins or manholes.
- Connections to a pipe system shall be made only at catchbasins or manholes. No wyes or tees are allowed except on roof/footing/yard drain systems on pipes 8 in. in diameter, or less, with clean-outs upstream of each wye or tee. Additional exceptions may be made by the local government.
- Provide 6 inches minimum vertical and 3 feet minimum horizontal clearance (outside surfaces) between storm drain pipes and other utility pipes and conduits. For crossings of sanitary sewer lines the Washington Department of Ecology criteria will apply. Note that for pipe diameters less than 12 inches in diameter (when not listed in these tables), use the cover specifications for the 12 inch diameter pipes.
- Pipe cover over storm pipes in local government road rights-of-way shall be per the Road Standards of the local government. Pipe cover is measured from the finished grade elevation down to the top of the outside surface of the pipe. Under collection roadways, driveways, parking stalls, or other areas subject to light vehicular loading, pipe cover may be reduced to a 1-foot minimum if recommended by pipe manufacturers.
- Pipecover in areas not subject to vehicular loads, such as landscape planters and yards, may be reduced to a 1 foot minimum.

#### (5) Debris Barriers

Debris barriers (trash racks) are required on all pipes entering a closed pipe system. See Figure III-2.8 for required debris barrier on pipe ends outside of roadways. See Figure III-2.10 and Section III-2.3.4 for requirements on pipe ends (culverts) projecting from driveways or roadway sideslopes.

#### (6) Drainage Easements

Drainage easements are required for maintenance and access over pipes located outside of the road right-of-way (see local government requirements), except downspout roof drains, yard drains, and footing drains.

### Methods of Analysis

Two methods of hydraulic analysis using Manning's equation are used for the analysis of pipe systems. The first method is the Uniform Flow Analysis Method and is used for the preliminary design of new pipe systems. The second method is the Backwater Analysis Method and is used to analyze the capacity of both proposed, and existing, pipe systems.

#### (1) Uniform Flow Analysis Method

Used for the preliminary sizing of new pipe systems to convey the peak rate of runoff for the 25-year design storm event.

#### Assumptions:

- Flow is uniform in each pipe (i.e., depth and velocity remain constant throughout the pipe for a given flow).
- Friction head loss in the pipe barrel alone controls capacity. Other head losses (i.e., entrance, exit, junction, etc.) and any backwater effects or

inlet control conditions, which may be present or anticipated in the system, are not specifically addressed.

Each pipe within the system is sized and sloped such that its barrel capacity at normal full flow (computed by Manning's Equation) is equal to or greater than the 25-Year design flow. The nomograph in Figure III-2.1 can be used for an approximate solution of Manning's Equation. For more precise results, or for partial pipe full conditions, solve Manning's Equation directly:

$$V = \frac{1.49 R^{2/3} s^{1/2}}{n}$$

or, using the continuity equation,  $Q = AV$

$$Q = \frac{1.49 AR^{2/3} s^{1/2}}{n}$$

where:

- Q = Discharge in cfs
- V = Velocity in fps
- A = Area in ft<sup>2</sup>
- n = Manning's roughness coefficient in s-ft<sup>1/6</sup> (see Table III-2.2)
- R = Hydraulic radius = area/wetted perimeter, in ft.
- s = Slope of the energy grade line in ft/ft

For pipes flowing partially full, the actual velocity may be estimated from the hydraulic properties shown in Figure III-2.1 by calculating  $Q_{full}$  and  $V_{full}$  and using the ratio of  $Q_{design}/Q_{full}$  to find V and d (depth of flow).

Table III-2.2 provides the recommended Manning's "n" values for preliminary design using the Uniform Flow Analysis Method for pipe systems. (Note, the "n" values for this method are 15% higher in order to account entrance, exit, junction, and bend head losses.)

Table III-2.2 Manning's "n" Values for Pipes

Type of Pipe Material	Analysis Method	
	Backwater Flow	Uniform Flow
A. Concrete pipe and CPEP-smooth interior pipe	0.014	0.012
B. Annular Corrugated Metal Pipe or Pipe Arch: 1.2-2/3" x 1/2" corrugation (riveted)		
a. plain or fully coated	0.028	0.024
b. paved invert (40% of circumference paved):		
(1) flow full depth	0.021	0.018
(2) flow 0.8 depth	0.018	0.016
(3) flow 0.6 depth	0.015	0.013
c. treatment 5	0.015	0.013
2.3" x 1" corrugation	0.031	0.027
3.6" x 2" corrugation (field bolted)	0.035	0.030
C. Helical 2-2/3" x 1/2" corrugation and CPEP-single wall	0.028	0.024
D. Spiral rib metal pipe and PVC pipe	0.013	0.011
E. Ductile iron pipe cement lined	0.014	0.012
F. High density polyethylene pipe (butt fused only)	0.009	0.009

## (2) Backwater Analysis Method

Used to analyze the capacity of both proposed and existing pipe systems to convey the peak rate of runoff for the 25, and 100-year design storm events (Note, structures for proposed pipe systems must be demonstrated to provide a minimum of 0.5 feet of freeboard between the headwater surface (hydraulic grade line) and the top of the structure for the 25-year peak rate of runoff. Structures may overtop for the 100-year peak rate of runoff. When overtopping occurs for the 100-year peak rate of runoff, the additional flow over the ground surface is analyzed using the methods described in Section III-2.3.6 and added to the flow capacity of the pipe system determined, as described below.)

This method is used to compute a simple backwater profile (hydraulic grade line) through a proposed, or existing, pipe system for the purposes of verifying adequate capacity. It incorporates a rearranged form of Manning's Equation expressed in terms of friction slope (i.e., slope of the energy grade line in ft/ft). The friction slope is used to determine the head losses to obtain water surface elevations at all structures along the pipe system.

The backwater analysis begins at the downstream end of the pipe system and is computed back through each pipe segment and structure upstream. The friction, entrance and exit head losses computed for each pipe segment are added to that segment's tailwater elevation (the water surface elevation at the pipe's outlet) to obtain its "outlet control" headwater elevation. This elevation is then compared with the "inlet control" headwater elevation, computed assuming the pipe's inlet alone is controlling capacity using the methods for inlet control presented in Section III-2.3.4. The condition that creates the highest headwater elevation then determines the pipe's capacity. The approach velocity head is then subtracted from the controlling headwater elevation and the junction and bend head losses are then added to compute the total headwater elevation which is then used as the tailwater elevation for the upstream pipe segment.

The Backwater Calculation Sheet in Figure III-2.3 can be used to compile the head losses and headwater elevations for each pipe segment. The numbered columns on this sheet are described in Figure III-2.4 simplify this analysis (as described in Figure III-2.4, therefore, this method should not be used to compute stage/discharge curves for level pool routing purposes. Instead, a more sophisticated backwater analysis, such as BWPIP, is recommended. The BWPIP computer program currently used by King County S.W.M. can be used to quickly compute a family of backwater profiles for a given range of flows through a proposed or existing pipe stream.

### Details

In addition to the details shown as Figures III-2.5 through III-2.12, Standard Construction Details are available in the local government Road Standards.

### III-2.3.4 Culverts

Culverts are relatively short segments of pipe of circular, elliptical, rectangular, or arch cross section. They are usually placed under road embankments to convey surface water flow safely under the embankment. They may be used to convey flow from constructed or natural channels including streams. In addition to the design criteria described below, other agencies such as the Washington State Departments of Fisheries or Wildlife may have requirements which will affect the design of proposed culverts.



Figure III-2.1 - Nomograph for Sizing Circular Drains Flowing Full

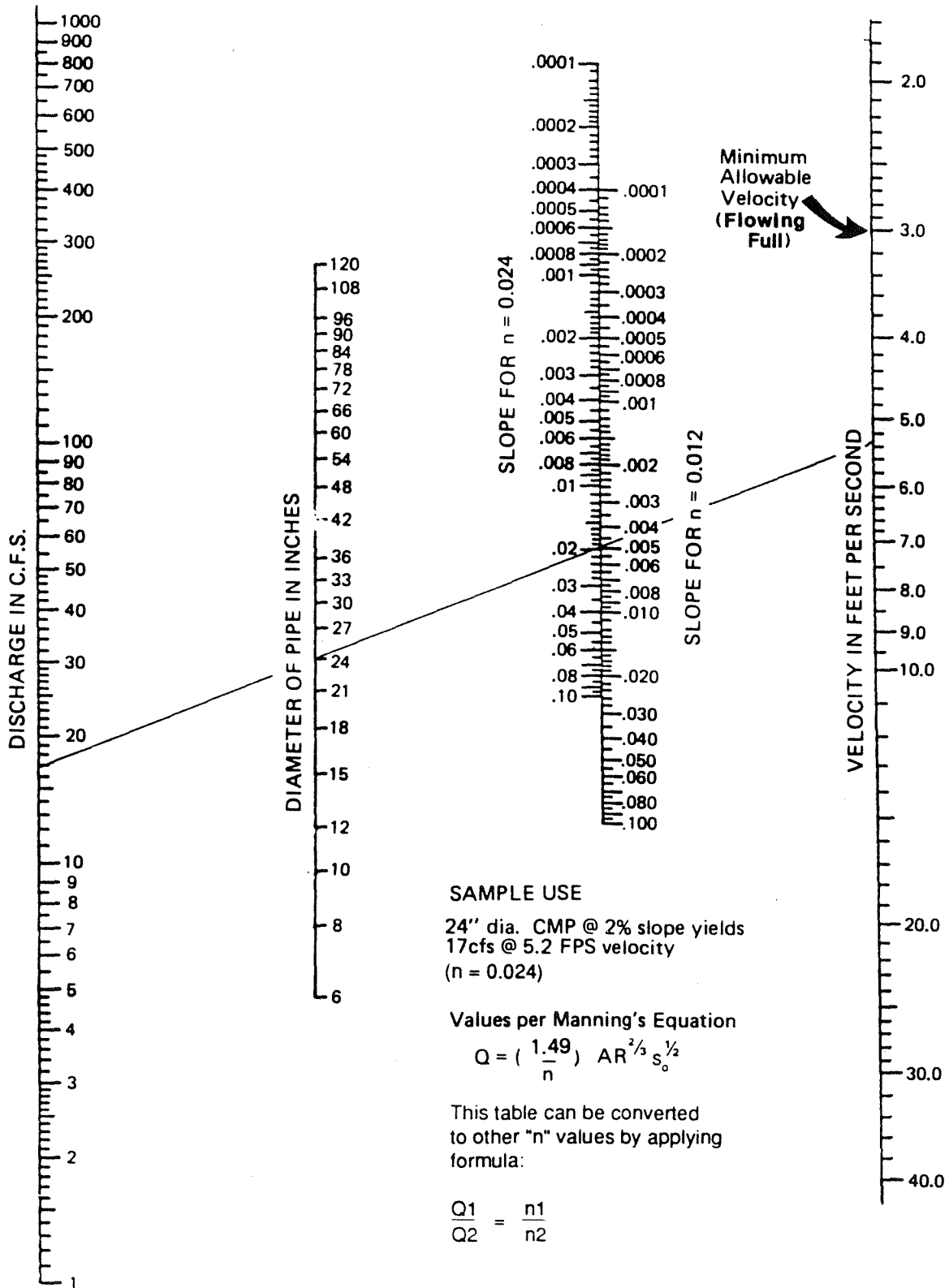


Figure III-2.2 - Circular Channel Ratios

Experiments have shown that  $n$  varies slightly with depth.  
 This figure gives velocity and flow rate ratios for varying  $n$  (solid line)  
 and constant  $n$  (broken line) assumptions.

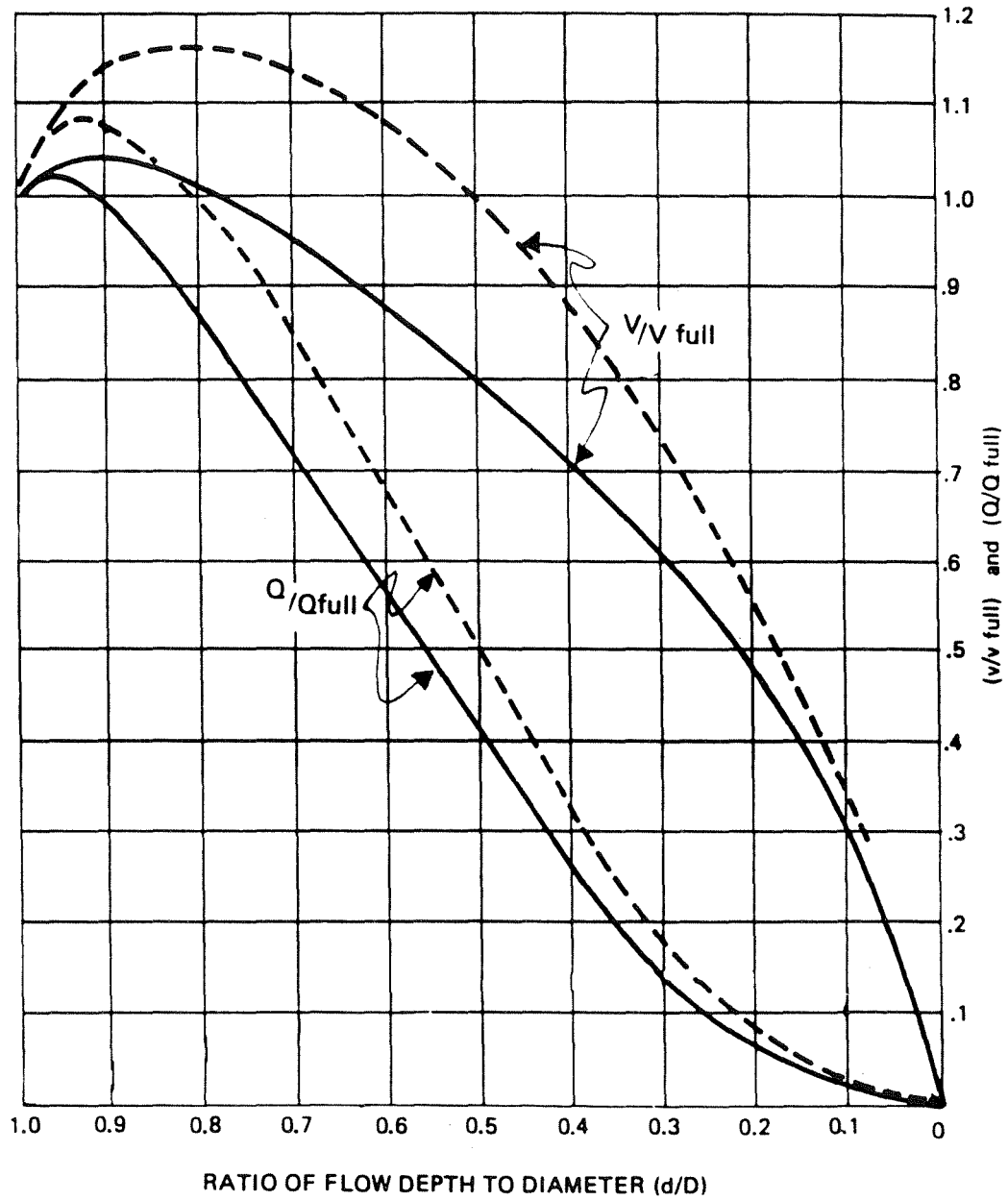


Figure III-2.3 - Backwater Calculation Sheet

BACKWATER CALCULATION SHEET																				
Pipe Segment CB to CB	(1) Q (cfs)	(2) Length (ft)	(3) Pipe Size	(4) "n" Value	(5) Outlet Elev (ft)	(6) Inlet Elev (ft)	(7) Barrel Area (sqft)	(8) Barrel Vel (fps)	(9) Bar Vel Head (ft)	(10) TW Elev (ft)	(11) Fric- tion Loss (ft)	(12) Entr HGL Elev (ft)	(13) Entr Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlet Constr Elev (ft)	(16) Inlet Constr Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)

Figure III-2.4 - Backwater Calculation Sheet Notes

- Column (1) - Design flow to be conveyed by pipe segment.
- Column (2) - Length of pipe segment.
- Column (3) - Pipe Size; indicate pipe diameter or span x rise.
- Column (4) - Manning's "n" value.
- Column (5) - Outlet Elevation of pipe segment.
- Column (6) - Inlet Elevation of pipe segment.
- Column (7) - Barrel Area is the full cross sectional area of the pipe.
- Column (8) - Barrel Velocity is the full velocity in the pipe as determined by:

$$V = Q/A \text{ or } \text{Col.}(8) = \text{Col.}(1) / \text{Col.}(7)$$

- Column (9) - Barrel Velocity Head =  $V^2/2g$  or  $(\text{Col.}(8))^2/2g$   
Where,  $g = 32.2 \text{ ft/sec}^2$  (acceleration due to gravity)

- Column (10) - Tailwater (TW) Elevation; this is the water surface elevation at the outlet of the pipe segment. If the pipe's outlet is not submerged by the TW and the TW depth is less than  $(D+d_c)/2$ , set the TW elevation equal to  $(D+d_c)/2$  to keep the analysis simple and still obtain reasonable results ( $D$  = pipe barrel height and  $d_c$  = critical depth, both in ft. See Figure 4.3.5H for determination of  $d_c$ ).

- Column (11) - Friction Loss =  $S_f \times L$  or  $S_f \times \text{Col.}(2)$   
Where,  $S_f$  is the friction slope or head loss per lineal foot of pipe as determined by Manning's Equation expressed in the form:

$$S_f = (nV)^2/2.22 R^{1.49}$$

- Column (12) - Hydraulic Grade Line (HGL) Elevation just inside the entrance of the pipe barrel; this is determined by adding the friction loss to the TW elevation:

$$\text{Col.}(12) = \text{Col.}(11) + \text{Col.}(10)$$

If this elevation falls below the pipe's inlet crown, it no longer represents the true HGL when computed in this manner. The true HGL will fall somewhere between the pipe's crown and either normal flow depth or critical flow depth, whichever is greater. To keep the analysis simple and still obtain reasonable results (ie, erring on the conservative side), set the HGL elevation equal to the crown elevation.

- Column (13) - Entrance Head Loss =  $K_e \times V^2/2g$  or  $K_e \times \text{Col.}(9)$  Where,  $K_e$  = Entrance Loss Coefficient (from Table 4.3.5A) This is the head lost due to flow contractions at the pipe entrance.

- Column (14) - Exit Head Loss =  $1.0 \times V^2/2g$  or  $1.0 \times \text{Col.}(9)$   
This is the velocity head lost or transferred downstream.

- Column (15) - Outlet Control Elevation =  $\text{Col.}(12) + \text{Col.}(13) + \text{Col.}(14)$   
This is the maximum headwater elevation assuming the pipe's barrel and inlet/outlet characteristics are controlling capacity. It does not include structure losses or approach velocity considerations.

- Column (16) - Inlet Control Elevation (See Section 4.3.5 for computation of inlet control on culverts). This is the maximum headwater elevation assuming the pipe's inlet is controlling capacity. It does not include structure losses or approach velocity considerations.

- Column (17) - Approach Velocity Head; this is the amount of head/energy being supplied by the discharge from an upstream pipe or channel section, which serves to reduce the headwater elevation. If the discharge is from a pipe, the approach velocity head is equal to the barrel velocity head computed for the upstream pipe. If the upstream pipe outlet is significantly higher in elevation (as in a drop manhole) or lower in elevation such that its discharge energy would be dissipated, an approach velocity head of zero should be assumed.

- Column (18) - Bend Head Loss =  $K_b \times V^2/2g$  or  $K_b \times \text{Col.}(17)$   
Where,  $K_b$  = Bend Loss Coefficient (from Figure 4.3.4E) This is the loss of head/energy required to change direction of flow in an access structure.

- Column (19) - Junction Head Loss; this is the loss in head/energy which results from the turbulence created when two or more streams are merged into one within the access structure. Figure 4.3.4F can be used to determine this loss or it can be computed using the following equations derived from Figure 4.3.4F:

$$\text{Junction Head Loss} = K_j \times V^2/2g \text{ or } K_j \times \text{Col.}(17)$$

Where,  $K_j$  is the Junction Loss Coefficient determined by:

$$K_j = (Q_1/Q_2)/(1.18 + 0.63(Q_1/Q_2))$$

- Column (20) - Headwater (HW) Elevation; this is determined by combining the energy heads in Columns 17, 18, and 19 with the highest control elevation in either Column 15 or 16, as follows:

$$\text{Col.}(20) = \text{Col.}(15 \text{ or } 16) + \text{Col.}(17) + \text{Col.}(18) + \text{Col.}(19)$$

Figure III-2-5 - Bend Head Losses in Structures

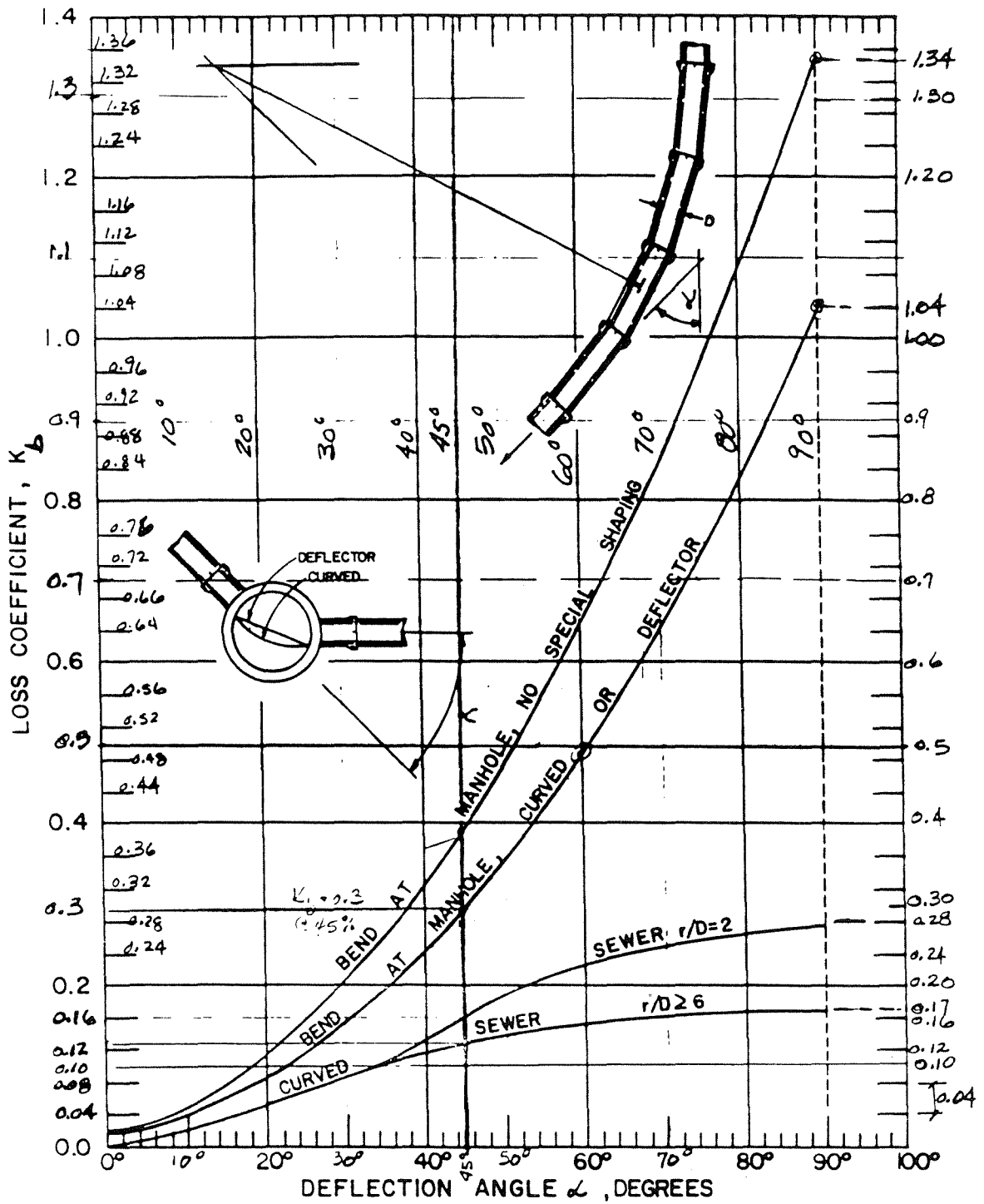
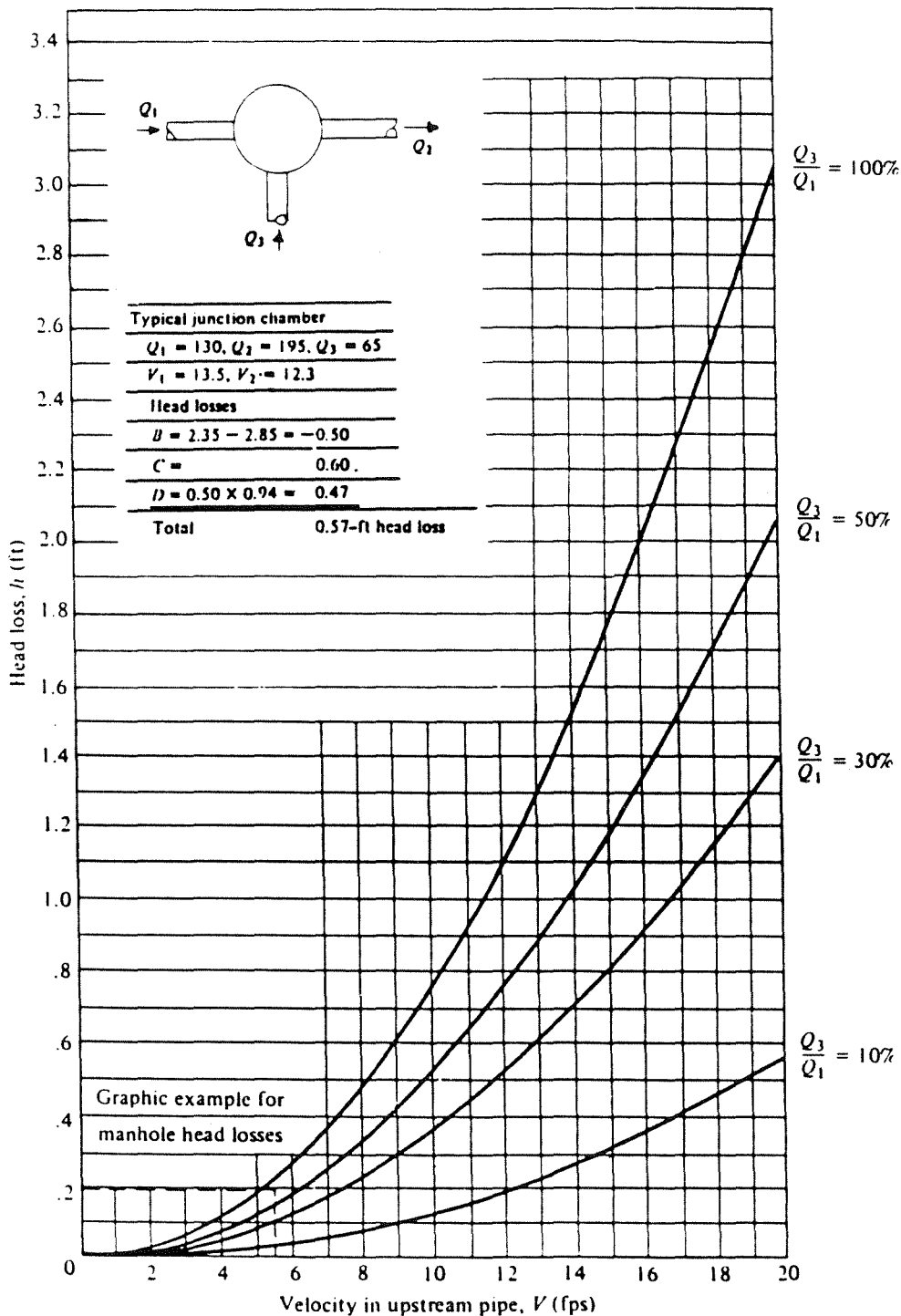
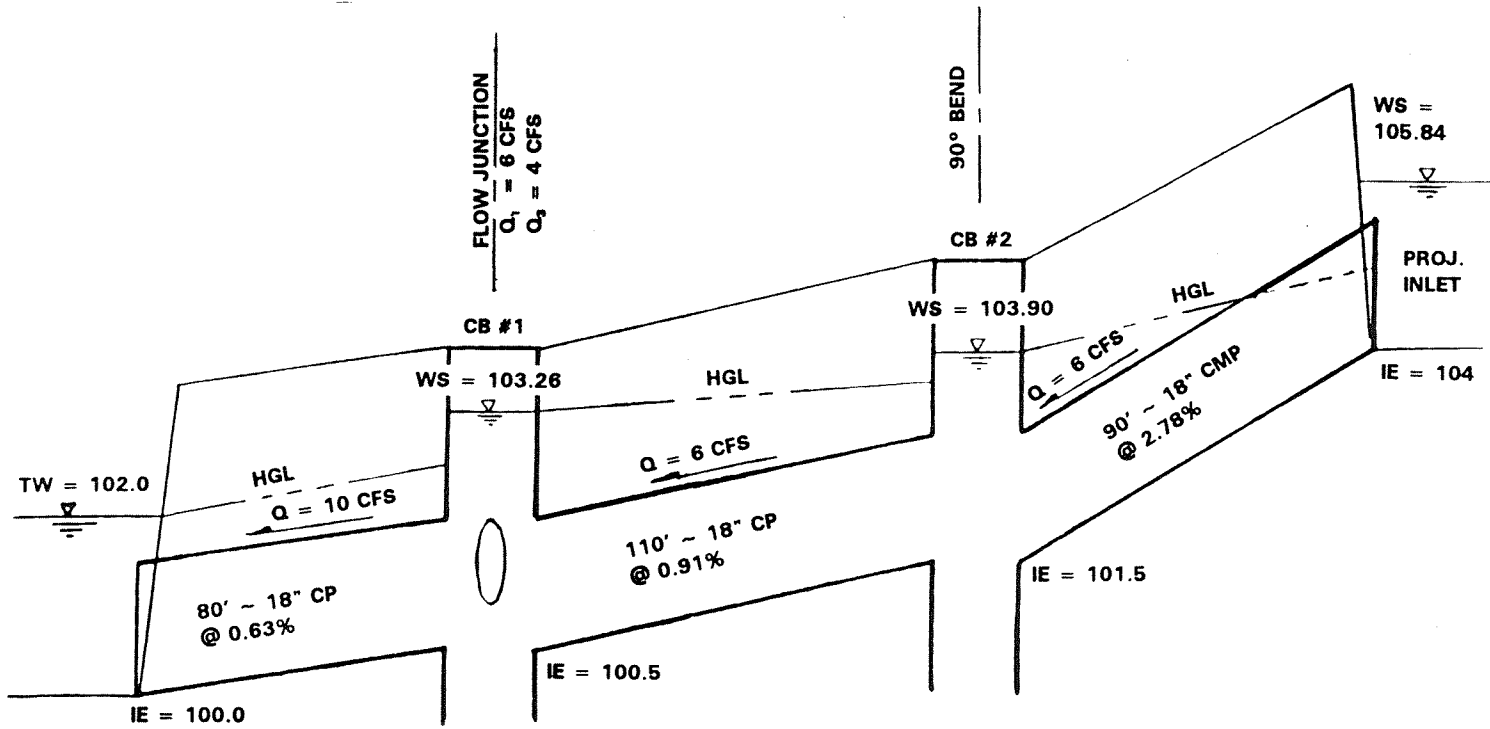


Figure III-2.6 - Junction Headloss in Structures



Source: Baltimore County Department of Public Works

Figure III-2.7 - Backwater Pipe Calculation



BACKWATER CALCULATION SHEET

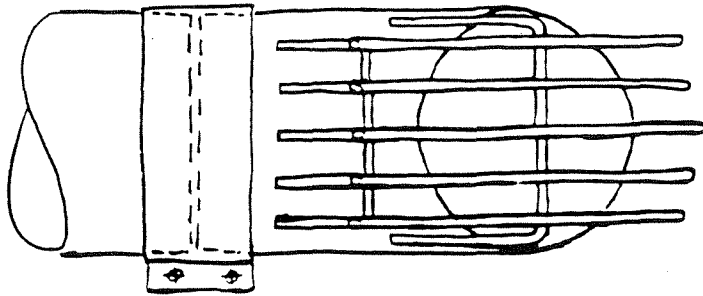
SELECT THE GREATER ELEVATION

Pipe Segment CB to CB	(1) Q (cfs)	(2) Length (ft)	(3) Pipe Size	(4) "n" Value	(5) Outlet Elev (ft)	(6) Inlet Elev (ft)	(7) Barrel Area (sqft)	(8) Barrel Vel (fps)	(9) Bar. Vel Head (ft)	(10) TH Elev (ft)	(11) Fric- tion Loss (ft)	(12) Entr. HGL Elev (ft)	(13) Entr. Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlet Contr Elev (ft)	(16) Inlet Contr Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)
1	10	80	18"	0.012	100.00	100.50	1.77	5.65	0.50	102.00	0.62	102.62	0.25	0.50	103.37	102.75	-0.18	0.002	0.07	103.26
2	6	110	18"	0.012	100.50	101.50	1.77	3.39	0.18	103.26	0.31	103.57	0.09	0.18	103.84	102.95	-0.18	0.24	0.0	103.90
3	6	90	18"	0.024	101.50	104.00	1.77	3.39	0.18	103.90	1.00	104.90 105.50	0.16	0.18	105.84	105.80	-0.0	0.0	0.0	105.84

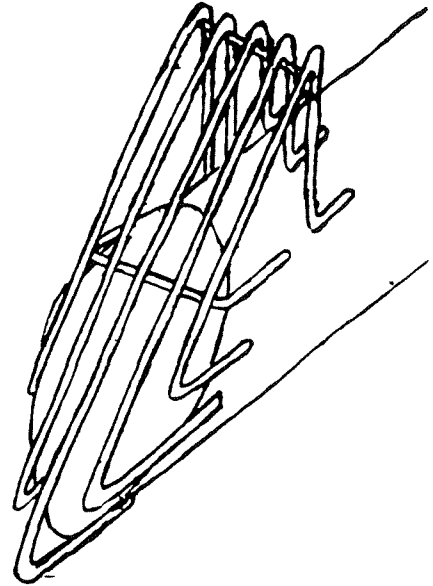
Figure III-2.8 - Debris Barrier

Notes:

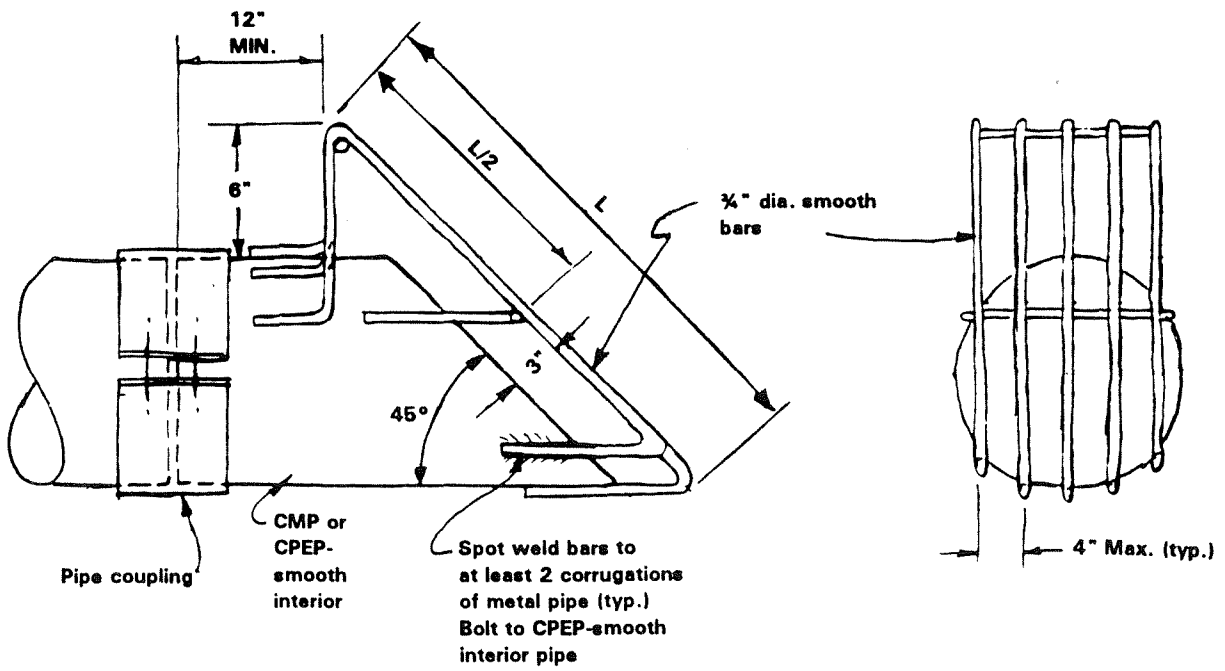
1. This debris barrier is for use outside roadways on pipes  $\leq 36"$  dia. See Fig. III-2.9 for debris barriers on pipes projecting from driveway or roadway sideslopes.
2. CPEP-smooth interior pipe requires bolts to secure debris barrier to pipe.



PLAN



ISOMETRIC



SIDE VIEW

END VIEW



Figure III-2.9 - Debris Barrier

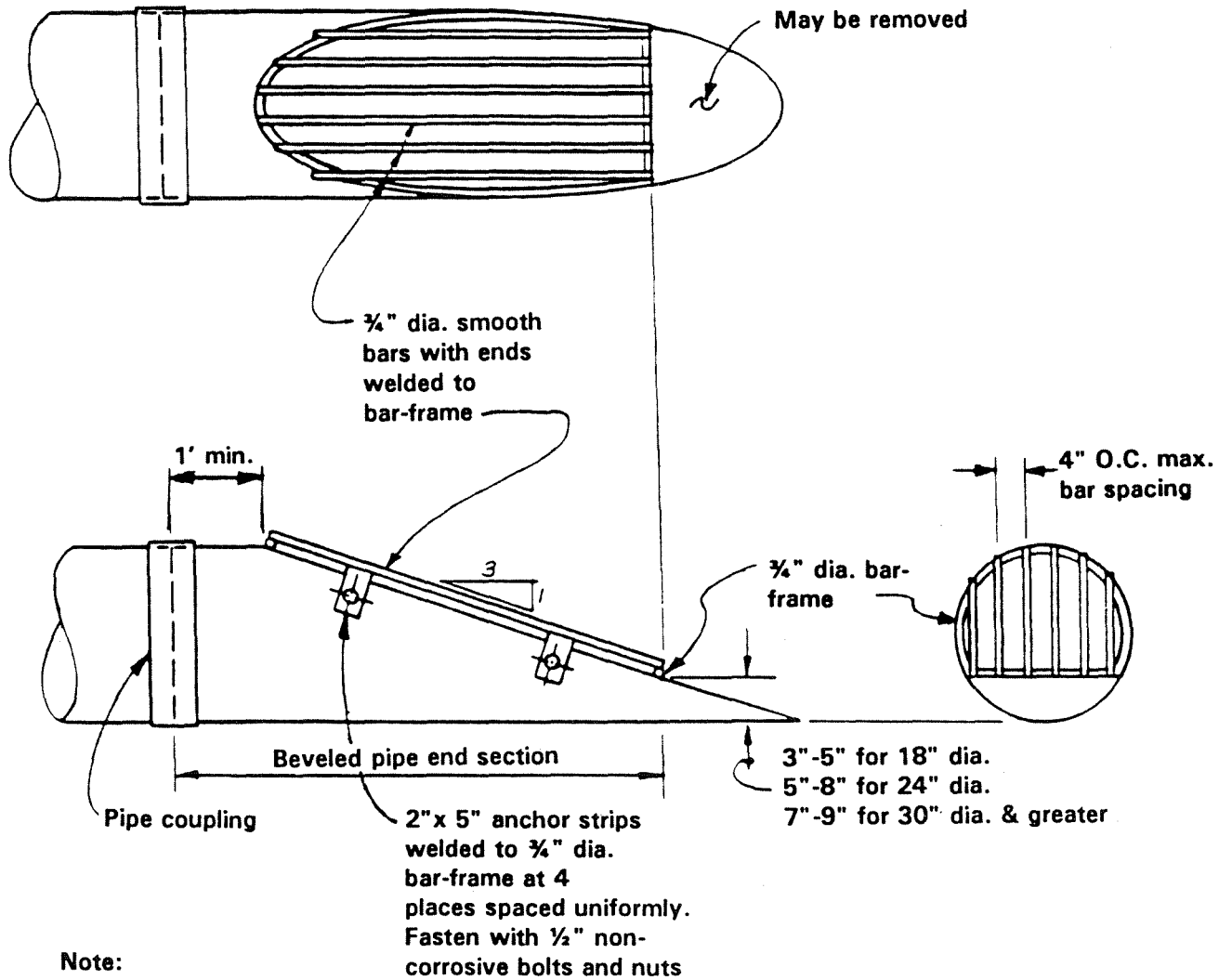
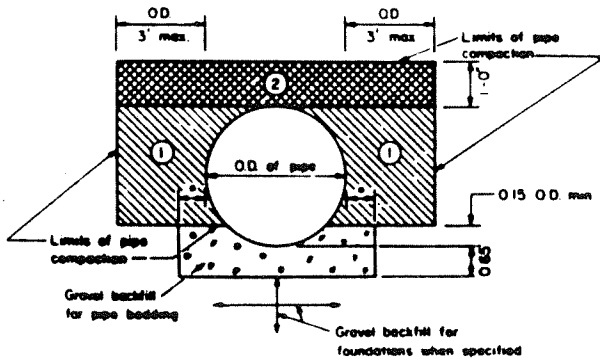
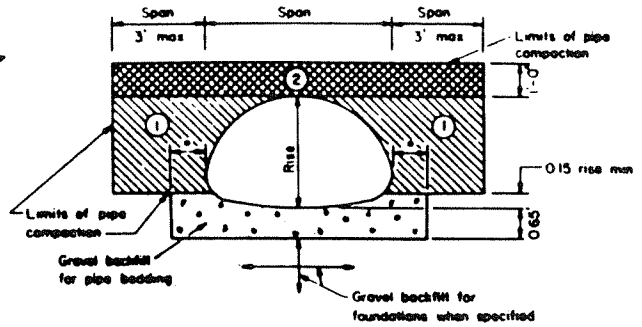


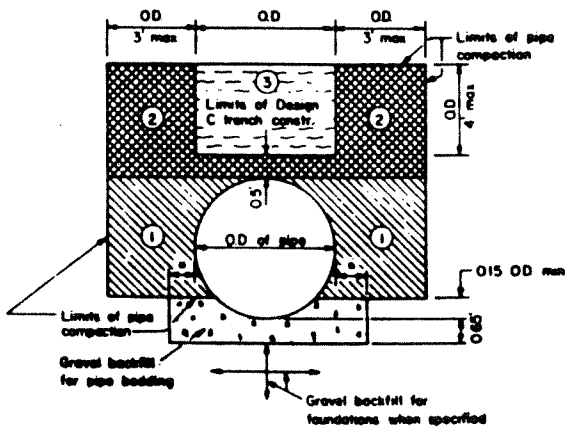
Figure III-2.10 - Pipe Comparison Designs (A and C) and Backfill



DESIGN A  
(For Metal and Concrete Pipe)



TYPICAL PIPE-ARCH INSTALLATION



DESIGN C  
(For Concrete Pipe With Circular Reinforcement Only)

CLEARANCE BETWEEN PIPES  
MULTIPLE INSTALLATIONS

PIPE	SIZE	MIN DIST BETWEEN BARRELS
CIRCULAR PIPE CONCRETE & METAL DESIGN A (DIAMETER)	12" to 24"	12"
	30" to 96"	DIAM - 2
	102" to 180"	48"
CIRCULAR PIPE CONCRETE ONLY DESIGN C (DIAMETER)	12" to 36"	2D
	42" to 96"	72"
	102" to 180"	72"
PIPE-ARCH METAL ONLY (SPAN)	18" to 36"	12"
	43" to 142"	SPAN - 3
	148" to 199"	48"

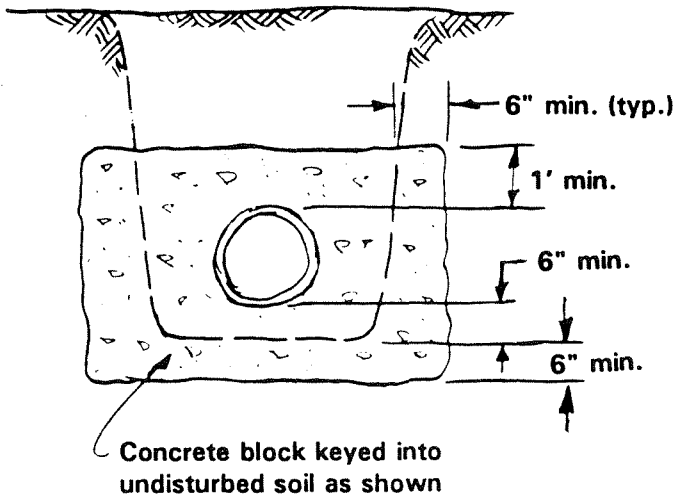
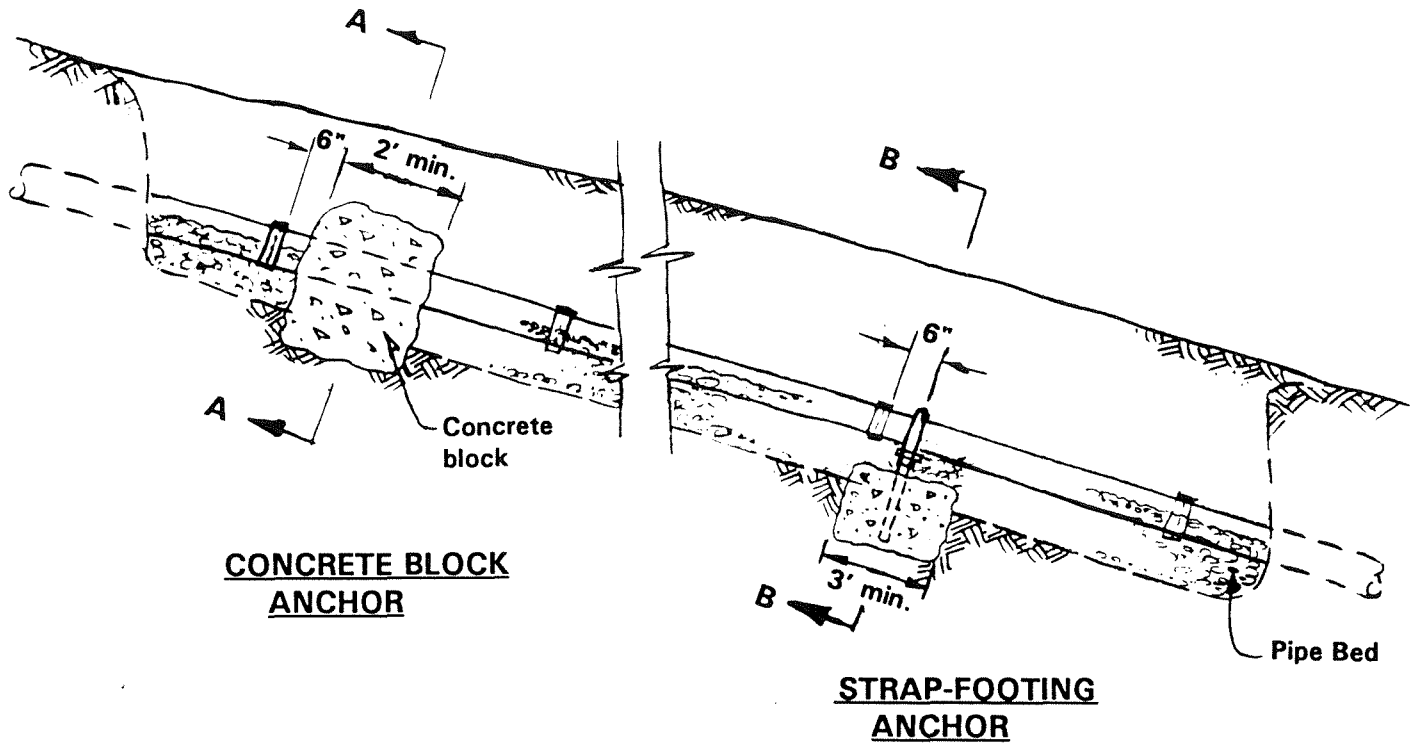
LEGEND  
PIPE COMPACTION ZONE

- 1 Backfill material placed in 0.5' loose layers and compacted to 95% maximum density.
- 2 Method B or C compaction.
- 3 Baled straw or hay with wires or strings cut (dry, commercial quality).

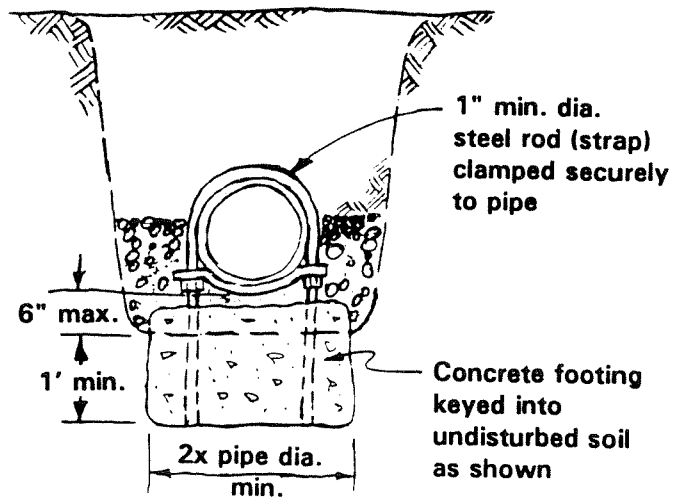
NOTES

- 1 Pipe compaction limits shown on this plan are for pipe construction in an embankment. For pipe construction in a trench, the horizontal limits of the pipe compaction zone shall be the walls of the trench.
- 2 All steel and aluminum pipe and pipe-arches shall be installed in accordance with Design A.
- 3 Concrete pipe with elliptical reinforcement shall be installed in accordance with Design A.
- 4 Concrete pipe, plain or with circular reinforcement, shall be installed with Design A or a combination of Designs A and C, as determined by the Engineer.
- 5 For Design C, it is essential that the walls for Zone 3 be constructed as near vertical as possible.
- 6 OD is equal to the outside diameter of a pipe or the outside span of pipe-arch. The dimensions shown as OD with 3' and 4' maximum shall be OD until OD equals 3' and 4' at which point 3' and 4' shall be used.
- 7 1'-0" for diameters 12" through 42" and for spans through 50". 2'-0" diameters greater than 42" and for spans greater than 50".

Figure III-2.11 - Pipe Anchor Detail



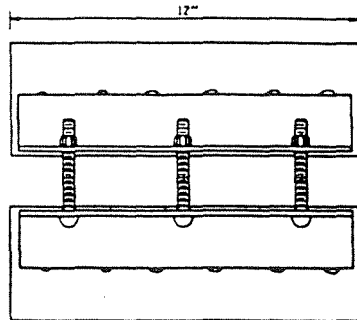
**SECTION A-A**  
nts



**SECTION B-B**  
nts

Note: For HDPP, pipe must be free to slide inside a 4' long section of pipe one size diameter larger.

Figure III-2.12 - Corrugated Metal Pipe, Coupling and/or General Pipe Anchor Assembly



SMOOTH COUPLING BAND FOR CONCRETE PIPE

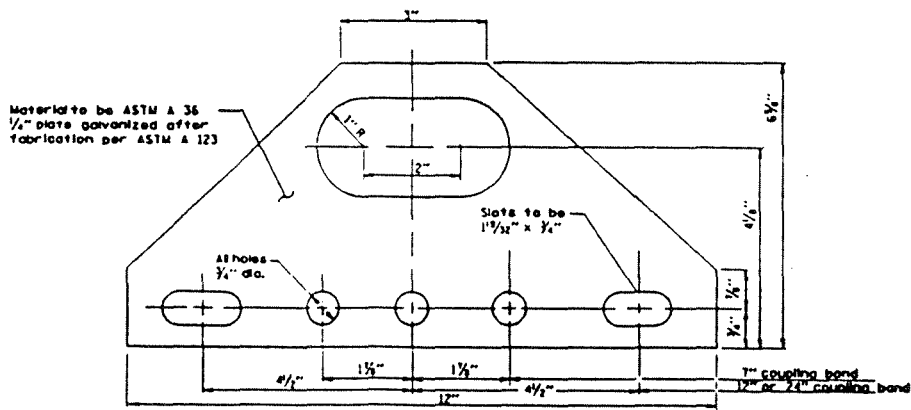
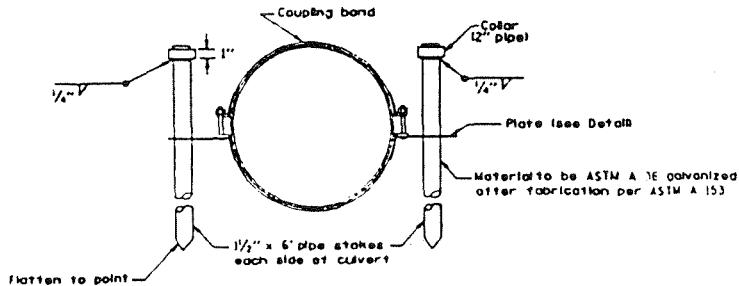
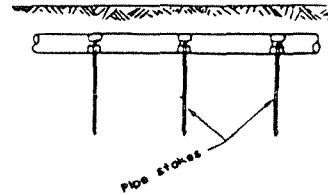


PLATE DETAIL



ANCHOR ASSEMBLY - CORRUGATED METAL PIPE

- NOTES:
1. Payment for pipe anchors which include all pipe stakes and hardware shall be considered as incidental and shall be included in the per linear foot cost of pipe.
  2. The smooth coupling band shall be used in combination with concrete pipe.
  3. Concrete pipe without bell and spigot shall not be installed on grades in excess of 20%.
  4. The first anchor shall be installed on the first section of the lower end of the pipe and remaining anchors evenly spaced throughout the installation.
  5. If the pipe being installed has a manhole or catch basin on the lower end of the pipe, the first anchor may be eliminated.
  6. When C.M.P. is used, the anchors may be attached to the coupling bands used to join the pipe as long as the specified spacing is not exceeded.
  7. All pipe anchors shall be securely installed before backfilling around the pipe.

## Design Criteria for Culverts

### Headwater

- For new culverts 18 inches in diameter or less, maximum allowable 25-year design storm event headwater elevation (measured from the inlet invert) shall not exceed 2 times the pipe diameter/arch culvert use.
- For new culverts larger than 18 inches in diameter, maximum 25-year design storm event headwater elevation for the new culvert shall not be less than 0.5 feet lower than the road or parking lot subgrade.
- Maximum design headwater elevation for new culverts shall be a minimum of 1 foot below road subgrade.

### Inlet

- For culverts 18 inches in diameter and larger, the embankment around the culvert inlet shall be protected from erosion by rock lining or riprap as specified in Table III-2.4, except the length and height shall be as follows:
  - Length: extend upstream of culvert 5 feet minimum
  - Height: at design headwater elevation
- Trash racks/debris barriers are required on culverts that are over 60 feet in length or that are inlets to pipe systems, and that are 18 inches to 36 inches in diameter (see Figures III-2.8 and III-2.9). Exceptions are culverts on Class 1 or 2 streams.
- Inlet structures, such as concrete headwalls, may provide a more economical design by allowing the use of smaller entrance coefficients, and hence smaller diameter culverts. When properly designed they will also protect the embankment from erosion and eliminate the need for rock lining.
- In order to maintain the stability of roadway embankments, concrete headwalls, wingwalls, or tapered inlets and outlets may be required if right-of-way and/or easement constraints prohibit the culvert extending to the toe of the embankment slope. Normally concrete inlet structures/headwalls installed in or near roadway embankments must be flush with, and conforming to the slope of the embankment.

### Outlets

- For culverts 18 inches in diameter and larger, the receiving channel of the outlet shall be protected from erosion by rock lining specified in Table III-2.4, except the height shall be 1 foot above maximum tailwater elevation or 1 foot above the crown - whichever is higher (see Figure III-2.21).
- Standard details for various culvert end designs such as wing walls and tapered inlets may be found in the Washington State Department of Transportation Highway Hydraulic Manual.

Table III-2.3 Entrance Loss Coefficients

Type of Structure and Design of Entrance	Coefficient $K_e$
<u>Pipe, Concrete and D.I.</u>	
Projecting from fill, socket (bell) end	0.2
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
End-section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
<u>Pipe, or Pipe-Arch, Corrugated Metal and Other Non-Concrete or D.I.</u>	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
End-section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
<u>Box, Reinforced Concrete</u>	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

\*Note: "End section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections incorporating a closed taper in their design have a superior hydraulic performance.

Table III-2.4 Rock Protection at Outfalls

Discharge Velocity at Design Flow (fps)			REQUIRED PROTECTION Minimum Dimensions				
			Type	Thickness	Width	Length	Height
0	to	≤5	Riprap*	1 ft.	Diameter + 6 ft.	8 ft. or 4X Dia., whichever is greater	Crown + 1 ft.
6	to	≤10	Riprap**	1 ft.	Diameter +6 ft. or 3X Diameter, whichever is greater	12 ft. or 3X Dia., whichever is greater	Crown +1 ft.
11	to	≤20	Gabion	1 ft.	(As required)	(As required)	Crown +1 ft.
20		NA	Engineered Energy Dissipator Required				

\* Riprap shall be in accordance with section 9-13.1 of the WSDOT/APWA Standard Specifications. Riprap to be reasonably well graded with rock gradation as follows:

Passing 8 inch square sieve 100% or Maximum stone size 8"  
 Passing 6 inch square sieve 40-60% or Medium stone size 6"  
 Passing 2 inch square sieve 0-10% or Minimum stone size 2"

\*\* Riprap to be reasonably well graded with rock gradation as follows:

Maximum stone size 24" (nominal diameter)  
 Median stone size 16"  
 Minimum stone size 4"

Note: Riprap sizing governed by the side slopes on outlet channel, assumed to be 3:1.

Methods of Analysis for Culverts

The theoretical analysis of culvert flow can be extremely complex because of the wide range of possible flow conditions which can occur due to various combinations of inlet and outlet submergence and flow regime within the culvert barrel. An exact analysis usually involves detailed backwater calculations, energy and momentum balance, and application of the results of hydraulic model studies.

Simple procedures have been developed, however, wherein the various flow conditions are classified and analyzed on the basis of a control section. A control section is a location where there is a unique relationship between the flow rate and the upstream water surface elevation. Many different flow conditions exist over time, but at any given time the flow is either governed by the culvert's inlet geometry

(inlet control); or by a combination of inlet geometry, barrel characteristics, and tailwater elevation (outlet control). Figure III-2.13 illustrates typical conditions of inlet and outlet control.

The procedures presented here provide for the analysis of both inlet and outlet control conditions to determine which is governing flow capacity and what that capacity is.

#### Inlet Control Analysis

Nomographs such as those provided in Figures III-2.14 and III-2.15 can be used to determine the inlet control headwater depth at design flow for various types of culverts and inlet configurations. These nomographs were originally developed by the Bureau of Public Roads - now the Federal Highway Administration (FHWA) - based on their studies of culvert hydraulics. These and other nomographs can be found in the FHWA publication, Hydraulic Design of Highway Culverts, HDS No. 5 (Report No. FHWA-IP-85-15), September 1985; or the WSDOT Hydraulic Manual.

Also available in the FHWA publication are the design equations used to develop the inlet control nomographs. These equations are presented below:

For unsubmerged inlet conditions defined by  $Q/AD^{0.5} \leq 3.5$ ;

$$\text{Form(1)* } HW/D = H_c/D + K(Q/AD^{0.5})^M - 0.5S^{**}$$

$$\text{Form(2)* } HW/D = K(Q/AD^{0.5})^M$$

For submerged inlet conditions defined by  $Q/AD^{0.5} \leq 4.0$ ;

$$HW/D = c(Q/AD^{0.5})^2 + Y - 0.5S^{**}$$

where:

HW	=	Headwater depth above inlet invert, ft.
D	=	Interior height of culvert barrel, ft.
$H_c$	=	Specific head at critical depth ( $d_c + V_c^2/2g$ ), ft.
Q	=	Flow, cfs.
A	=	Full cross sectional area of culvert barrel, sq ft.
S	=	Culvert barrel slope, ft/ft
K, M, c, Y	=	Constants from Table III-2.6
$d_c$	=	Critical depth (see Figure III-2.18), ft.
$V_c$	=	Flow velocity at critical depth, fps.
g	=	Acceleration due to gravity, 32.2 ft/sec <sup>2</sup> .

\* The appropriate equation form for various inlet types is specified in Table III-2.7.

\*\* For mitered inlets use +0.7S instead of -0.5S.

Note, between the unsubmerged and submerged conditions, there is a transition zone ( $3.5 < Q/AD_{0.5} < 4.0$ ) for which there is only limited hydraulic study information. The transition zone is defined empirically by drawing a curve between and tangent to the curves defined by the unsubmerged and submerged equations. In most cases, the transition zone is short and the curve is easily constructed.

#### Outlet Control Analysis

Nomographs such as those provided in Figures III-2.16 and III-2.17 can be used to determine the outlet control headwater depth at design flow for various types of culverts and inlets. Outlet control nomographs other than those provided can be found in FHWA HDS No.5 or the WSDOT Hydraulic Manual.



The outlet control headwater depth can also be determined using the simple backwater analysis procedure presented in Section III-2.3.3 for analyzing pipe system capacity. This procedure is summarized as follows for culverts:

$$HW = H + TW - LS$$

where:

- H =  $H_f + H_c + H_{ex}$   
 $H_f$  = Friction Loss, ft. =  $V^2 n^2 L / 2.22 R^{1.33}$   
 Note, if  $(H_f + TW - LS) < D$ , adjust  $H_f$  such that  $(H_f + TW - LS) = D$ . This will keep the analysis simple and still yield reasonable results (erring on the conservative side).  
 $H_c$  = Entrance Head Loss, ft. =  $K_c(V^2/2g)$   
 $H_{ex}$  = Exit Head Loss, ft. =  $V^2/2g$   
 $TW$  = Tailwater depth above invert of culvert outlet, ft.  
 Note, if  $TW < (D+d_c)/2$ , set  $TW = (D+d_c)/2$ . This will keep the analysis simple and still yield reasonable results.  
 L = Length of culvert, ft.  
 S = Slope of culvert barrel, ft/ft.  
 D = Interior height of culvert barrel, ft.  
 V = Barrel velocity, fps.  
 n = Manning's roughness coefficient (from Table III-2.2).  
 R = Hydraulic radius, ft.  
 $K_c$  = Entrance loss coefficient (from Table III-2.3).  
 g = Acceleration due to gravity, 32.2 ft/sec<sup>2</sup>.  
 $d_c$  = Critical depth (see Figure III-2.19), ft.

Note, the above procedure should not be used to develop stage/discharge curves for level pool routing purposes because its results are not precise for flow conditions where the hydraulic grade line falls significantly below the culvert crown (i.e., less than full flow conditions).

#### **Fish Passage Guidelines: Culvert Installations**

This guidance, dated April 12, 1990, has been provided by the Washington State Department of Fisheries.

#### Introduction

This report presents guidelines for use by designers and resource managers to assure juvenile and adult salmonid (trout and salmon) fish passage, as required, at culvert installations. Guidelines for special structures such as fishways and streambed controls are not included. In general, these special structures are not considered satisfactory for fish passage at road crossings except in extraordinary circumstances.

#### Authority

The authority of the Washington Department of Fisheries (WDF) and Washington Department of Wildlife (WDW) in this regard is the Hydraulic Law, RCW 75.20.100 which requires that a Hydraulic Project Approval (HPA) be obtained from these agencies for work within the ordinary high water line of streams. In addition, if a culvert is a fish obstruction, RCW 75.20.060 requires that fish passage be provided with a fishway, or that the obstruction be removed.

#### Fish Migration Needs

Maintaining free upstream passage for migrating salmonids at culvert sites is essential. The success or failure of a fish migrating through a culvert depends on the swimming ability of the fish, the hydraulic conditions at the site, and proper

maintenance of the culvert (e.g. debris removal). An interruption or delay by any obstruction in the upstream migration of adult salmonids can adversely affect the spawning success by depleting the fish's limited energy budget before the fish reaches an acceptable spawning area.

This can result in spawning in marginal spawning areas or loss of spawning ability and increasing the possibility of injury, disease, or predation. A complete obstruction will result in full loss of production from the habitat upstream of that point.

In many areas, necessary juvenile upstream migration occurs as a response to water conditions, predation, and population pressures. Juvenile migration and redistribution is a means for increased survival and full stream production. An obstruction to juvenile fish migration may result in a limit to production both upstream and downstream from the barrier. Design guidelines for areas requiring upstream juvenile migration are very restrictive due to the size and limited swimming ability of these fish.

Excessive water velocity, inadequate water depth, excessive vertical drop at the culvert outfall, and debris blockages are the most frequent causes of fish passage problems at culverts. Consideration of these factors for successful fish passage must include design provisions for the fish having the most restrictive swimming ability rather than just the strongest swimmer. Otherwise, undesirable genetic selection will occur in favor of the strongest fish.

#### Culvert Design Criteria

Table III-2.5 presents the hydraulic criteria for the design of culverts for the passage of salmon and steelhead. Satisfaction of these criteria is essential to approval of the culvert installation. These criteria are based on numerous literature references, of which the most significant are included in the attached bibliography. These criteria are the limits of athletic ability for the weakest fish of each species; there is no safety factor for fish passage built into a structure designed by these criteria. In a natural stream channel, the average flow characteristic may often exceed these criteria. The diversity of natural channel beds and formations, however, provides paths of access with suitable depths and velocities and only brief exposure to excessive conditions. Relatively smooth culverts, on the other hand, provide no such diversity and the average flow characteristics within the culvert approach the maximum.

Baffles within culverts are not recommended as a means of providing fish passage and are acceptable only if all other options are deemed unfeasible or less desirable by the fisheries agencies. Full bridging structures (bottomless structures with foundations and supports placed beyond the margin of the channel) are preferred to ensure against fish passage problems. In important spawning areas, culverts are not allowed unless assurance can be made, to the satisfaction of the fisheries agencies, for full replacement of habitat disrupted or lost.

It is recognized that fish passage through culverts as well as through many natural channels cannot be practically provided at all discharges. Acceptable hydraulic design of culverts includes selection of appropriate design flows from which the flow characteristics can be derived by hydraulic analysis. The low flow depth design should be the 2-year, 7-day low flow discharge for the subject basin or 95 percent exceedance flow for migration months of the fish species of concern. When sufficient data is available, the high flow design discharge, to determine velocity, should be the flow that is not exceeded more than 10 percent of the time during the months of adult migration ( $Q_{10\%}$ ). That flow can be approximated by

$$Q_{10\%} = 0.18 \times (Q_2) + 36$$

for cases where the 2-year flood event is greater than 44 cfs.  $Q_2$  is the 2-year flood event in cubic feet per second. For cases where  $Q_2$  is less than 44 cfs, the design flow can be approximated as equalling the 2-year flood event (Bates, 1988).

Appropriate statistical or hydrological methods must be applied for the determination of these flows. These methods, as well as the methods of calculating the resulting hydraulic characteristics, should be documented within the HPA application. An acceptable alternative to the hydrologic and hydraulic analysis is described in the following section.

These flow event criteria may be modified for specific proposals as necessary for unusual fish passage requirements, or where other mutually agreed upon methods of empirical or hydrologic analysis are used, or where special facilities are deemed adequate by the fisheries agencies.

#### Culvert Size and Slope

Culvert size (diameter or equivalent) and slope must consider and accommodate juvenile and/or adult fish passage. At any given flow, hydraulic characteristics within a culvert are most sensitive to the variables of size and slope. Acceptable hydraulic characteristics (depth, velocity) and the design flows from which they are derived are presented in Table III-2.5.

The velocity criteria for juvenile salmonids is based on the assumption that, for culverts up to 60 feet in length, roughness within the culvert will provide a passable migration path along flow boundaries, where the velocity will be less than the 4.0 fps average flow velocity required by Table III-2.5. By limiting the design flow velocity to 4.0 fps, bed material can be expected to deposit in the culvert to provide that roughness. Also, juvenile salmonid passage typically occurs when flows are much less than the 2-year flood frequency flow design suggested by Table III-2.5.

A hydrologic analysis may not be warranted for very small streams. An acceptable alternative to the hydrologic and hydraulic analyses described above is to install a culvert on level grade (0% slope), with a diameter (or span) at least as large as the characteristic toe width of the stream channel. The toe width, the horizontal distance between the points where the banks and streambed join, includes the width of gravel bars, if present. Consideration must, of course, also be given to flood capacity and debris and bed load passage. No culvert should be designed to be structurally jeopardized at flows less than a 100-year flood.

Debris racks are not an acceptable alternative to passage of debris through the culvert. Placement of multiple parallel culverts is not desirable due to increased potential of blockage by debris.

#### Elevation

Culverts must be placed below the natural channel grade (countersunk) by a minimum 20 percent of the culvert diameter or rise. The natural channel grade is defined as the profile connecting the low flow hydraulic controls in the natural channel. Culvert capacity for flood design flow must be determined by using the remaining capacity of the culvert.

The minimum depth criteria presented in Table III-2.5 can be applied to the culvert, assuming no bed material is retained within the structure.

In the case of culverts proposed for channels with gradients that, if applied to the culvert, would cause a water velocity greater than that acceptable for fish passage, the upstream end of the culvert may be further countersunk. Approval of either option must be on a site-specific basis. Generally, an additional countersink of

1.0 foot at the upstream end is acceptable for culverts in channels with gradients up to 3.0 percent. A bridge may be required in more severe cases.

General Design Considerations

To design a culvert solely by the criteria presented here ignores the presence or potential of on-going or eventual changes in dimensions or characteristics of the stream channel. Natural changes related to the continual evolution of the basin and channel are always present. Such changes may be accelerated or reversed by basin land use changes or by influences of structural changes or development within a particular reach of channel. Such changes must be accounted for in the design of any effective hydraulic structure within a natural stream corridor. This is especially important in the case of culverts, since the athletic limitations of fish are more restrictive and often prevail as a limiting design factor over corresponding structural and hydraulic constraints.

Table III-2.5 Fish Passage Design Criteria for Culvert Installation

Criteria	Juvenile Salmonid <sup>1</sup> < 6 in. (150 mm)	Adult Trout < 6 in. (150 mm)	Adult Pink Chum	Adult Sockeye Coho, Chinook Steelhead
1. Velocity, maximum (fps) <sup>2</sup>				
Culvert length (ft.)				
a. 10 - 60	4.0	4.0	5.0	6.0
b. 60 - 100	(Not allowed) <sup>3</sup>	4.0	4.0	5.0
c. 100 - 200		3.0	3.0	4.0
d. > 200		2.0	2.0	3.0
2. Depth, minimum (ft.) <sup>4</sup>	0.3	0.8	0.8	1.0

- Juvenile salmonid passage is required for reaches of streams where migration to seasonal rearing habitat occurs. This is a site-specific requirement to be determined by the resource agency's field representatives.
- High design flow for velocity shall be 2-year frequency flood flow unless specifically stated otherwise.
- For culverts longer than 60 feet, an excessive risk of passage failure exists for juvenile salmonids.
- Low design flow depth shall be 2-year, 7-day low flow unless specifically stated otherwise. Depth considerations do not apply within structures with natural beds.

Fish passage improvements may be required as a result of channel evolution and changes. Any fish passage improvement should initially be located at the downstream end of the scour pool at the discharge of the culvert. For this reason, in new project planning, an area extending at least 30 feet downstream of the culvert should be included within the right-of-way or under the control of the owner of the road crossing.

A scour pool may develop at the culvert outlet due to poor energy dissipation through the culvert. The scour pool is important to the protection of the downstream channel. In a bedrock or non-erodible channel, a scour pool may not form by itself, in which case one should be constructed. A pool 3 feet deep by 20 feet long is recommended.

## Fish Culvert Installation Bibliography

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Table III-2.6 - Constants for Inlet Control Equations

Table III - 2.6

FHWA Chart No.*	Shape and Material	Mono-graph Scale	Inlet Edge Destination	UNSUBMERGED			SUBMERGED		
				Equation Form	K	M	C	Y	Reference
1	Circular Concrete	1	Square edge w/headwall	1	0.0098	2.0	0.0398	0.67	(56)(57)
		2	Groove end w/headwall		.0078	2.0	.0292	.74	(56)(57)
		3	Groove end projecting		.0045	2.0	.0317	.69	(56)(57)
2	Circular CMP	1	Headwall	1	.0078	2.0	.0379	.69	(56)(57)
		2	Mitered to slope		.0210	1.33	.0463	.75	(57)
		3	Projecting		.0340	1.50	.0553	.54	(57)
3	Circular	A	Beveled ring, 45° bevels	1	.0018	2.50	.0300	.74	(57)
		B	Beveled ring, 33.7° bevels*		.0018	2.50	.0243	.83	(57)
8	Rectangular Box	1	30° to 75° wingwall flares	1	.026	1.0	.0385	.81	(56)
		2	90° and 15° wingwall flares		.061	0.75	.0400	.80	(56)
		3	0° wingwall flares		.061	0.75	.0423	.82	(8)
9	Rectangular Box	1	45° wingwall flare d = .0430	2	.510	.667	.0309	.80	(8)
		2	18° to 33.7° wingwall flare - d = .0830		.486	.667	.0249	.83	(8)
10	Rectangular Box	1	90° headwall wi. 3/4" chamfers	2	.515	.667	.0375	.79	(8)
		2	90° headwall wi. 45° bevels		.495	.667	.0314	.82	(8)
		3	90° headwall wi. 33.7° bevels		.486	.667	.0252	.865	(8)
11	Rectangular Box	1	3/4" chamfers; 45° skewed headwall	2	.522	.667	.0402	.73	(8)
		2	3/4" chamfers; 30° skewed headwall		.533	.667	.0425	.705	(8)
		3	3/4" chamfers; 15° skewed headwall		.545	.667	.04505	.68	(8)
		4	45° bevels; 10°-45° skewed headwall		.498	.667	.0327	.75	(8)
12	Rectangular Box 3/4" chamfers	1	45° wingwall flares - offset	2	.497	.667	.0339	.803	(8)
		2	33.7° wingwall flares - offset		.493	.667	.0361	.806	(8)
		3	18.4° non-offset wingwall flares- 30° skewed barrel		.495	.667	.0386	.71	(8)
13	Rectangular Box Top Bevels	1	45° wingwall flares - offset	2	.497	.667	.0302	.835	(8)
		2	33.7° wingwall flares - offset		.495	.667	.0252	.881	(8)
		3	18.4° wingwall flares - offset		.493	.667	.0227	.887	(8)
16-19	C M Boxes	1	90° headwall	1	.0083	2.0	.0379	.69	(57)
		2	Thick wall projecting		.0145	1.75	.0419	.64	(57)
		3	Thin wall projecting		.0340	1.5	.0496	.57	(57)

\*See FHWA HDS No. 5

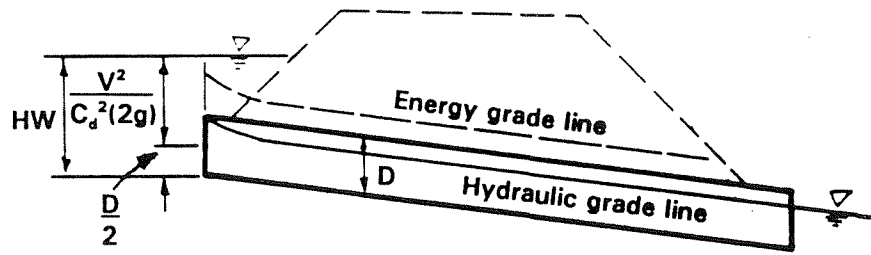


Table III-2.6 - Constants for Inlet Control Equations (Continued)

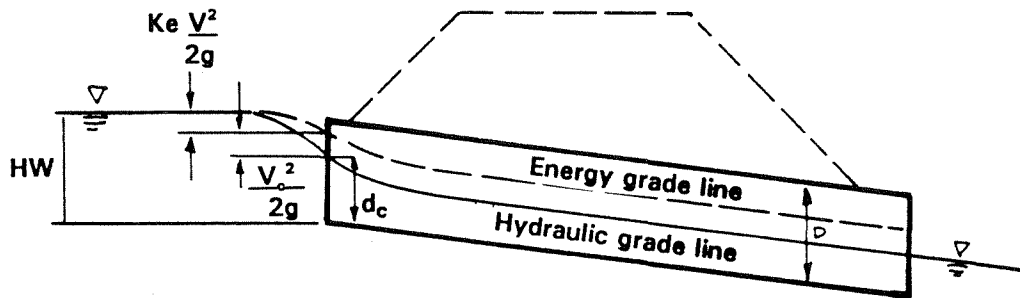
Table III - 2.6, continued

FHWA Chart No. *	Shape and Material	Mono-graph Scale	Inlet Edge Destination	UNSUBMERGED			SUBMERGED		
				Equation Form	K	M	C	Y	Reference
29	Horizontal	1	Square edge with headwall	1	0.0100	2.0	.0398	.67	(57)
	Elipse	2	Groove end with headwall		.0018	2.5	.0292	.74	(57)
	Concrete	3	Groove end projecting		.0045	2.0	.0317	.69	(57)
30	Vertical	1	Square edge with headwall	1	.0100	2.0	.0398	.67	(57)
	Elipse	2	Groove end with headwall		.0018	2.5	.0292	.74	(57)
	Concrete	3	Groove end projecting		.0095	2.0	.0317	.69	(57)
34	Pipe arch	1	90° headwall	1	.0083	2.0	.0496	.57	(57)
	18° corner	2	Mitered to slope		.0300	1.0	.0463	.75	(57)
	Radius CM	3	Projecting		.0340	1.5	.0496	.53	(57)
35	Pipe arch	1	Projecting	1	.0296	1.5	.0487	.55	(56)
	18° corner	2	No bevels		.0087	2.0	.0361	.66	(56)
	Radius CM	3	33.7° bevels		.0030	2.0	.0264	.75	(56)
36	Pipe arch	1	Projecting	1	.0296	1.5	.0487	.55	(56)
	31° corner	2	No bevels		.0087	2.0	.0361	.66	(56)
	Radius CM	3	33.7° bevels		.0030	2.0	.0264	.75	(56)
40-42	Arch CM	1	90° headwall	1	.0083	2.0	.0379	.69	(57)
		2	Mitered to slope		.0300	2.0	.0463	.75	(57)
		3	Thin wall projecting		.0340	1.5	.0496	.57	(57)
55	Circular	1	Smooth tempered inlet throat	2	.534	.555	.0196	.89	(3)
		2	Rough tapered inlet throat		.519	.64	.0289	.90	(3)
56	Elliptical Inlet face	1	Tapered inlet - beveled edges	2	.536	.622	.0368	.83	(3)
		2	Tapered inlet - square edges		.5035	.719	.0478	.80	(3)
		3	Tapered inlet - thin edge projecting		.547	.80	.0598	.75	(3)
57	Rectangular	1	Tapered inlet throat	2	.475	.667	.0179	.97	(3)
58	Rectangular Concrete	1	Side tapered - less favorable edges	2	.56	.667	.0466	.85	(3)
		2	Side tapered - more favorable edges		.56	.667	.0378	.87	(3)
59	Rectangular Concrete	1	Slope tapered - less favorable edges	2	.50	.667	.0466	.65	(3)
			Slope tapered - more favorable edges		.50	.667	.0378	.71	(3)

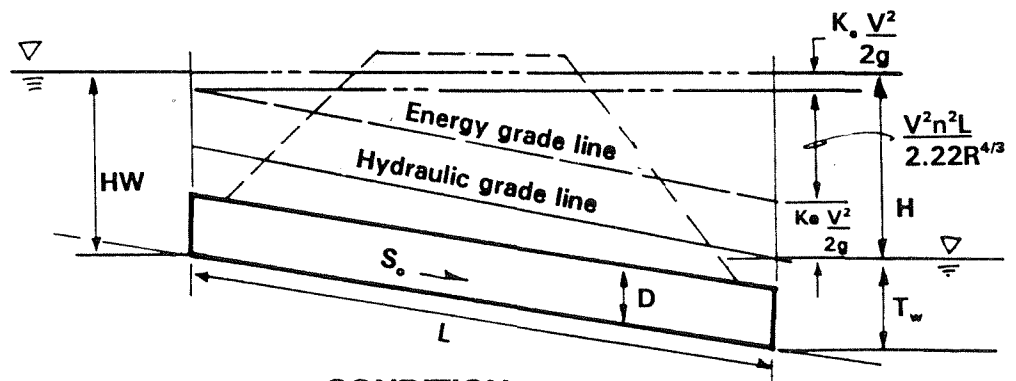
Figure III-2.13 - Inlet/Outlet Control Conditions



**CONDITION 1a**  
**INLET CONTROL - SUBMERGED INLET, FREE OUTFALL**  
 $\frac{HW}{D} > 1.3$



**CONDITION 1b**  
**INLET CONTROL**  
 $\frac{HW}{D} < 1.3$



**CONDITION 2**  
**OUTLET CONTROL - SUBMERGED INLET AND OUTLET**

Figure III-2.14 - Headwater Depth for Smooth Interior Pipe Culverts With Inlet Control

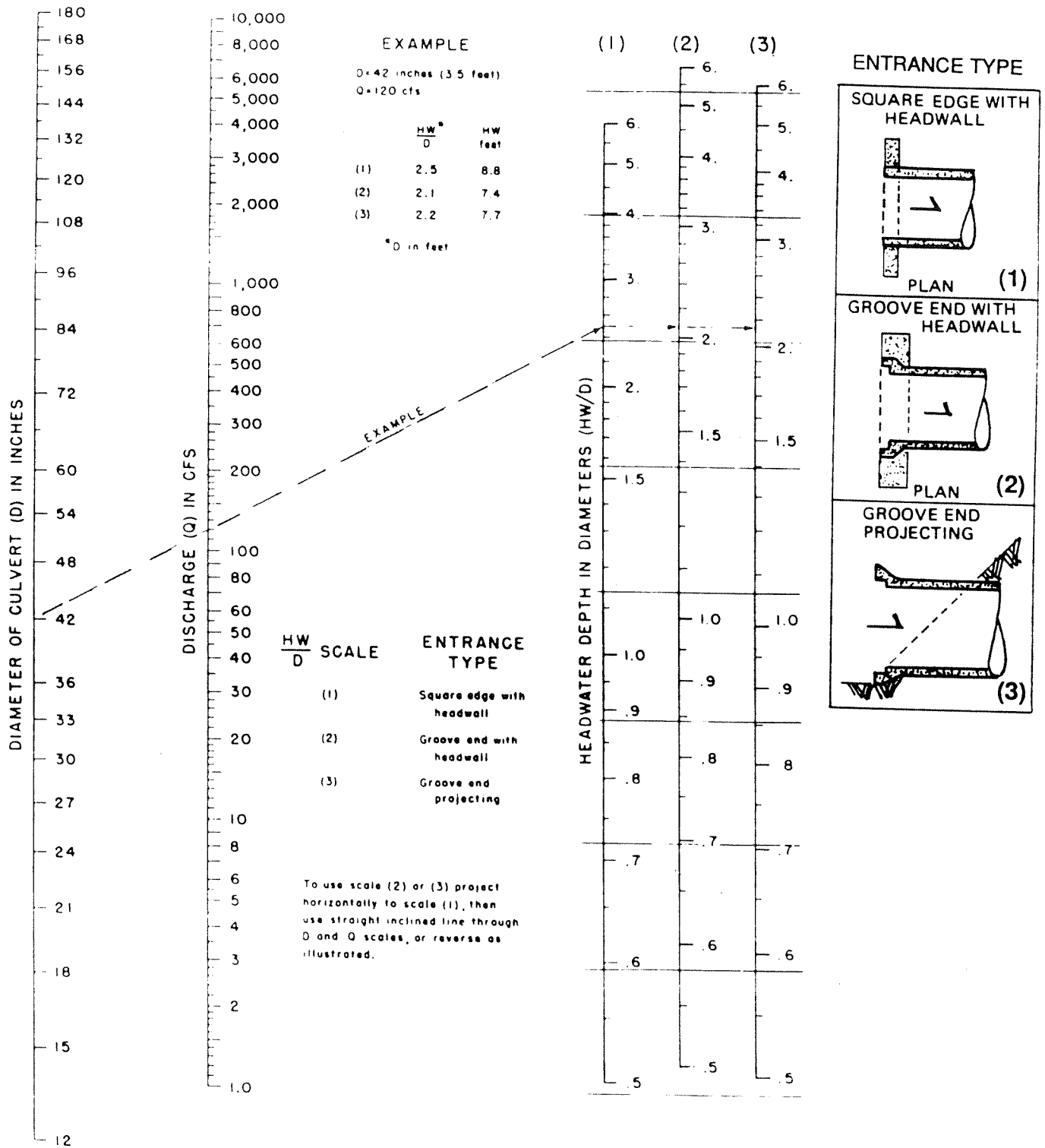


Figure III-2.15 - Headwater Depth for Corrugated Pipe Culverts With Inlet Control

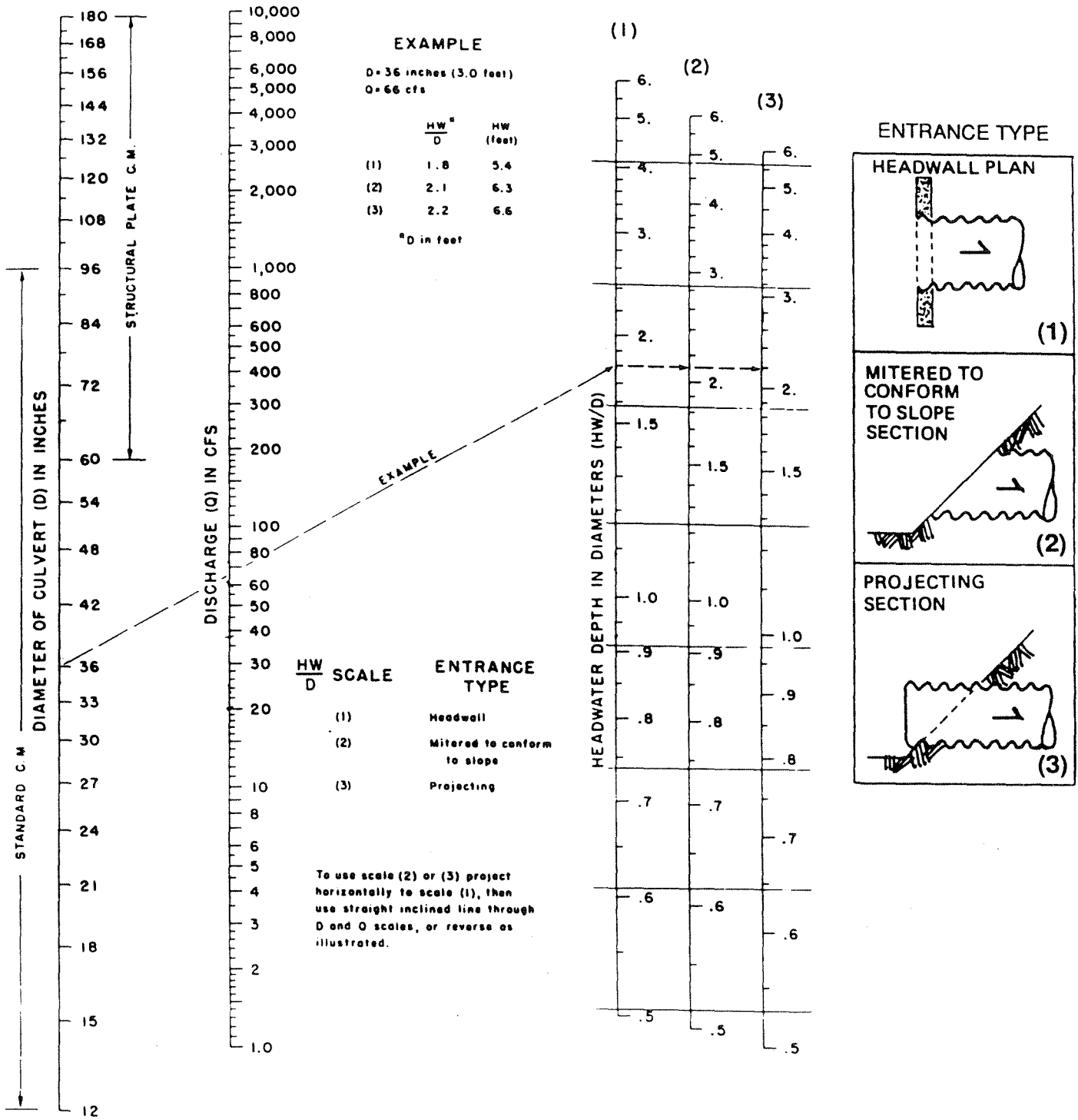


Figure III-2.16 - Head for Culverts (Pipe W/"n" = 0.024), Flowing Full With Outlet Control

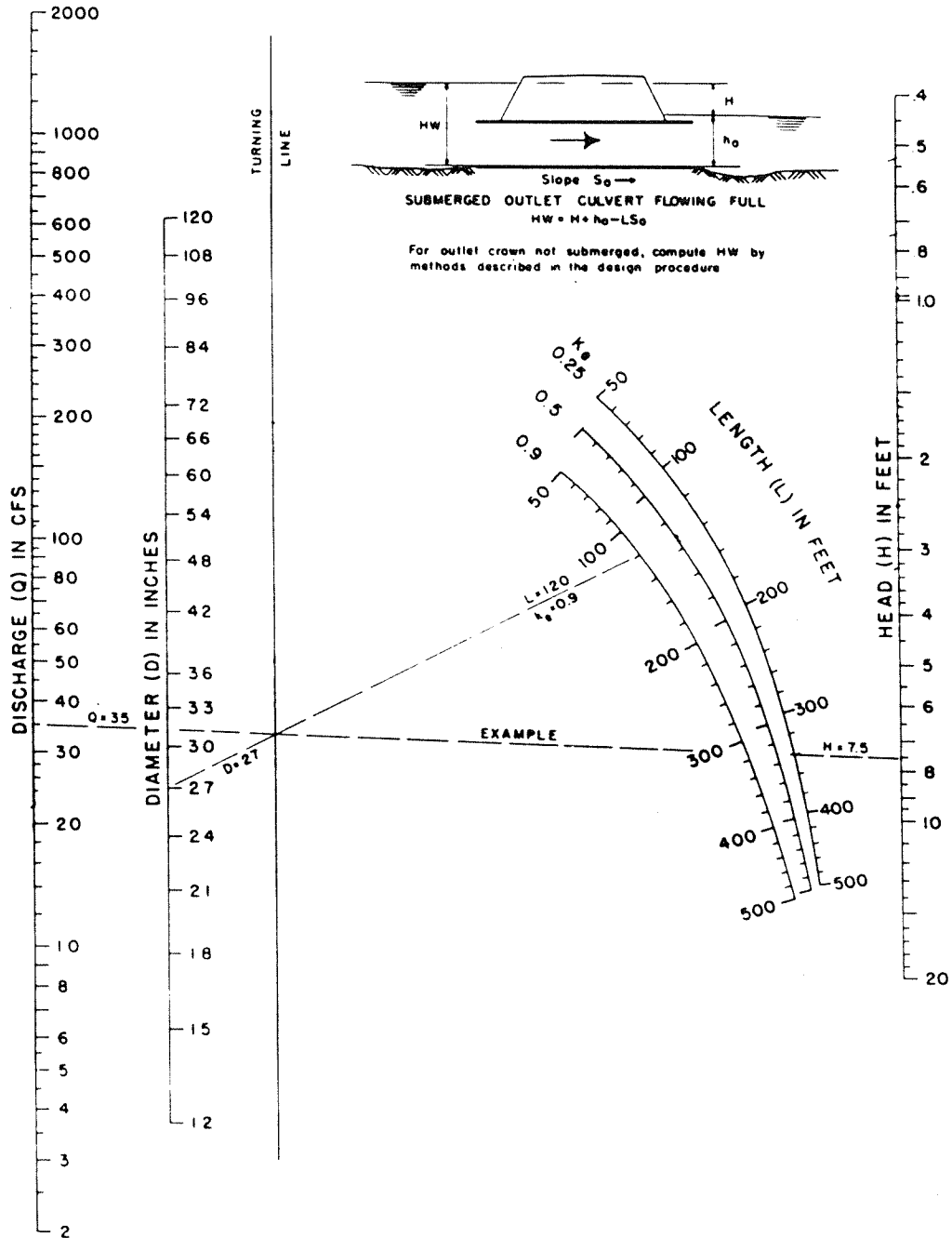


Figure III-2.17 - Head for Culverts (Pipe W/"n" = 0.012), Flowing Full With Outlet Control

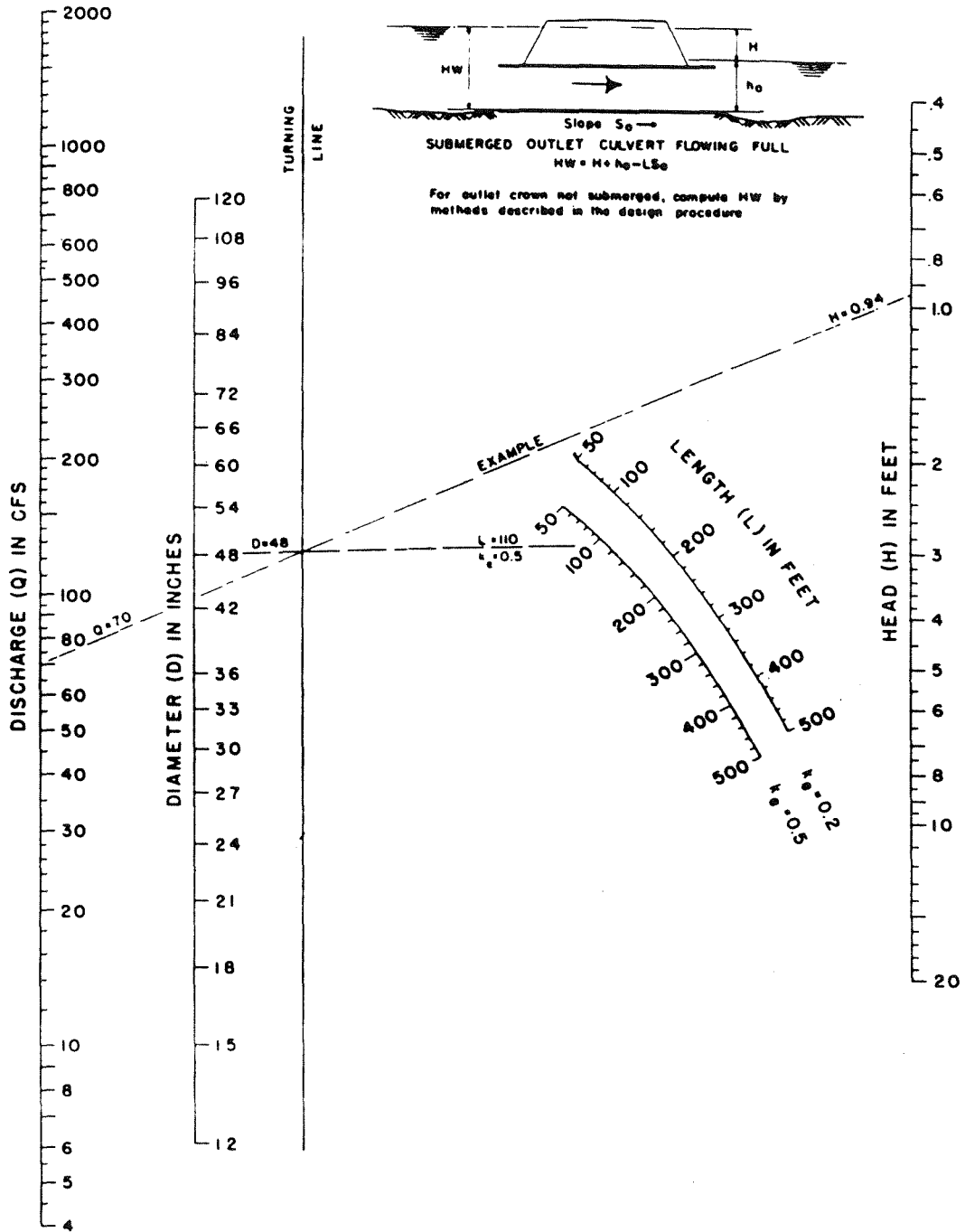


Figure III-2.18 - Headwater Depth for Concrete Box Culverts Flowing Full With Outlet Control ("n" = 0.012)

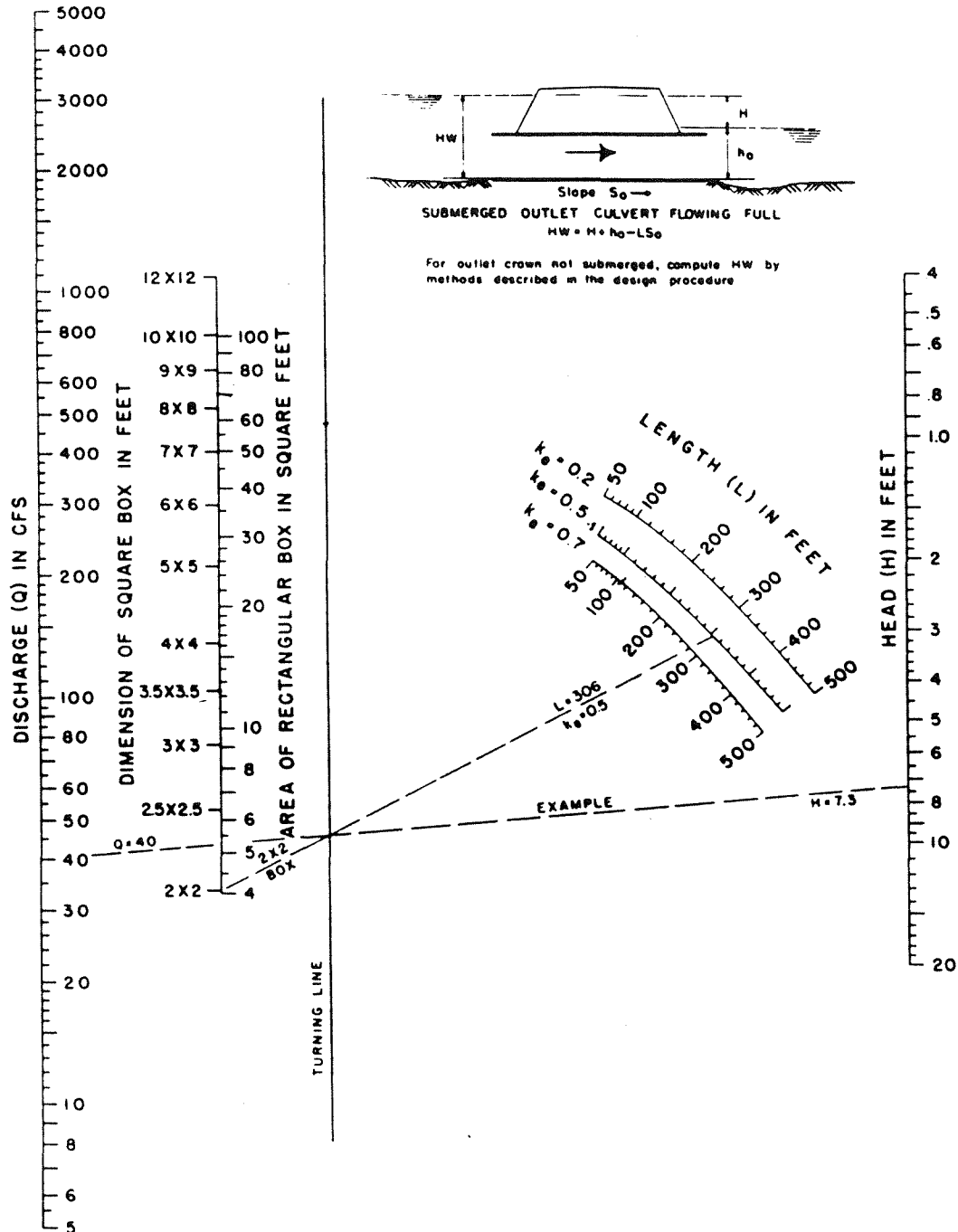


Figure III-2.19 - Critical Depth of Flow for Circular Culverts

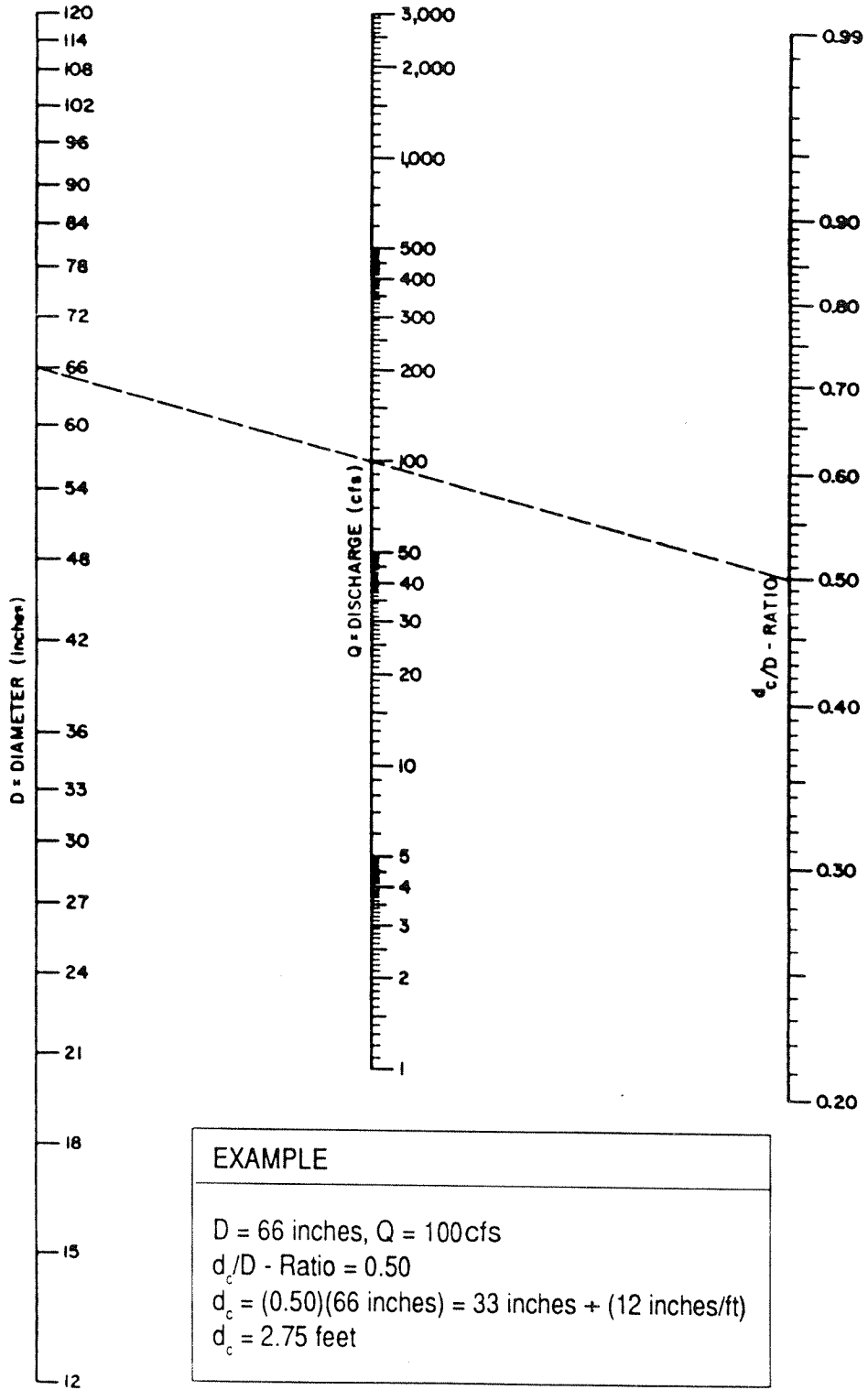
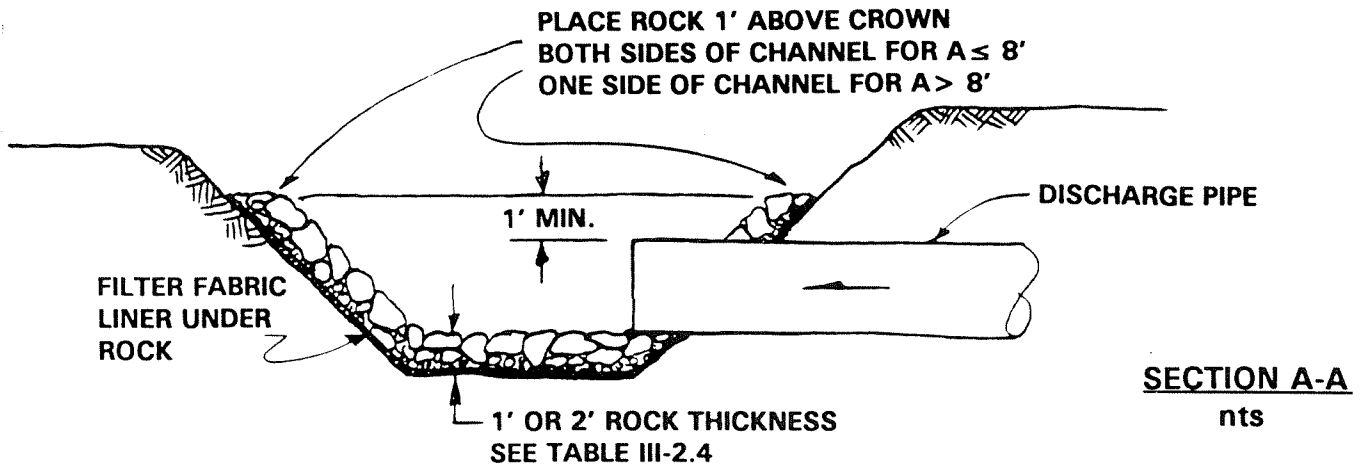
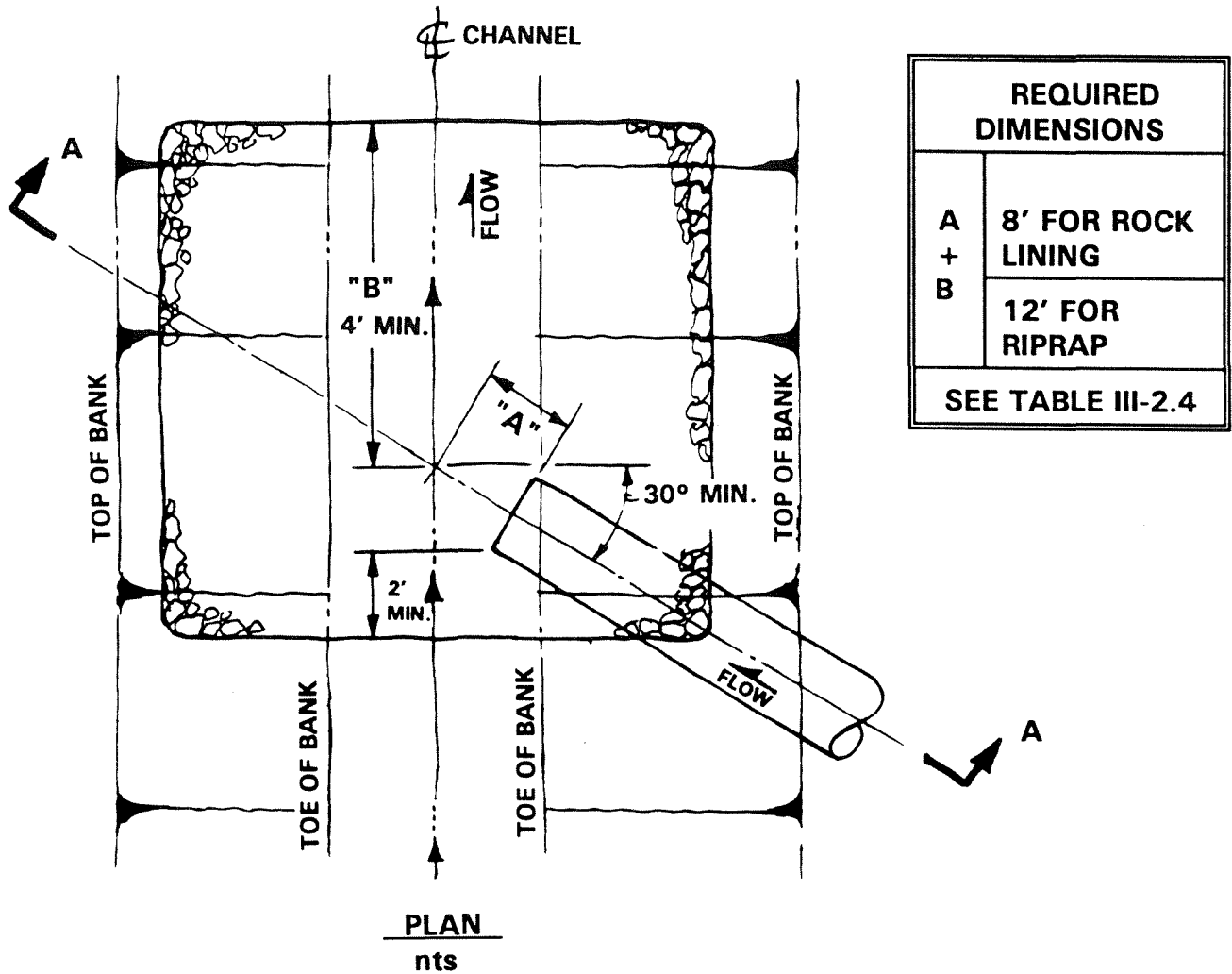




Figure III-2.20 - Culvert Discharge Protection



### III-2.3.5 Outfalls

#### Design Criteria and Methods of Analysis for Outfalls

- All outfalls (at a minimum) shall be provided with a rock splash pad (see Figure III-2.21). The flow dispersal trench shown in Figure III-2.22 shall only be used as an outfall as described. For outfalls with a velocity at design flow greater than 10 fps, a gabion dissipator or engineered energy dissipator shall be required (see Table III-2.7).
- Mechanisms which reduce velocity prior to discharge from an outfall are encouraged. Examples are drop manholes and rapid expansion into pipes of much larger size.
- Engineered energy dissipators, including stilling basins, drop pools, hydraulic jump basins, baffled aprons, and bucket aprons, are required for outfalls with velocity at design flow greater than 20 fps. These should be designed using published or commonly known techniques found in such references as Hydraulic Design of Energy Dissipators for Culverts and Channels published by the Federal Highway Administration of the United States Department of Transportation (1); Open Channel Hydraulics, by V.T. Chow (2); Hydraulic Design of Stilling Basins and Energy Dissipators, EM 25, Bureau of Reclamation 1978 (3), and others, such as those published by the Soil Conservation Service.
- Examples of alternate mechanisms include concepts such as a bubble-up structure (which will eventually drain) and a structure fitted with reinforced concrete posts. Alternate mechanisms such as these should be designed using sound hydraulic principles and consideration of ease of construction and maintenance.
- Inlet control will usually dictate outfall pipe system capacity. These conditions should be carefully examined, as well as the consequences, should the inlet to the pipe system become plugged or capacity exceeded.

#### Outfall Systems Traversing Steep Slopes

- Based on past experience in King County, and elsewhere, outfall systems constructed of pipe segments which are banded and/or gasketed have failed. This has resulted from leaks developing at the joints, accelerating erosion around the pipe, and inevitable failure of the system. These failures on steep or unstable slopes can result in incision of the adjacent slopes and downstream sedimentation which clogs conveyance systems and destroys wildlife habitat or worse, mudflows which can cause extensive damage and pose a serious risk of injury or death.
- These outfall failures have promoted the requirement for the use of continuously fused, welded or flange bolted mechanical joint pipe systems with proper anchoring for outfalls on steep slopes. For the past several years high density polyethylene pipe (HDPP) has been used very successfully in preventing these failures. While high in material costs, its relative ease of installation, high performance, and durability makes its life cycle cost comparable, if not much lower than traditional installations. Ductile iron pipe with flange-bolted mechanical joints also has proven reliable for steep slope applications.

#### Design Criteria for Outfall Systems Traversing Steep Slopes

- Outfall pipes systems shall be installed in trenches with standard bedding on slopes up to 20 percent. On slopes greater than 20 percent, outfall

pipe systems shall be placed on the ground surface with proper pipe anchorage.

- HDPP outfall systems must be designed to address the material limitations as specified by the manufacturer, in particular thermal expansion/contraction, and pressure design. The coefficient of thermal expansion and contraction for HDPP is on the order of 0.001 inch per foot per Fahrenheit degree. Sliding sleeve connections to address this thermal expansion and contraction shall be used. These sleeve connections consist of a section of the appropriate length of the next larger size diameter of pipe into which the outfall pipe is fitted. These sleeve connections must be located as close to the discharge end of the outfall system as is practical.
- Due to HDPP's ability to transmit flows of very high energy, special consideration for energy dissipation must be made. A sample gabion mattress energy dissipator for this purpose has been provided in Figure III-2.21. Flows of very high energy will require a specifically engineered energy dissipator structure, as described above.

#### III-2.3.6 Open Channels

Open channels can be classified as either natural or constructed. Natural channels are generally referred to as streams, creeks, or swales, while constructed channels are most often called ditches or, simply, channels. The local government's Sensitive Areas Ordinance and Rules (if adopted) and the Minimum Requirements (Chapter I-2) should be reviewed for requirements related to streams.

Natural channels are defined as those which have occurred naturally due to the flow of surface waters or those that, although originally constructed by human activity, have taken on the appearance of a natural channel including a stable route and biological community. They may vary hydraulically along each channel reach and should be left in their natural condition wherever feasible or required, in order to maintain natural hydrologic functions and wildlife habitat benefits from established vegetation.

Constructed channels are those constructed or maintained by human activity and include bank stabilization of natural channels. Constructed channels shall be either rock-lined, vegetation-lined, or lined with appropriately "bio-engineered" vegetation.

Vegetation-lined channels are the preferred type of constructed channels when properly designed and constructed. The vegetation stabilizes the slopes of the channel, controls erosion of the channel surface, and removes pollutants. The channel storage, low velocities, water quality benefits, and greenbelt multiple-use benefits create significant advantages over other constructed channels. The presence of vegetation in channels creates turbulence which results in loss of energy and increased flow retardance; therefore, the design engineer must consider sediment deposition and scour, as well as flow capacity.

Rock-lined channels are necessary where a vegetative lining will not provide adequate protection from erosive velocities. They may be constructed with quarry spall riprap, gabions, or slope mattress linings. The rock lining increases the turbulence, resulting in a loss of energy and increased flow retardance. Rock lining also permits a higher design velocity and therefore a steeper design slope than in grass-lined channels. Rock linings are also used for erosion control at culvert/storm drain outlets, at sharp channel bends, channel confluences, and locally steepened channel sections. Rock-lined channels should only be used when careful consideration has shown that vegetated channels are not feasible.

Figure III-2.21 - Gabion Outfall Detail

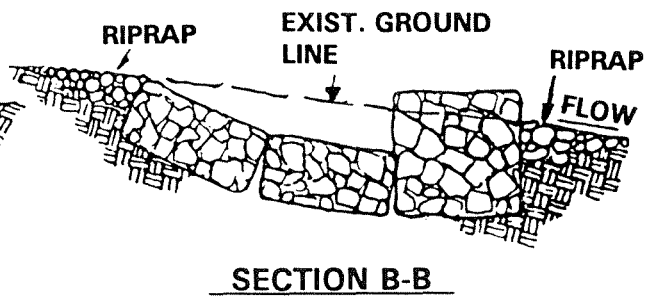
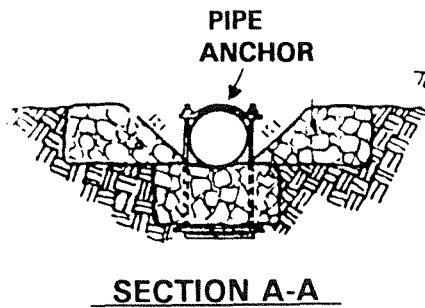
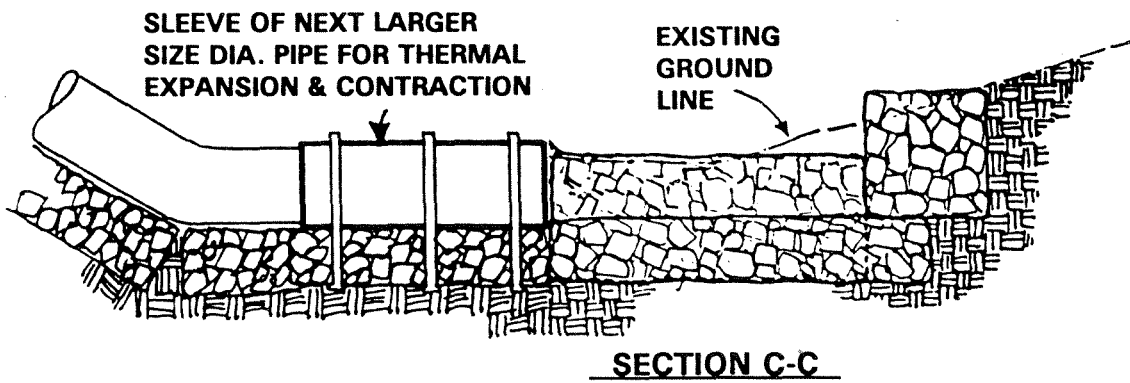
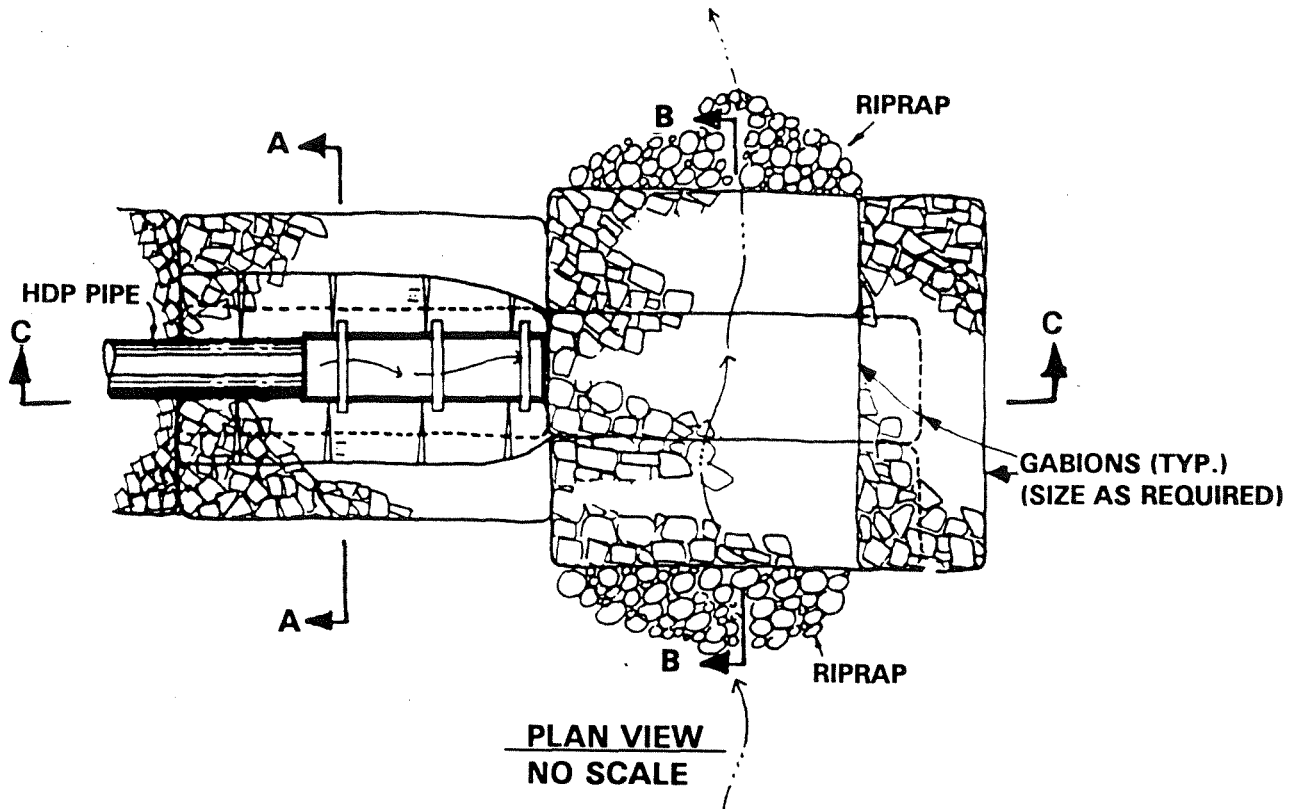
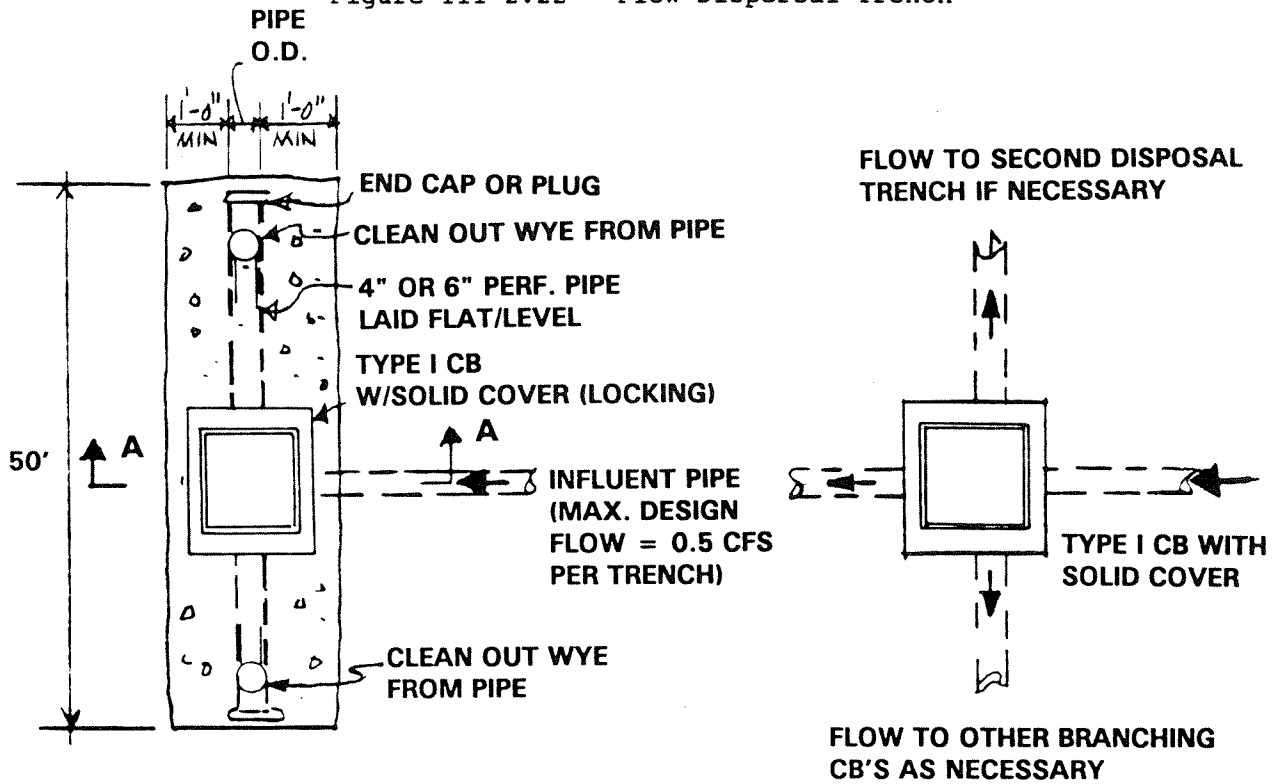
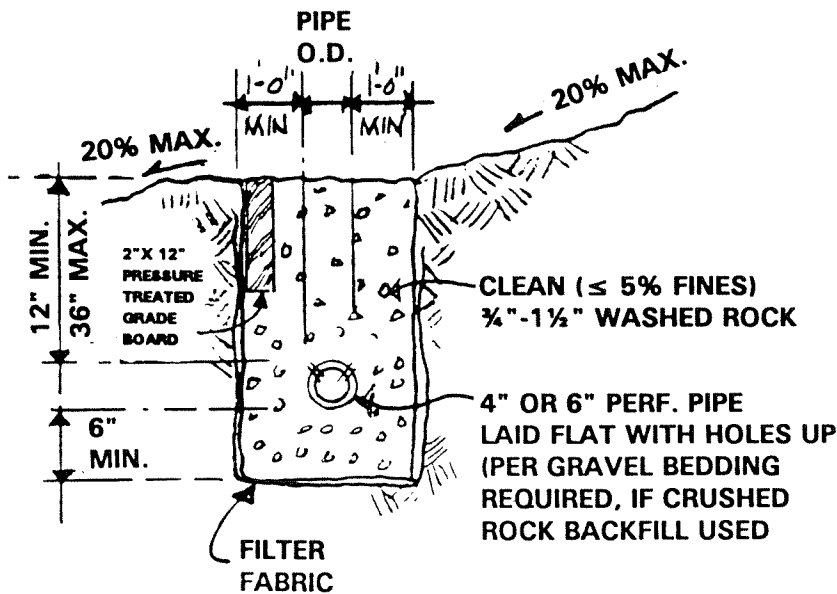


Figure III-2.22 - Flow Dispersal Trench



PLAN  
nts



SECTION A-A  
nts

**NOTES:**

1. THIS TRENCH SHALL BE CONSTRUCTED SO AS TO PREVENT POINT DISCHARGE AND/OR EROSION.
2. TRENCHES MAY BE PLACED NO CLOSER THAN 50 FEET TO ONE ANOTHER.
3. TRENCH AND GRADE BOARD MUST BE LEVEL; ALIGN TO FOLLOW CONTOURS OF SITE.
4. GRADE BOARD SUPPORT POST SPACING AS REQUIRED BY SOIL CONDITIONS.

## Design Criteria

**Geometry:** Channel section geometry shall be trapezoidal, V-shaped parabolic, or segmental as shown in Figures III-2.26 through III-2.28. Side slopes shall be not steeper than 3:1 for vegetation-lined channels and 2:1 for rock-lined channels unless engineered (roadside ditches shall be per local government Road Standards).

**Minimum Velocity:** In order to promote infiltration, biofiltration, and deposition of silt prior to entering closed pipe systems or natural channels, the minimum velocity is 0.5 fps.

**Channel Freeboard:** Provide minimum 0.5 ft. above design flows.

**Maximum Slope/Velocity:** Vegetation-lined channels shall have bottom slope gradients of 5 percent or less and a maximum average velocity at design flow of 5 fps.

**Stabilization:** Rock-lined channels or bank stabilization of natural channels shall be used when design flow velocities exceed 5 fps. Rock lining shall be in accordance with Table III-2.7 or stabilized with bioengineering methods as described below.

**Easements:** An access easement for maintenance is required along all constructed channels located on private property. Required easement widths and building setback lines vary with channel top width as required by the local government.

## Bioengineered Channels and Bank Stabilization

Soil "Bioengineering" is a highly specialized science that uses living plants and plant parts to stabilize eroded or damaged land. Its application to eroded stream or river banks provides desirable alternatives to the conventional methods of rock armoring.

Properly bioengineered systems are capable of providing a measure of immediate soil protection and mechanical reinforcement. As the plants grow they produce a vegetative protective cover and a root reinforcing matrix in the soil mantle. This root reinforcement serves several purposes:

- (1) The developed anchor roots provide both shear and tensile strength to the soil, thereby providing protection from the frictional shear and tensile velocity components to the soil mantle during the time when flows are receding and pore pressure is high in the saturated bank.
- (2) The root mat provides a living filter in the soil mantle which allows for the natural release of water after the high flows have receded.
- (3) The combined root system exhibits active friction transfer along the length of the living roots. This consolidates soil particles in the bank and serves to protect the soil structure from collapsing and the stabilization measures from failing.

The vegetative cover provides immediate protection during high flows by laying flat against the bank and covering the soil like a blanket. It also reduces pore pressure in saturated banks through transpiration by acting as a natural "pump" to "pull" the water out of the banks after flows have receded. For further details on bioengineering methods see BMPs E2.45, E2.80, E2.85 and E2.90 in Volume II, Erosion and Sediment Control.

### Riprap Design

(from a paper prepared by M. Schaefer, Ph.D., Dam Safety Section, Washington State Department of Ecology.)

In the placing of riprap, stones are placed on the channel sides and bottom to protect the underlying material from being eroded. Proper riprap design requires the determination of the median size of stone, the thickness of the riprap layer, the gradation of stone sizes and the selection of angular stones which will interlock when placed. Research by the U.S. Army Corps of Engineers has provided criteria for selecting the median stone size,  $W_{50}$  (Figure III-2.23). If the riprap is to be used in a highly turbulent zone, such as at a culvert outfall, downstream of a stilling basin, at sharp changes in channel geometry, etc., the median stone ( $W_{50}$ ) should be increased from 200 percent to 600 percent depending on the severity of the locally high turbulence. The thickness of the riprap layer should generally be twice the median stone diameter ( $D_{50}$ ) or at least that of the maximum stone. The riprap should have a reasonably well graded assortment of stone sizes within the following gradation:

$$1.25 \leq \frac{D_{max}}{D_{50}} \leq 1.50, \quad \frac{D_{15}}{D_{50}} = 0.50, \quad \frac{D_{min}}{D_{50}} = 0.25$$

For a more detailed analysis and design procedure for riprap requiring water surface profiles and estimates of tractive force, refer to the paper by Maynard et al., Journal of Hydraulic Engineering (A.S.C.E.), July, 1989.

### Riprap Filter Design

The riprap should be underlain by a sand and gravel filter (or filter fabric) to keep the fine materials in the natural channel from being washed through the voids in the riprap. Likewise, the filter material must be selected so that it is not washed through the voids in the riprap. Adequate filters can usually be provided by a reasonably well graded sand and gravel material where:

$$D_{15} < 5d_{85}$$

Where  $d$  refers to the sieve opening through which 85 percent of the material being protected will pass and  $D_{15}$  has the same interpretation for the filter material. A filter with a  $D_{50}$  of 0.5 mm will protect any finer material including clay. Where very large riprap is used it is sometimes necessary to use two filter layers between the material being protected and the riprap.

#### Example:

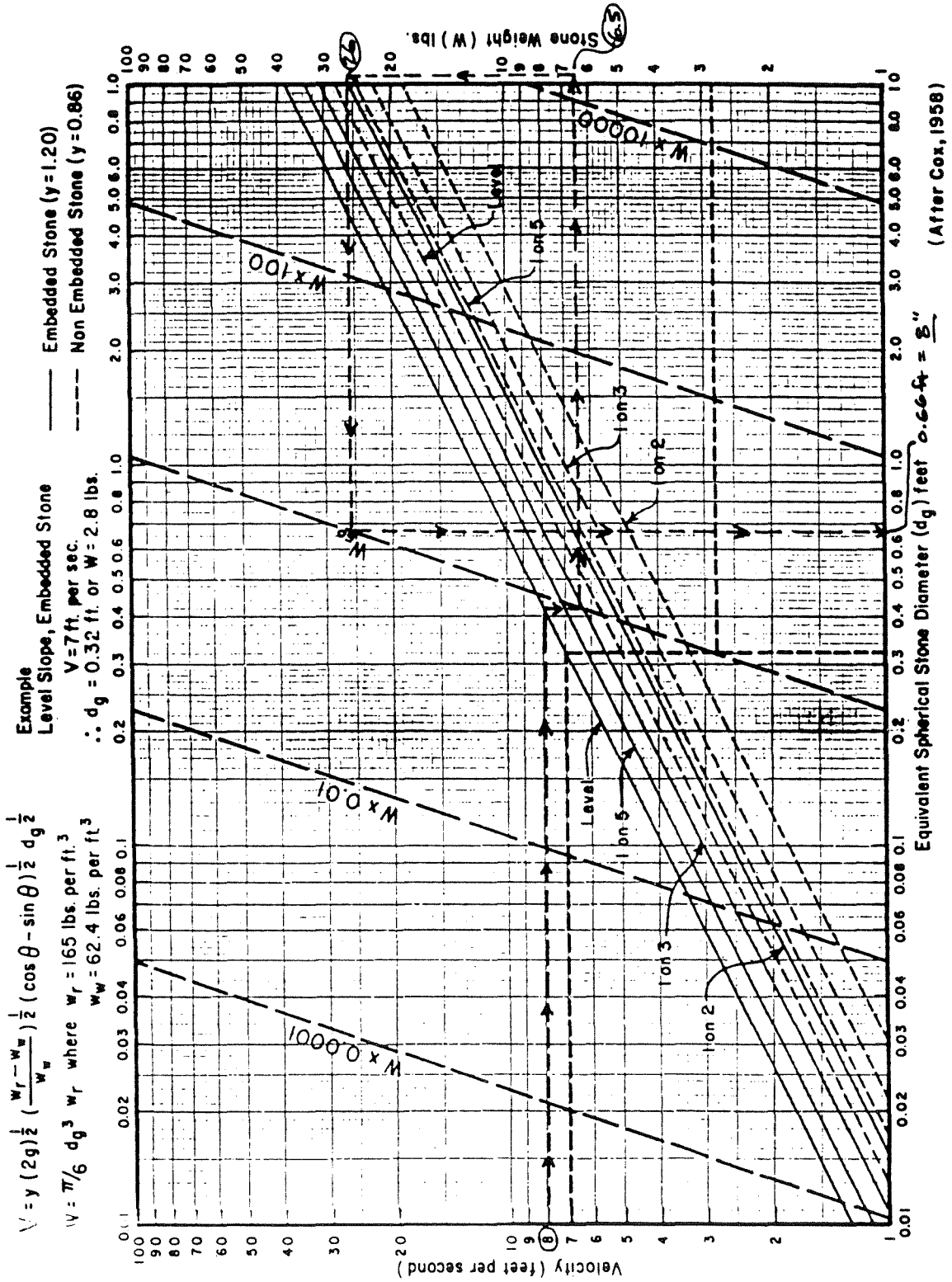
What riprap design should be used for protection of a stream bank at a culvert outfall where the outfall velocities in the vicinity of the downstream toe are expected to be about 8 fps?

From Figure III-2.23,  $W_{50} = 6.5$  lbs, since the downstream area below the outfall will be subjected to severe turbulence, increase  $W_{50}$  by 400%,  
use:

$$W_{50} = 26 \text{ lbs, } D_{50} = 8.0 \text{ inches}$$

The gradation of the riprap is shown in Figure III-2.24, and the minimum thickness would be 1 foot (from Table III-2.7); however, 16 inches to 24 inches of riprap thickness would provide some additional insurance that the riprap will function properly in this highly turbulent area.

Figure III-2.23 - Mean Channel Velocity vs. Median Stone Weight ( $W_{50}$ ) and Equivalent Stone Diameter





Inspection of Figure III-2.24 shows that the gradation curve for ASTM C-33, size number 57 coarse aggregate (used in concrete mixes), would meet the filter criteria. Applying the filter criteria to the coarse aggregate would demonstrate that any underlying material whose gradation was coarser than that of a concrete sand would be protected.

For additional information and procedures for specifying filters for riprap and general guidance, refer to the Army Corps of Engineers Manual EM 1110-2-1601 (1970) "Hydraulic Design of Flood Control Channels," paragraph 14, Rip Rap Protection.

Table III-2.7 Channel Protection

Velocity at Design Flow (fps)		Required Protection	Thickness	Min. Height Above Design Water Surface
Greater than	Less than or equal to			
0	5	Grass Lining***	N/A	0.5 ft.
5	8	Riprap*, ***	1 ft.	1 ft.
8	12	Riprap**	2 ft.	2 ft.
12	20	Slope mattress Gabion, etc.	Varies	2 ft.

\* Riprap shall be in accordance with section 9-13.1 of the WSDOT/APWA Standard Specifications.

\* Riprap shall be reasonably well graded assortment of rock with the following gradation:

Maximum stone size 12"  
Median stone size 8"  
Minimum stone size 2"

\*\* Riprap shall be reasonably well graded assortment of rock with the following gradation:

Maximum stone size 24"  
Median stone size 16"  
Minimum stone size 4"

Note: Riprap sizing governed by side slopes on channel, assumed ~3.1.

\*\*\* Bioengineered lining allowed for design flow up to 8 fps.

#### Methods of Analysis

Three methods of analysis are presented here for sizing and analyzing open channels.

##### (1) Manning's Equation for Preliminary Sizing of Open Channels

This method is used for preliminary sizing of open channel reaches of uniform cross-section and slope (i.e., prismatic channels), and uniform roughness. It assumes the

flow depth (or normal depth), and flow velocity, remain constant throughout the channel reach for a given flow.

The charts in Figures III-2.26 and III-2.27 can be used to obtain graphic solutions of Manning's Equation for common ditch sections. For conditions outside the range of these charts, or for more precise results, Manning's Equation can be solved directly from its classic forms:

$$V = 1.49/n R^{2/3} S^{1/2} \quad \text{or} \quad Q = 1.49/n A R^{2/3} S^{1/2}$$

Table III-2.8 provides a reference for selecting the appropriate "n" values for open channels. A number of engineering reference books, such as "Open-Channel Hydraulics" by V.T. Chow (Table 5-6 and Figure 5-5), may also be used as a guide in the selection of "n" values. Figure III-2.28 contains the geometric elements of common channel sections useful in determining area (A), wetted perimeter (WP), and hydraulic radius ( $R = A/WP$ )

Note, if flow restrictions occur which raise the water level above normal depth within a channel reach, a backwater condition (or non-uniform flow) is said to exist. This condition can result from flow restrictions created by a downstream culvert, bridge, dam, pond, lake, etc., or a downstream channel reach having a higher than normal flow depth. If backwater conditions are found to exist, a backwater profile should be computed to verify that the channel's capacity is still adequate. The Direct Step or Standard Step backwater methods can be used for this purpose.

#### (2) Direct Step Backwater Method

This method may be used to calculate a water surface profile for a channel when the downstream receiving facility creates a restriction to normal flow (e.g. an open channel transition to a culvert). Application of this method to prismatic channels is characterized by dividing the channel into short reaches for analysis. A reach is any length of channel which exhibits common hydraulic characteristics such as cross-section, roughness, and slope.

Table III-2.8 - Values of the Roughness Coefficient, "n"

Type of Channel and Description	Manning's "n" (Normal)	Type of Channel and Description	Manning's "n" (Normal)
<b>A. Constructed Channels</b>			
a. Earth, straight and uniform		6. Sluggish reaches, weedy deep pools	0.070
1. Clean, recently completed	0.018	7. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.100
2. Gravel, uniform section, clean	0.025	b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	
3. With short grass, few weeds	0.027	1. Bottom: gravel, cobbles, and few boulders	0.040
b. Earth, winding and sluggish	0.025	2. Bottom: cobbles with large boulders	0.050
1. No vegetation	0.025	<b>B-2 Flood plains</b>	
2. Grass, some weeds	0.030	a. Pasture, no brush	
3. Dense weeds or aquatic plants in deep channels	0.035	1. Short grass	0.030
4. Earth bottom and rubble sides	0.030	2. High grass	0.035
5. Stony bottom and weedy banks	0.035	b. Cultivated areas	
6. Cobble bottom and clean sides	0.040	1. No crop	0.030
c. Rock lined		2. Mature row crops	0.035
1. Smooth and uniform	0.035	3. Mature field crops	0.040
2. Jagged and irregular	0.040	c. Brush	
d. Channels not maintained, weeds and brush uncut		1. Scattered brush, heavy weeds	0.050
1. Dense weeds, high as flow depth	0.080	2. Light brush and trees	0.060
2. Clean bottom, brush on sides	0.050	3. Medium to dense brush	0.070
3. Same, highest stage of flow	0.070	4. Heavy, dense brush	0.100
4. Dense brush, high stage		d. Trees	
4. Dense brush, high stage		1. Dense willows, straight	0.150
<b>B. Natural Streams</b>	0.100	2. Cleared land with tree stumps, no sprouts	0.040
B-1 Minor streams (top width at flood stage < 100 ft.)		3. Same as above, but with heavy growth of sprouts	0.060
a. Streams on plain		4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
1. Clean, straight, full stage no rifts or deep pools	0.030	5. Same as above, but with flood stage reaching branches	0.120
2. Same as above, but more stones and weeds	0.035		
3. Clean, winding, some pools and shoals	0.040		
4. Same as above, but some weeds	0.040		
5. Same as 4, but more stones	0.050		

\*Note, these "n" values are "normal" values for use in analysis of channels. For conservative design for channel capacity the "maximum" values listed in other references should be considered. For channel bank stability the minimum values should be considered.

Figure III-2.24 - Riprap Gradation Curve

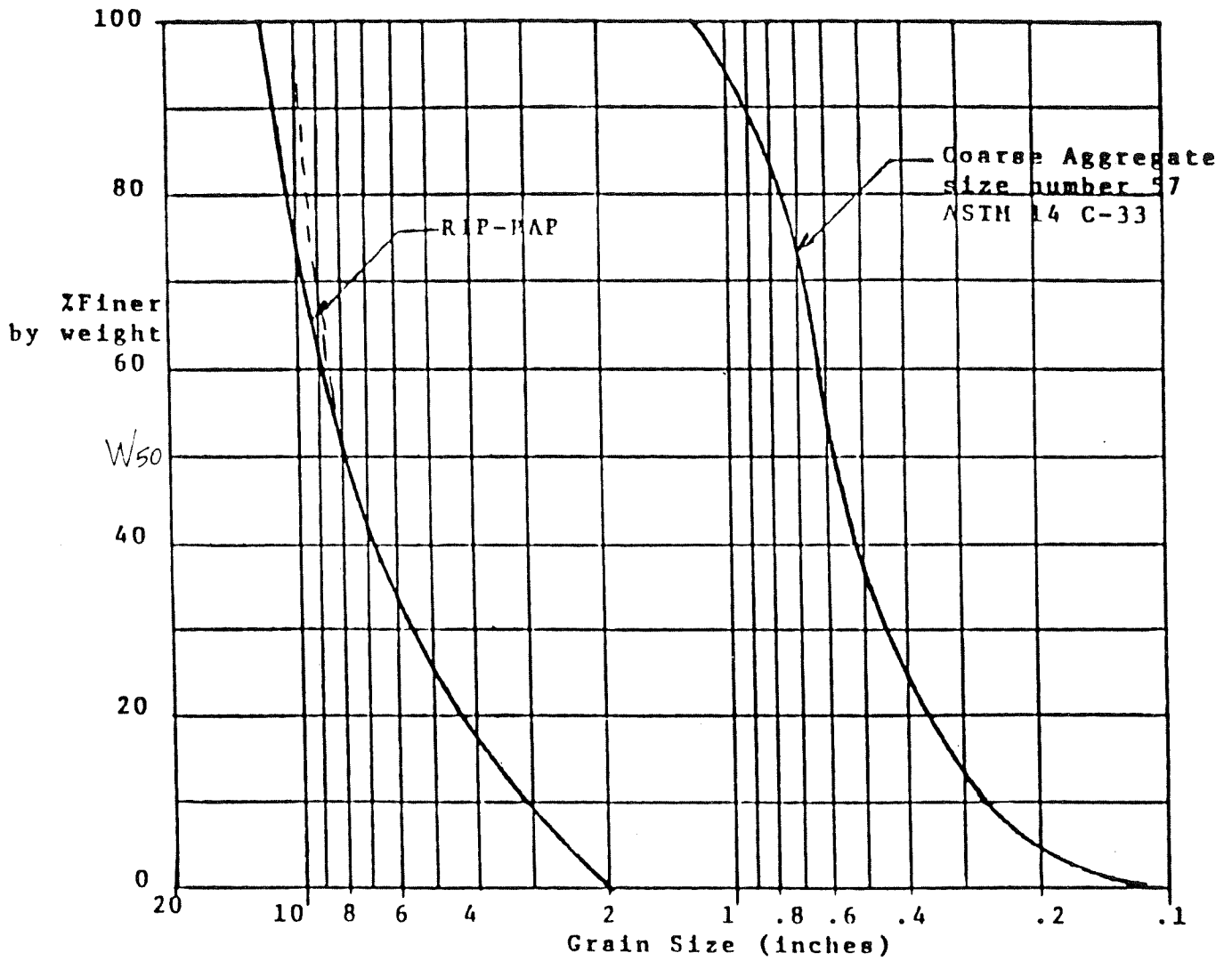


Figure III-2.25 - Open Channel Flow Profile Computation

$Q =$ _____ $n =$ _____ $S_0 =$ _____ $\alpha =$ _____ $Y_n =$ _____												
$y$	$A$	$R$	$R^{4/3}$	$V$	$\alpha V^{1/2}g$	$E$	$\Delta E$	$S_f$	$\hat{S}_f$	$S_0 - \hat{S}_f$	$\Delta x$	$x$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

Figure III-2.26 - Ditches, Common Sections

PROPERTIES OF DITCHES

NO.	DIMENSIONS				HYDRAULICS			
	SLOPE SLOPES	B	H	W	a	p	R	R <sup>4</sup>
D-1	—	—	6"	5'-0"	1.84	5.16	0.356	0.502
D-1C	—	—	6"	25'-0"	6.25	25.5	0.245	0.391
D-2A	1 1/2:1	2'-0"	1'-0"	5'-0"	3.50	5.61	0.624	0.730
B	2:1	2'-0"	1'-0"	6'-0"	4.00	6.47	0.618	0.726
C	3:1	2'-0"	1'-0"	8'-0"	5.00	8.32	0.601	0.712
D-3A	1 1/2:1	3'-0"	1'-6"	7'-6"	7.88	8.41	0.937	0.958
B	2:1	3'-0"	1'-6"	9'-0"	9.00	9.71	0.927	0.951
C	3:1	3'-0"	1'-6"	12'-0"	11.25	12.49	0.901	0.933
D-4A	1 1/2:1	3'-0"	2'-0"	9'-0"	12.00	10.21	1.175	1.114
B	2:1	3'-0"	2'-0"	11'-0"	14.00	11.94	1.173	1.112
C	3:1	3'-0"	2'-0"	15'-0"	18.00	15.65	1.150	1.097
D-5A	1 1/2:1	4'-0"	3'-0"	13'-0"	25.50	14.82	1.721	1.436
B	2:1	4'-0"	3'-0"	16'-0"	30.00	17.42	1.722	1.437
C	3:1	4'-0"	3'-0"	22'-0"	39.00	22.97	1.696	1.473
D-6A	2:1	—	1'-0"	4'-0"	2.00	4.47	0.447	0.584
B	3:1	—	1'-0"	6'-0"	3.00	6.32	0.475	0.609
D-7A	2:1	—	2'-0"	8'-0"	6.00	8.94	0.895	0.979
B	3:1	—	2'-0"	12'-0"	12.00	12.65	0.949	0.965
D-8A	2:1	—	3'-0"	12'-0"	18.00	13.42	1.341	1.716
B	3:1	—	3'-0"	18'-0"	27.00	18.97	1.423	1.765
D-9	7:1	—	1'-0"	12'-0"	7.00	14.14	0.495	0.676
D-10	7:1	—	2'-0"	28'-0"	28.00	28.28	0.990	0.993
D-11	7:1	—	3'-0"	42'-0"	42.00	42.43	1.445	1.302

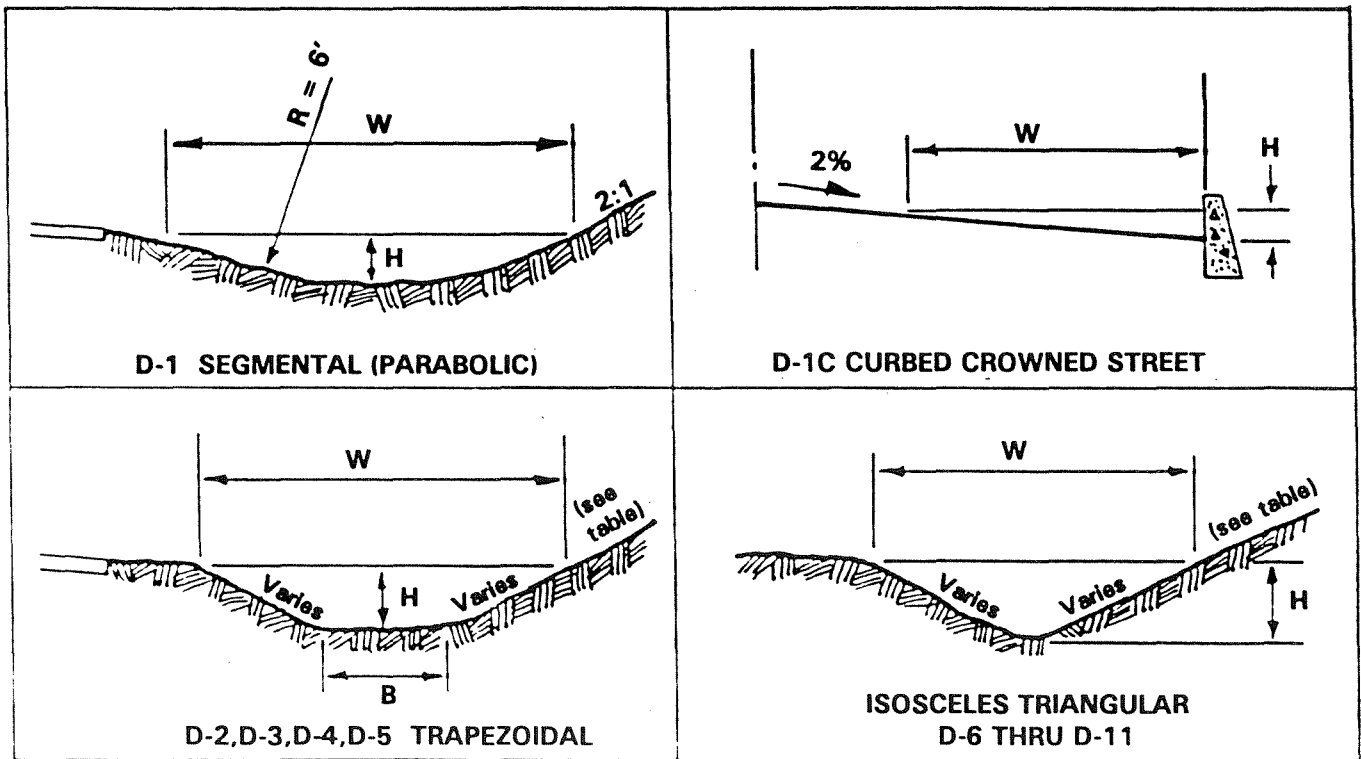


Figure III-2.27 - Drainage Ditches, Common Sections

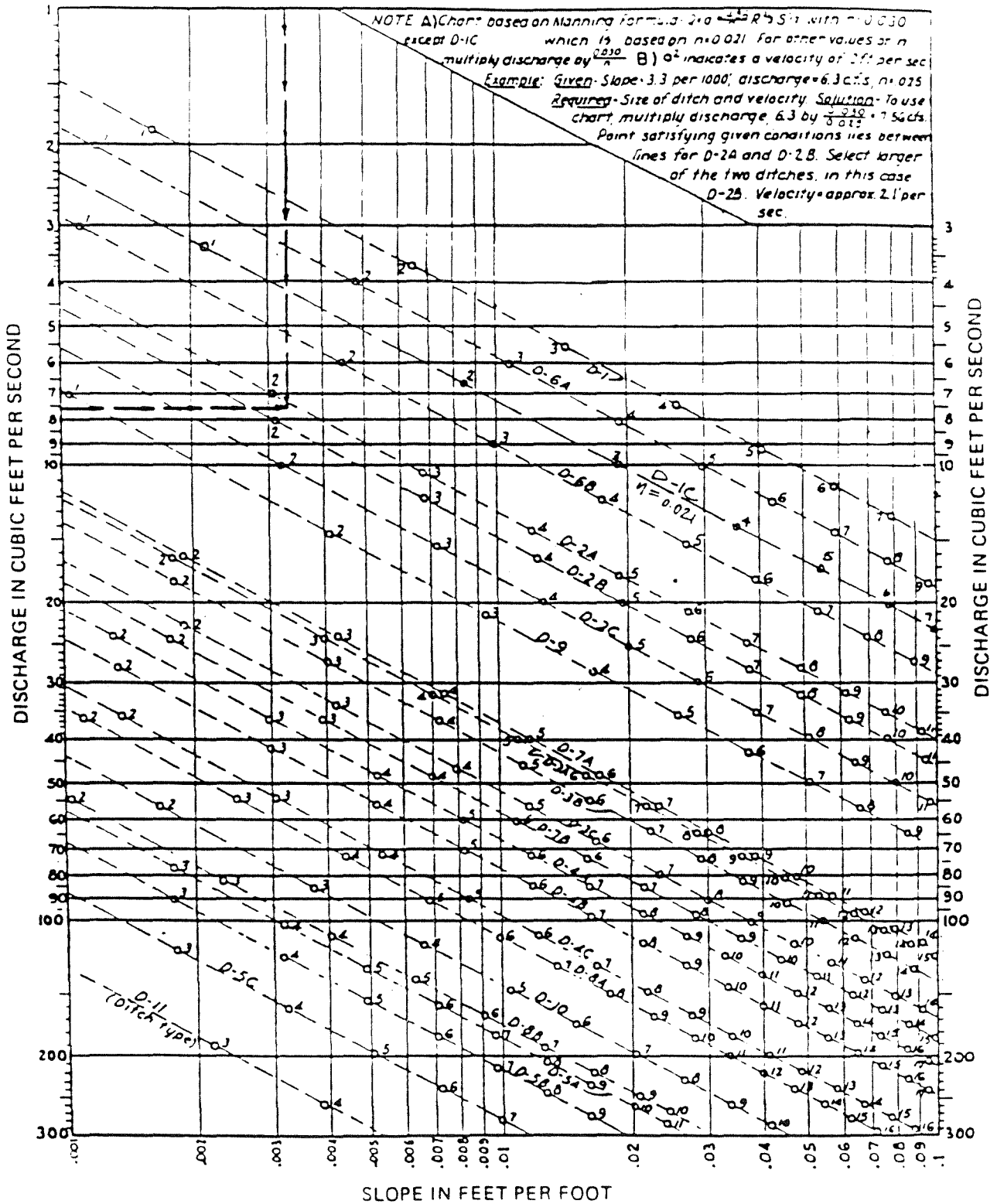


Figure III-2.28 - Geometric Elements of Common Sections

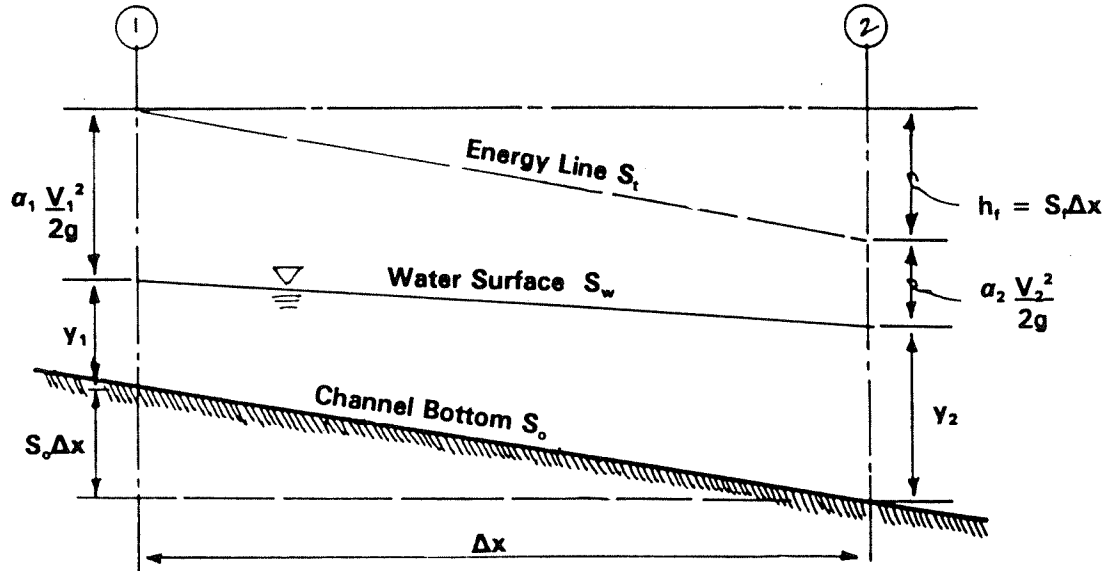
Section	Area $A$	Wetted perimeter $P$	Hydraulic radius $R$	Top width $T$	Hydraulic depth $D$	Section factor $Z$
 Rectangle	$by$	$b + 2y$	$\frac{by}{b + 2y}$	$b$	$y$	$by^{1.48}$
 Trapezoid	$(b + zy)y$	$b + 2y\sqrt{1 + z^2}$	$\frac{(b + zy)y}{b + 2y\sqrt{1 + z^2}}$	$b + 2zy$	$\frac{(b + zy)y}{b + 2zy}$	$\frac{[(b + zy)y]^{1.48}}{\sqrt{b + 2zy}}$
 Triangle	$zy^2$	$2y\sqrt{1 + z^2}$	$\frac{zy}{2\sqrt{1 + z^2}}$	$2zy$	$\frac{1}{2}y$	$\frac{\sqrt{2}}{2}zy^{1.48}$
 Circle	$\frac{1}{8}(\theta - \sin \theta)d_0^3$	$\frac{1}{2}\theta d_0$	$\frac{1}{4}\left(1 - \frac{\sin \theta}{\theta}\right)d_0$	$\frac{(\sin \frac{1}{2}\theta)d_0}{2\sqrt{y(d_0 - y)}}$ or $\frac{(\sin \frac{1}{2}\theta)d_0}{2\sqrt{y(d_0 - y)}}$	$\frac{1}{8}\left(\frac{\theta - \sin \theta}{\sin \frac{1}{2}\theta}\right)d_0$	$\frac{\sqrt{2}}{32}\frac{(\theta - \sin \theta)^{1.48}}{(\sin \frac{1}{2}\theta)^{0.48}}d_0^{2.48}$
 Parabola	$\frac{3}{8}Ty$	$T + \frac{8y^2}{3T}$	$\frac{2T^2y}{3T^2 + 8y^2}$	$\frac{3A}{2y}$	$\frac{3}{8}y$	$\frac{3}{8}\sqrt{6}Ty^{1.48}$
 Round-cornered rectangle ( $y > r$ )	$\left(\frac{\pi}{2} - 2\right)r^2 + (b + 2r)y$	$(\pi - 2)r + b + 2y$	$\frac{(\pi/2 - 2)r^2 + (b + 2r)y}{(\pi - 2)r + b + 2y}$	$b + 2r$	$\frac{(\pi/2 - 2)r^2}{b + 2r} + y$	$\frac{[(\pi/2 - 2)r^2 + (b + 2r)y]^{1.48}}{\sqrt{b + 2r}}$
 Round-bottomed triangle	$\frac{T^2}{4z} - \frac{r^2}{z}(1 - z \cot^{-1} z)$	$\frac{T}{z}\sqrt{1 + z^2} - \frac{2r}{z}(1 - z \cot^{-1} z)$	$\frac{A}{P}$	$2[z(y - r) + r\sqrt{1 + z^2}]$	$\frac{A}{T}$	$A\sqrt{\frac{A}{T}}$

\* Satisfactory approximation for the interval  $0 < z \leq 1$ , where  $z = 4y/T$ . When  $z > 1$ , use the exact expression  $P = (T/2)[\sqrt{1 + z^2} + 1/z \ln(z + \sqrt{1 + z^2})]$ .



To illustrate analysis of a single reach, consider the following diagram, Figure III-2.29:

Figure III-2.29 - Cross-Sections for Use in the Direct Step Backwater Method



Equating the total head at cross-sections 1 and 2, the following equation may be written:

$$s_o \Delta x + y_1 + \frac{\alpha_1 V_1^2}{2g} = y_2 + \frac{\alpha_2 V_2^2}{2g} + s_f \Delta x$$

Solving for  $\Delta x$ ,

$$\Delta x = \frac{E_2 - E_1}{s_o - s_f} = \frac{\Delta E}{s_o - s_f}$$

Where  $E$  is specific energy and assuming  $\alpha_1 = \alpha_2 = \alpha$ , where  $\alpha$  is the energy coefficient which corrects for the non-uniform distribution of velocity over the channel cross-section.

$$E = y + \frac{\alpha V^2}{2g}$$

- and:  $y$  = depth of flow  
 $V$  = mean velocity  
 $\alpha$  = energy coefficient  
 $s_o$  = bottom slope  
 $s_f$  = friction slope =  $\frac{n^2 V^2}{2.21 R^{4/3}}$

$g$  = acceleration due to gravity = 32.2 ft/s<sup>2</sup>

Typical values of the energy coefficient,  $\alpha$ , are as follows:

Channels, regular section	1.15
Natural streams	1.3
Shallow vegetated flood fringes (includes channel)	1.75



For a given flow, channel slope, Manning's "n", and energy coefficient,  $\alpha$ , together with a beginning water surface elevation,  $y_2$ , the values of  $\Delta x$  may be calculated for arbitrarily chosen values of  $y_1$ . The coordinates defining the water surface profile are obtained from the cumulative sum of  $\Delta x$  and corresponding values of  $y$ . Values of Manning's n may be found in Table III-1.8.

The normal flow depth,  $y_n$ , should first be calculated from Manning's Equation to establish the upper limit of the backwater effect.

Calculating the coordinates of the water surface profile using this method is an iterative process achieved by choosing a range of flow depths, beginning at the downstream end, and proceeding incrementally up to the point of interest or to the point of normal flow depth. This is best accomplished by the use of a table (see Figures III-2.30 and III-2.31) or a computer program (as discussed below).

To illustrate this method, consider the following example:

Given:  $Q = 30$  cfs  
 $n = 0.030$   
 $s_o = 0.007$   
 $\alpha = 1.15$

Assume a culvert is flowing full at 30 cfs with a headwater depth of 6 feet. The channel entering the culvert is a V-section with 2:1 side slopes.

Calculate the backwater profile upstream of the culvert to a point near the normal flow.

$$\text{From Manning, } y_n = \frac{[Qn]^{3/8}}{1.486 s_o} = 1.98 \text{ ft.}$$

The step computations are carried out as shown in Figure III-2.31 above. The values in each column of the table are explained as follows:

- Col. 1. Depth of flow in ft. assigned from 6 to 2 ft.
- Col. 2. Water area in ft.<sup>2</sup> corresponding to depth  $y$  in Col. 1
- Col. 3. Hydraulic radius in ft. corresponding to  $y$  in Col. 1
- Col. 4. Four-thirds power of the hydraulic radius
- Col. 5. Mean velocity in fps obtained by dividing  $Q(30 \text{ cfs})$  by the water area in Col. 2.
- Col. 6. Velocity head in feet
- Col. 7. Specific energy in ft. obtained by adding the velocity head in Col. 6 to depth of flow in Col. 1.
- Col. 8. Change of specific energy in ft. equal to the difference between the E value in Col. 7 and that of the previous step.
- Col. 9. Friction slope  $S_f$ , computed from  $V$  as given in Col. 5 and  $R^{4/3}$  in Col. 4.
- Col. 10. Average friction slope between the steps, equal to the arithmetic mean of the friction slope just computed in Col. 9 and that of the previous step.
- Col. 11. Difference between the bottom slope  $S_o$ , and the average friction slope,  $S_f$ .
- Col. 12. Length of the reach in ft. between the consecutive steps, computed by  $\Delta X = \Delta E / (S_o - S_f)$  or by dividing the value in Col. 8 by the value in Col. 11.
- Col. 13. Distance from the beginning point to the section under consideration. This is equal to the cumulative sum of the values in Col. 12 computed for previous steps.

Figure III-2.31 Example Direct Step Backwater Method

y	A	R	R <sup>4/3</sup>	V	$\alpha V^3/2g$	E	$\Delta E$	S <sub>f</sub>	S <sub>f</sub>	S <sub>0</sub> - S <sub>f</sub>	$\Delta x$	x
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
6.0	72.0	2.68	3.72	0.42	0.0031	6.0031	—	0.00002	—	—	—	—
5.5	60.5	2.46	3.31	0.50	0.0040	5.5040	0.4990	0.00003	0.000025	0.00698	71.50	71.5
5.0	50.0	2.24	2.92	0.60	0.0064	5.0064	0.4976	0.00005	0.000040	0.00696	71.49	142.99
4.5	40.5	2.01	2.54	0.74	0.0098	4.5098	0.4966	0.00009	0.000070	0.00693	71.64	214.63
4.0	32.0	1.79	2.17	0.94	0.0157	4.0157	0.4941	0.00016	0.000127	0.00687	71.89	286.52
3.5	24.5	1.57	1.82	1.22	0.0268	3.5268	0.4889	0.00033	0.000246	0.00675	72.38	358.90
3.0	18.0	1.34	1.48	1.67	0.0496	3.0496	0.4772	0.00076	0.000547	0.00645	73.95	432.85
2.5	12.5	1.12	1.16	2.40	0.1029	2.6029	0.4467	0.00201	0.001387	0.00561	79.58	512.43
2.0	8.0	0.89	0.86	3.75	0.2511	2.2511	0.3518	0.00663	0.004320	0.00268	131.27	643.70

The step computations are carried out as shown in Figure 4.3.7G, above. The values in each column of the table are explained as follows:

- Col. 1. Depth of flow in ft. assigned from 6 to 2 ft.
- Col. 2. Water area in ft.<sup>2</sup> corresponding to depth y in Col. 1
- Col. 3. Hydraulic radius in ft. corresponding to y in Col. 1
- Col. 4. Four-thirds power of the hydraulic radius
- Col. 5. Mean velocity in fps obtained by dividing Q(30 cfs) by the water area in Col. 2.
- Col. 6. Velocity head in feet
- Col. 7. Specific energy in fps obtained by adding the velocity head in Col. 6 to depth of flow in Col. 1.
- Col. 8. Change of specific energy in ft. equal to the difference between the E value in Col. 7 and that of the previous step.
- Col. 9. Friction slope S<sub>f</sub>, computed from V as given in Col. 5 and R<sup>4/3</sup> in Col. 4.
- Col. 10. Average friction slope between the steps, equal to the arithmetic mean of the friction slope just computed in Col. 9 and that of the previous step.
- Col. 11. Difference between the bottom slope, S<sub>0</sub>, and the average friction slope, S<sub>f</sub>.
- Col. 12. Length of the reach in ft. between the consecutive steps, computed by  $X = E/(S_0 - S_f)$  or by dividing the value in Col. 8 by the value in Col. 11.
- Col. 13. Distance from the beginning point to the section under consideration. This is equal to the cumulative sum of the values in Col. 12 computed for previous steps.

As with the hydrologic methods described in Chapter 1, there are a number of software programs available for use on personal computers that use variations of the standard direct step backwater method for determining water surface profiles. The most common and widely accepted program is published and is supported by the United States Army Corps of Engineers Hydraulic Engineering Center and is called HEC-2. It is the model required by the Federal Emergency Management Administration (FEMA) for use in performing flood hazard studies for preparing flood insurance maps. Other programs include WSP-2 published by the SCS, WSPRO or E-431 published by U.S.G.S., and the "BW" programs written by the Surface Water Management Division at King County.

### (3) Standard Step Backwater Method for Analyzing Channel Capacity

This method is a variation of the Direct Step Backwater Method and can be used to compute backwater profiles on both prismatic and non-prismatic channels. In this method, stations are established along the channel where cross-section data is known or has been determined through field survey. The computation is carried out in steps from station to station rather than throughout a given channel reach as is done in the Direct Step method. As a result, the analysis involves significantly more trial and error calculation in order to determine the flow depth at each station.

Because of the iterative calculations involved, use of a computer to perform the analysis, is recommended, such as the "BW" series of programs available from King County, SWM Division.

### III-2.3.7 Floodplain/Floodway Analysis

#### Determination of a Minor Floodplain

In some situations, a minor floodplain must be determined in order to address the compatibility and impacts of a proposed project, such as in ditches behind roadway cross culverts. When evaluating the conveyance system capacity, the floodplain may be determined using the direct step backwater method, standard step backwater method, or software programs described in Section III-2.3.6.

#### Major Floodplain/Floodway Studies

When a floodplain/floodway study will be used under a Sensitive Areas Ordinance or to justify a Flood Insurance Rate Map revision to the Federal Emergency Management Administration (FEMA), the study must conform to FEMA regulations described in Part 65 of 44 CFR. Note that FEMA has a map correction process for individual properties based on demonstrating an error in the original mapping by submitting new technical information (see Part 70 of CFR Ch. 1). For additional requirements, consult the local government.

### **III-2.4 CONTROL STRUCTURES**

A control structure is a catchbasin with a restrictor device designed to control the outflow from the catchbasin to meet a desired performance level. The restrictor device is usually a multiple orifice, consisting of two (or more) orifices and a weir section sized and located to meet performance.

Multiple Orifices A maximum of five orifices may be used to meet performance requirements.

In some cases, only two orifices are necessary to meet the 2, 10, and 100-year water quality/optional flood control requirement: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

The minimum orifice diameter is 0.5 inch, though diameters of 1 inch or more are preferred.

In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to physically construct (e.g., a 13-inch-diameter orifice positioned 0.5 feet from top of riser). In these cases, a notch weir in the riser pipe may be used to meet performance as described below.

Riser and Weir Restrictor Properly designed weirs may be used as flow restrictors, however, they must be sized to pass the developed peak flow for the 100-year, 24-hour design storm for developed site conditions.

Riser (or weir) overflow may be utilized for that portion of the release rates above the 6-month, 24-hour design storm flow, provided the combined orifice and overflow do not exceed performance requirements.

Figure III-2.38 can be used to calculate the head in feet above a riser of given diameter and for a given flow (usually the 100-year, 24-hour design storm flow for developed conditions).

III-2.4.1 Methods of Analysis

The methods of analysis for detention storage volume and discharge rates shall be in accordance with the hydrologic methods described in Chapter III-1.

Flow analysis of orifices and weirs may be done using the following methods:

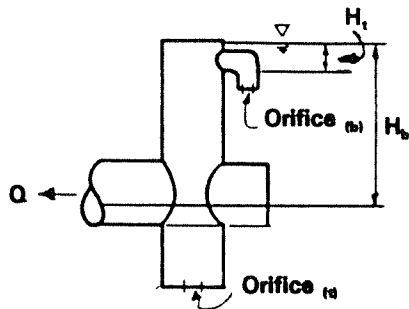
**Orifices:** Flow-through orifice plates in a standard "tee" section or turn-down elbow may be approximated by the general equation:

$$Q = CA (2gh)^{0.5} \text{ in cfs}$$

- where:
- A = area of orifice, ft<sup>2</sup>
  - C = 0.62, coefficient of discharge
  - h = hydraulic head in feet
  - g = acceleration of gravity = 32.2 ft/sec<sup>2</sup>

Figure III-2.32 illustrates this simplified application of the orifice equation.

Figure III-2.32 Simple Orifice



$$Q = C A_b (2gh_b)^{1/2} + C A_t (2bh_t)^{1/2}$$

$$= C (2g)^{1/2} (A_b (h_b)^{1/2} + A_t (h_t)^{1/2}) \text{ cfs}$$

$h_b$  = distance from hydraulic grade line at the 2 year flow of the outflow pipe to the overflow elevation

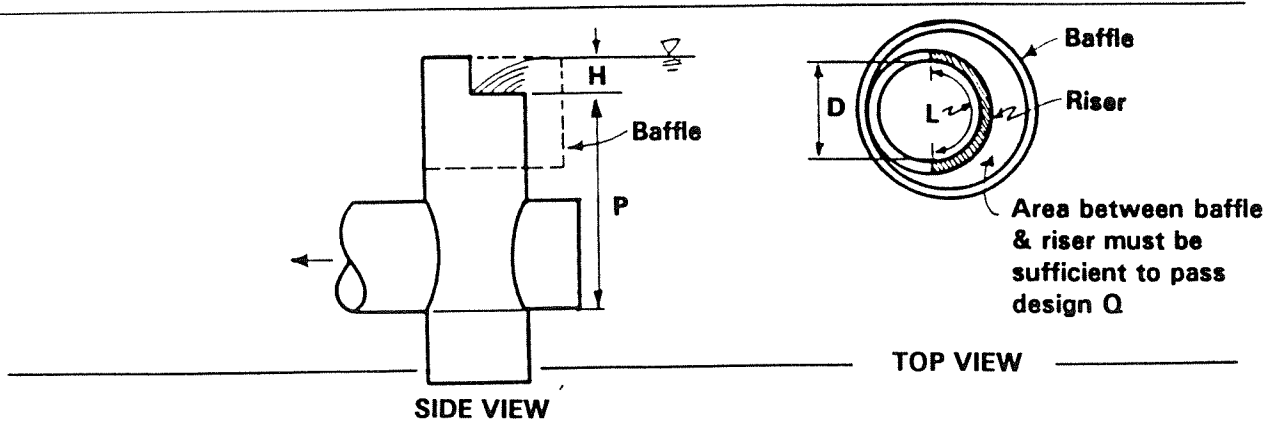
**Rectangular, Sharp Crested Weir:** The notch weir design shown in Figure III-2.33 may be analyzed using standard weir equations for the fully contracted condition.

$$Q = C(L-0.2H)H^{3/2} \text{ cfs}$$

- where:
- C = 3.27 + 0.40 H/P (in feet).
  - L = Length of the portion of the riser circumference as necessary (in feet), not to exceed 50 percent of the circumference.
  - H and P as shown in the figure
  - D = Inside riser diameter

Note that to account for side contractions, subtract 0.1 H from L for each side of the notch weir.

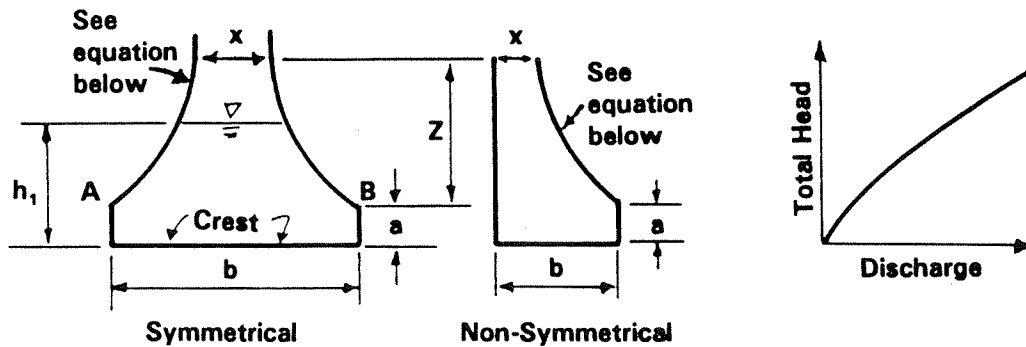
Figure III-2.33 Notch Weir



**Proportional or Sutro Weir:** This weir is designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet required performance.

The Sutro Weir consists of a rectangular section joined to a curved portion which provides proportionality for all heads above a line connecting points A and B (see Figure III-2.34).

Figure III-2.34 Sutro Weir



The head-discharge relationship is:

$$Q = C_d b (2ga)^{0.5} (h_1 - a/3)$$

Values of  $C_d$  for both symmetrical and non-symmetrical Sutro Weirs are summarized below in Table III-2.9 (Note that when  $b > 1.50$  or  $a > 0.30$  use  $C_d = 0.6$ ):

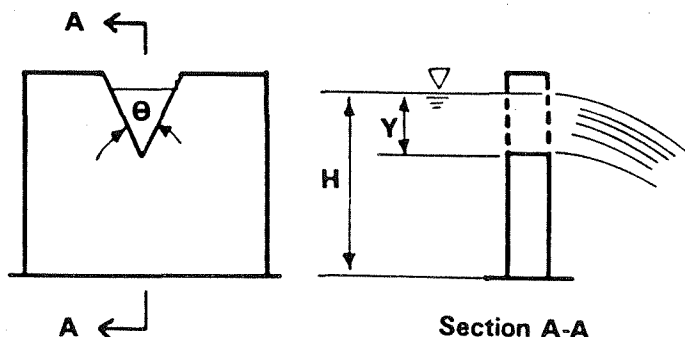
Table III-2.9 Values of  $C_d$  for Sutro Weirs

$C_d$ Values, Symmetrical					
a (ft)	b, ft.				
	0.50	0.75	1.0	1.25	1.50
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608

$C_d$ Values, Non-Symmetrical					
a (ft)	b, ft.				
	0.50	0.75	1.0	1.25	1.50
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612	0.6135	0.614

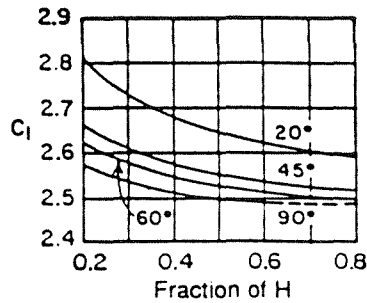
**V-Notch, Sharp Crested Weir:** V-Notch weirs, as shown in Figure III-2.35, may be analyzed using standard equations for the fully contracted condition.

Figure III-2.35 V-Notch, Sharp Crested Weir



Where values of  $C_d$  may be taken from the following chart:





$$Q = C_d(\tan(\theta/2))H^{5/2}, \text{ in cfs}$$

Details

Standard control structure details are shown in Figures III-2.36 and III-2.37.

III-2.4.3 Maintenance of Control Structures

Control structures and catch basins have a history of maintenance-related problems and it is imperative that a good maintenance program be established for their proper functioning. A typical problem is that sediment builds up inside the structure which blocks or restricts flow to the inlet. To prevent this problem these structures should be routinely cleaned out a least twice per year. Regular inspections of control structures should be conducted to detect the need for non-routine cleanout, especially if construction or land-disturbing activities are occurring in the contributing drainage area.

A 15-foot wide access road to the control structure should be installed for inspection and maintenance.

Table III-2.10 provides maintenance recommendations for control structures and catch basins.

Figure III-2.36 Standard Control Structure Detail - Orifice Control

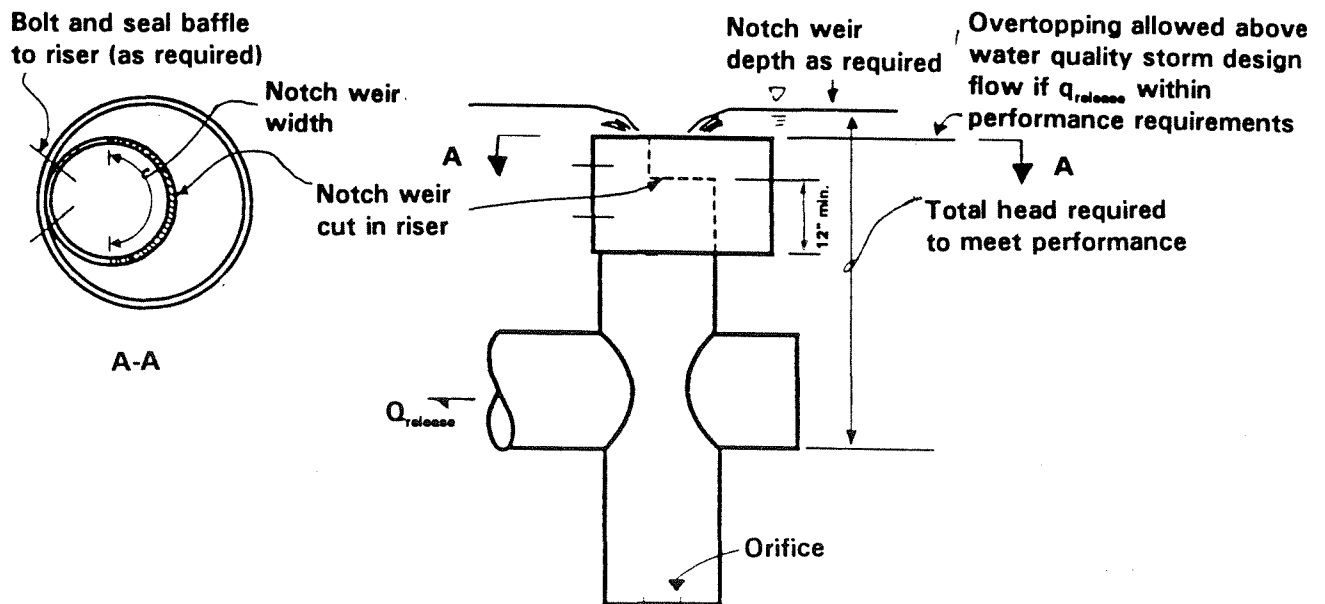
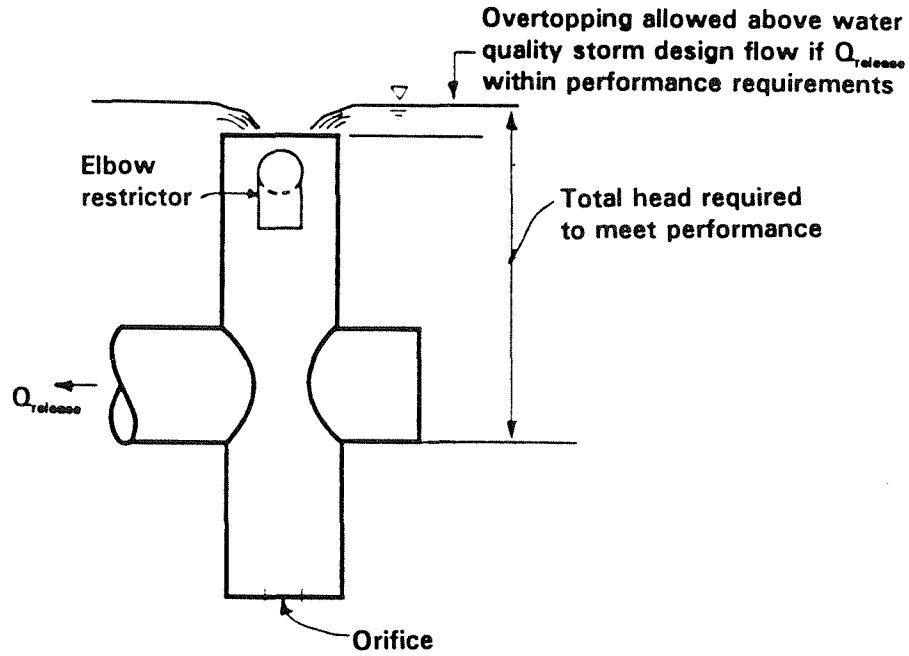
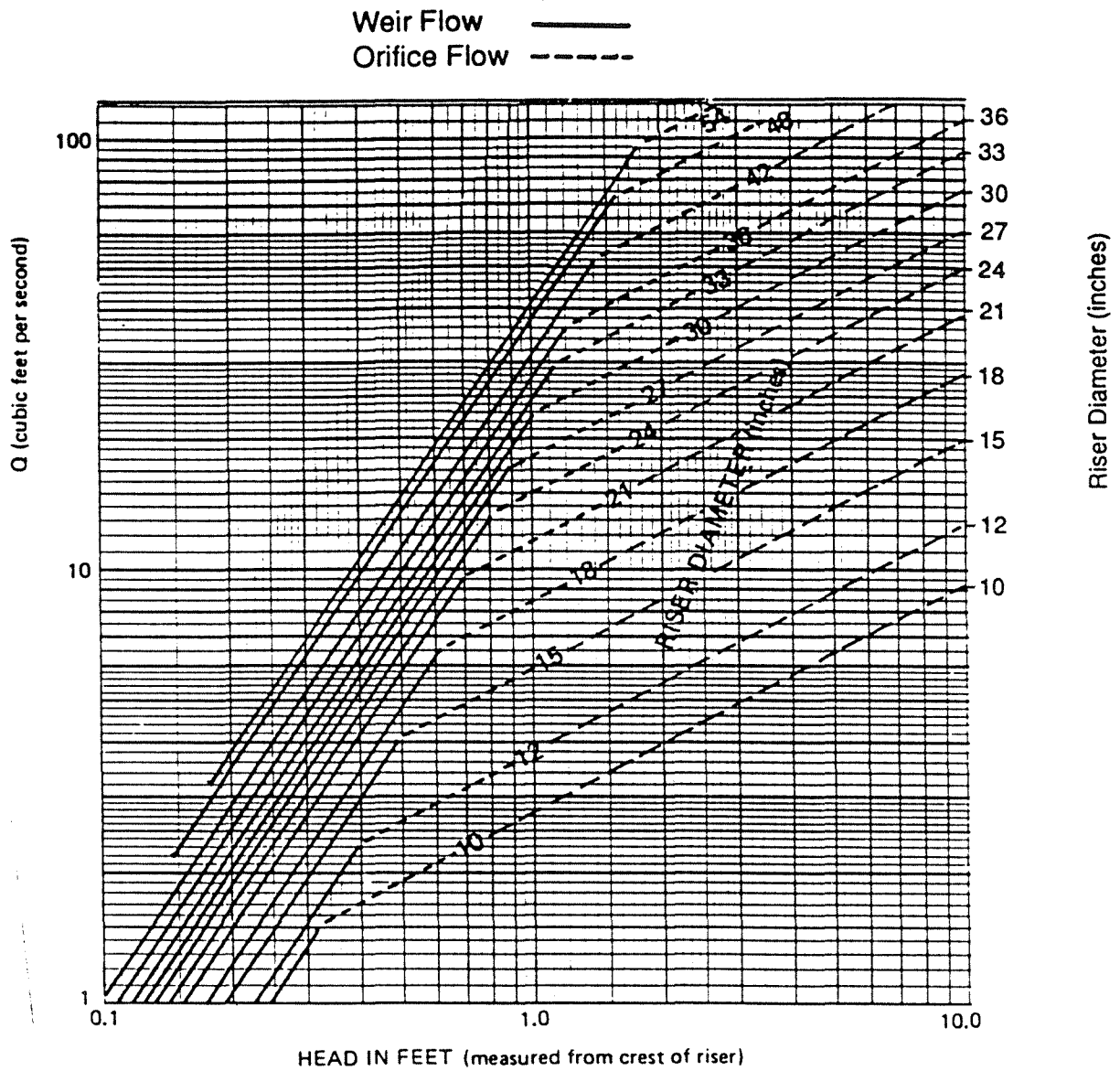


Figure III-2.37 Standard Control Structure Detail - Notch Control

Figure III-2.38 Riser Inflow Curves



SOURCE: USDA-SCS

$$Q_{\text{WEIR}} = 9.739 DH^{3/2}$$

$$Q_{\text{ORIFICE}} = 3.782 D^2 H^{1/2}$$

Q in cfs, D and H in feet

Table III-2.10 Maintenance of Control Structures and Catchbasins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
I. Control Structure/ Flow Restrictor - General	Trash & Debris (includes sediment)	Distance between debris buildup & bottom of orifice is < 1½ feet.	All trash & debris removed.
	Structural Damage	Structure is not securely attached to manhole wall & outlet pipe structure should support at least 1000# of up or down pressure.  Structure is not in upright position (up to 10% from plumb allowed).  Connections to outlet pipe are not watertight & show signs of rust.  Any holes - other than designed holes - in structure.	Structure securely attached to wall & outlet pipe.  Structure in correct position.  Connections to outlet pipe are watertight; structure repaired or replaced and works as designed.  Structure has no holes other than designed holes.
Cleanout Gate	Damaged or missing	Cleanout gate is not watertight or is missing.  Gate cannot be moved up & down by one maintenance person.  Chain leading to gate is missing or damaged.  Gate is rusted over 50% of its surface area.	Gate is watertight and works as designed.  Gate moves up and down easily and is watertight.  Chain is in place & works as designed.  Gate is repaired or replaced to meet design standards.
Overflow Pipe	Obstructions	Trash, debris, sediment or vegetation blocking the plate.	Plate is free of all obstructions & works as designed.
Manhole	Obstructions	Trash or debris is blocking or potentially blocking the overflow pipe.	Pipe is free of all obstructions & works as designed.
		See "Pipes/Tanks" standard, Section III-4.6.1.	See "Pipes/Tanks" standard, Section III-4.6.1.
II. Catchbasins - General	Trash & Debris (includes sediment)	Trash & debris ≥ ½ ft. <sup>3</sup> which is located immediately in front of the catchbasin opening of is blocking capacity by > 10%.	No trash or debris immediately in front of the catchbasin opening.
		Trash or debris in the basin that exceeds ¼ the depth from the bottom of basin to the invert of the lowest pipe.	No trash or debris in the catchbasin.
		Trash or debris in any inlet or pipe blocking more than ¼ of its height.	Inlet & outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors or dangerous gases (e.g. methane).	No dead animals or vegetation present within the catchbasin.

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Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Catchbasins - General, con't.	Structural Damage to Frame and/or Top Slab	No condition present which would attract or support the breeding of insects or rodents.  Frame is even with curb.  Top slab is free of holes & cracks.  Frame is sitting flush on top slab.	
	Cracks in Basin Walls or Bottom	Basin repaired or replaced to design standards.  No cracks more than 1/4 in. wide at the joint of inlet/outlet pipe.	
	Settlement/misalignment	Basin replaced or repaired to design standards.	
	Fire Hazard	No flammable chemicals present.	
	Vegetation	No vegetation blocking opening to basin.  No vegetation or root growth present.	
	Pollution	No pollution present other than surface film	
	68°F or wider than 1/2 in. & longer than 1 ft. at the joint of any inlet or outlet pipe or any evidence of soil particles entering the catchbasin through cracks.  Basin has settled > 1 in. or has rotated > 2 in. out of alignment.  Presence of chemicals such as natural gas, oil and gasoline.  Vegetation growing across & blocking > 10% of the basin opening.		

III-2.5 REFERENCES

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CHAPTER III-3

INFILTRATION AND FILTRATION BEST MANAGEMENT PRACTICES

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## CHAPTER III-3

## INFILTRATION AND FILTRATION BEST MANAGEMENT PRACTICES

## III-3.1 INTRODUCTION

III-3.1.1 Background

Infiltration and filtration are two stormwater management techniques which are becoming more widespread in use. *Infiltration* systems percolate runoff into the soil, where it can remove pollution and recharge ground water. *Filtration* systems use treatment media such as sand to treat pollutants. A filtration BMP will typically have an underdrain system that conveys treated runoff to a detention BMP or to the point of ultimate discharge.

Infiltration is the preferred stormwater management practice due to its ability to both effectively treat runoff and control streambank erosion. Benefits of infiltration include preservation of baseflow in streams, recharge of ground water, reduction of peak runoff flows which can cause flooding, and reduction/elimination of expensive stormwater conveyance systems.

Filtration BMPs typically provide runoff treatment but not streambank erosion control. In general, these BMPs are not as effective at removing pollutants as infiltration BMPs but this may change as research continues into the use of other filtration media, such as compost and peat.

Experience has shown that infiltration and filtration can be successfully utilized if adherence to proper design, construction, and maintenance standards is followed. Where operating problems with infiltration BMPs have occurred, the primary causes of failure have been:

- inadequate soil investigation, resulting in poorly designed systems (infiltration);
- improper construction practices, especially compaction of soil (both infiltration and filtration);
- siltation which clogs soils used for infiltration, especially due to construction-related erosion and sedimentation. All infiltration and filtration BMPs must be preceded by a pretreatment BMP to remove suspended solids (both infiltration and filtration).

The standards in this chapter are intended to prevent these problems from occurring. In addition to these standards, there may be local, state, and national regulatory requirements which must be met.

Infiltration BMPs are not practical in all cases. The feasibility of using infiltration depends not only on the nature of the soils but also on the need to protect ground water quality. The location and depth to bedrock, the water table, or impermeable layers (such as glacial till) can preclude the use of infiltration. In addition, the proximity of infiltration BMPs to wells, foundations, septic tank drainfields, unstable slopes, and other features can restrict its use. General limitations are described in Section III-3.3.

III-3.1.2 Purpose and Scope

The purpose of this chapter is to present general and specific criteria for the evaluation, design, construction, and maintenance of infiltration and filtration BMPs.

Sections III-3.2 and III-3.3 should be read carefully before proceeding to other sections in this chapter. Section III-3.2 discusses the important differences between runoff treatment and streambank erosion control, as applied to infiltration and filtration BMPs. Section III-3.3 provides important planning information specifically for *infiltration* BMPs, including identifying conditions which may preclude the use of infiltration.

Criteria for the following BMPs is presented (note that infiltration BMPs are denoted as "RI" whereas filtration BMPs are denoted "RF"):

BMP RI.05	Water Quality Infiltration Basin
BMP RI.06	Streambank Erosion Control Infiltration Basin
BMP RI.10	Water Quality Infiltration Trench
BMP RI.11	Streambank Erosion Control Infiltration Trench
BMP RI.15	Roof Downspout System
BMP RI.20	Water Quality Porous Pavement
BMP RI.21	Streambank Erosion Control Porous Pavement
BMP RI.30	Water Quality Concrete Grid and Modular Pavement
BMP RI.31	Streambank Erosion Control Concrete Grid and Modular Pavement
BMP RF.05	Sand Filtration Basin
BMP RF.10	Sand Filtration Trench
BMP RF.15E	Aquatard System (Experimental)

Experimental BMPs, such as an aquatard system, are encouraged, subject to the conditions described in Chapter I-2.

### III-3.2 RUNOFF TREATMENT AND STREAMBANK EROSION CONTROL

Minimum Requirements #4 and #5 require development sites to provide runoff treatment and control streambank erosion, respectively (see Chapter I-2). The runoff treatment (water quality) design storm is the 6-month, 24-hour event. The streambank erosion control standard is to limit peak flows discharged from the *developed* site to 50 percent of the *existing* condition 2-year, 24-hour event and maintain the *existing* condition peak flow rates for the 10-year and 100-year, 24-hour design storms, with appropriate correction factors (see Chapter III-1 for further details).

A clear distinction is made between infiltration BMPs used for runoff treatment in contrast to those used for streambank erosion control. For runoff treatment to be provided soils must contain sufficient organic matter to accomplish pollutant removal. Coarser soils cannot be used for runoff treatment as they lack clay minerals or an oxide coating and will be less efficient at adsorbing heavy metal and phosphate ions. Excessively drained soils should be used, however, for streambank erosion control, provided that stormwater is treated *prior* to discharge to these soils. There may be some instances when a soil can be used for both runoff treatment and streambank erosion control. A more likely scenario is that the infiltration BMP used for runoff treatment will be located "off-line" from the main conveyance system and that the infiltration BMP with coarser soils will be located "on-line" to provide streambank erosion control.

Filtration BMPs, unlike some infiltration BMPs, should not be used for streambank erosion control; their primary function will be to treat runoff. These BMPs should be placed "off-line" as experience has shown that when filtration BMPs are installed "on-line" they are more prone to failure due to siltation, resuspension of trapped particles, and displacement of treatment media by erosive flows.

Infiltration BMPs used for runoff treatment will be labeled as "Water Quality" BMPs while those used only for streambank erosion control (SBEC) will be so labeled.

*Runoff treatment* is accomplished by infiltration BMPs by utilizing the ability of soils and vegetative root systems to bind, decompose, and/or trap pollutants contained in stormwater runoff. Soils must have an adequate infiltration rate, contain sufficient organic material, and maintain aerobic conditions in order to provide optimum treatment of runoff.

In filtration BMPs using sand media, pollutants are removed primarily by physical means. These BMPs have limited ability to provide biological treatment.

*Streambank erosion* can be controlled most effectively by infiltration, in some cases maintaining pre-development hydrologic conditions. The ability of soil to meet this requirement depends primarily on soil permeability (infiltration rate) and subsurface conditions.

In cases where infiltration is feasible but cannot fully meet the runoff treatment and streambank erosion control standards, it should still be utilized to the fullest extent possible, in conjunction with other BMPs. Note, however, that soils suitable for runoff treatment will likely drain too slowly to be used for controlling streambank erosion. Likewise, soils suitable for controlling streambank erosion will be too coarse to adequately treat runoff.

Filtration BMPs should not be used for streambank erosion control.

### III-3.3 FEASIBILITY ANALYSIS AND GENERAL LIMITATIONS FOR INFILTRATION BMPs

#### III-3.3.1 Overview

This section provides the basis for an assessment of the maximum amount of on-site infiltration that is practically achievable for each hydrologic soil group. In addition, it provides guidance in determining important design variables.

The most desirable situation, of course, is to mimic the natural situation by infiltrating an amount of runoff in the developed state such that the amount of runoff occurring in the pre-developed state is maintained. In practice this becomes difficult to achieve when there are large increases in impervious surface.

For a site to be suitable it must meet or exceed all of the specific criteria listed under GL-1 through 6. Should a site investigation reveal that any one of the General Limitations cannot be met, the implementation of the infiltration practice should not be pursued.

#### III-3.3.2 General Limitations

The General Limitations (GL's) are governed by the physical suitability of the site and the need to prevent pollution of ground water. They include:

- GL-1 Soil Suitability
- GL-2 Depth to Bedrock, Water Table, or Impermeable Layer, or Dissimilar soil layer
- GL-3 Proximity to Drinking Water Wells, Septic Tanks, Drainfields, Building Foundations, Structures, Native Growth Protection Easements, and Property Lines
- GL-4 Land Slope
- GL-5 Drainage Area
- GL-6 Control of Siltation

#### GL-1 Soil Suitability

The suitability of soil for infiltration is to be based on evaluating the following:

- (a) For runoff treatment, the soil infiltration rate, (f), shall be between 0.5 and 2.4 inches per hour;
- (b) For streambank erosion control there is no limitation on soil infiltration rate but a minimum rate of 0.5 inches per hour is recommended;
- (c) Runoff must infiltrate through at least 18 inches of soil which has a minimum cation exchange capacity (CEC) of 5 milliequivalents per 100 grams of dry soil.
- (d) Soils with 30 percent or greater clay content or 40 percent or greater silt/clay content shall not be used;
- (e) Infiltration systems shall not utilize fill material nor be placed over fill soils;
- (f) Any stone subgrade installed as part of an infiltration structure must extend below the frost line.
- (g) Aerobic conditions are to be maintained to the fullest extent possible for runoff treatment BMPs by designing them to drain the water quality design storm in 24 hours or less. *(Note: If a Water Quality Infiltration Basin or Trench (BMP RI.05 or RI.06, respectively) is preceded by a Presettling Basin (BMP RD.10) then the combination of both BMPs (i.e., the Presettling Basin and the Infiltration BMP) must be designed to drain the 6-month, 24-hour design storm within 24 hours. This is necessary to ensure that aerobic conditions are maintained in the infiltration BMP.)*

In addition, it is recommended that a more detailed soils investigation be conducted if potential impacts to ground water are a concern, or if the applicant is proposing to infiltrate in areas underlain by till or other impermeable layers. No formal procedures have been adopted for use in this manual. For further investigations, consultation with soils and ground water specialists is recommended. One document which may be of use is the Soil Conservation Service's "Washington State Water Quality Guide," available (in limited supply) from the SCS office in Spokane, Washington (W. 316 Boone Avenue, Spokane, WA 99201-2348).

GL-2 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all facilities shall be located at least three feet above the seasonal high water mark, bedrock (or hardpan), and/or impermeable layer. A high water table can indicate the potential for ground water contamination. Also, infiltration may be inhibited by the water table; this could result in the BMP not functioning as designed.

GL-3 Proximity to Drinking Water Wells, Septic Tanks, Drainfields, Building Foundations, Structures, Native Growth Protection Easements (NGPE), and Property Lines

The proximity of infiltration facilities to other structures and facilities must be taken into account. Otherwise the potential exists to contaminate ground water, disrupt the proper functioning of septic tank systems, damage foundations and other property. The site designer/engineer must conduct an investigation to determine the most appropriate locations of infiltration facilities; this is best done on a case-by-case basis but the following basic criteria is provided for information purposes:

- Infiltration facilities on commercial and industrial sites should be placed no closer than 100 feet from drinking water wells, septic tanks

or drainfields, and springs used for public drinking water supplies.

- Infiltration facilities should be situated at least 20 feet downslope and 100 feet upslope from building foundations. Infiltration facilities should be situated at least 20 feet from a NGPE. An exception is roof downspout systems which should be located a minimum of 10 feet from any structure, property line or NGPE, and 30 feet from a water supply well, septic tank or drainfield.

#### GL-4 Land Slope

Slope restrictions depend on the BMP selected. Application of infiltration practices on a steep grade increases the chance of water seepage from the subgrade to the lower areas of the site and reduces the amount of water which actually infiltrates.

Infiltration facilities can be located on slopes up to 15 percent as long as the slope of the base of the facility is less than 3 percent. All basins should be a minimum of 50 feet from any slope greater than 15 percent.

#### GL-5 Drainage Area

Infiltration BMPs are limited in their ability to accept flows from larger drainage areas. The following drainage area limitations will be applied:

- Infiltration basins - maximum of 50 acres
- Infiltration trenches - maximum of 15 acres
- Porous pavement - maximum of 15 acres
- Concrete grid/modular pavement - maximum of 15 acres
- Roof downspout system - maximum of 5000 square feet

#### GL-6 Control of Siltation

Surveys show that siltation is one of the major reasons for failure of infiltration facilities. This often occurs during construction, thus it is most important not to excavate trenches or ponds to final grade during this phase. Even after construction it is vital to prevent as much sediment as possible from entering by first routing the water through a pretreatment BMP. Also there may be other construction activities upstream that take place and could result in surges of sediment entering the site.

The following conditions also apply:

- (a) Final construction of infiltration facilities shall not be done until after other site construction has finished and the site has been properly stabilized with permanent erosion control practices as outlined in Volume II, Erosion and Sediment Control.
- (b) Infiltration facilities are not recommended for use as temporary sediment traps during the construction phase. Infiltration facilities should be constructed only after upstream drainage areas have been stabilized. If an infiltration BMP is to be used as a sediment trap it must not be excavated to final grade until after the upstream drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.
- (c) Inflow to infiltration BMPs used for runoff treatment, other than roof downspout systems, must first pass through a pretreatment BMP in order to minimize the suspended solid load and prevent siltation of the infiltration facility.

### III-3.3.3 Feasibility Analysis Discussion

Collection and analysis of soils, geologic, and hydrologic information are a critical component of the planning and design process for infiltration BMPs. A subsurface investigation must be conducted under the supervision of an engineer or scientist of appropriate qualifications. The investigation shall involve both a review of the available literature from the U.S. Soil Conservation Service and any other relevant sources and a field investigation as part of the overall geotechnical site investigation.

A soils report is required for each location. A soil log should be taken at a minimum 3 foot depth below the proposed base of the facility and an additional soil log shall be taken for every 5,000 square feet of infiltrating surface area.

To effectively design an infiltration structure, the following information is required:

- (a) Textural character of the soil horizons and/or strata units within the subsoil profile. Based on this textural analysis the following variables are to be determined:
  - (i) soil infiltration rate, "f"
  - (ii) soil cation exchange capacity (or CEC),
  - (iii) percent clay content in soil
- (b) Location of the seasonal high ground water table, depth to bedrock or impermeable layer, and/or depth to dissimilar soil layers (duplex soils).

The first step in determining the site capabilities should be to conduct an on-site investigation, in conjunction with consulting the available soil survey data. Soil Surveys are available for all counties in Washington and may be obtained from the Soil Conservation Service of the local Soil Conservation District. Due to glaciation, soil types may vary dramatically within a small area. An on-site investigation is always necessary because local conditions may be different than what published soil survey data indicates.

For larger land developments, soil information has traditionally been collected during the geotechnical site investigation in order to determine foundation conditions for structures and to design earth structures such as fills and cuts. The standard method of conducting subsurface investigations is to drill holes and collect a 1- $\frac{1}{2}$  inch diameter soil sample, 1.5 feet long at 3 to 5 foot intervals in the boring using a split-spoon sampler. Solid augers are also used to collect large samples for compaction testing but do not provide an accurate picture of the soil profile.

The soil final infiltration rate and cation exchange capacity are obtained by identifying the soil textures by a gradation test for each of the changes in soil profile. The soil textures presented in Table III-3.1 correspond to the soil textures of the U.S. Dept. of Agriculture (USDA) Textural Triangle presented in Figure III-3.1. (Note: much work remains in order to determine the cation exchange capacity of soils; the information provided in this manual is preliminary and will be revised as more information becomes available).

The data presented in Table III-3.1 are based on the analysis of over 5,000 soil samples under carefully controlled procedures by the USDA. The cation exchange capacity values are preliminary at this time. The use of the soil properties established in the table for design and review procedures will offer two advantages. First, it will provide for consistency of results in the design procedures, and

second, it will eliminate the need for the laborious and costly process of conducting field and laboratory infiltration and permeability tests.

For runoff treatment, the most suitable soils will generally be in Hydrologic Group B (see Table III-3.2 for a list of Puget Sound soils by this grouping); Group A soils are excessively well-drained and create a potential ground water pollution problem. Some Group C soils may also be suitable for runoff treatment, such as the Alderwood series which have porous A & B horizons. However, Group C soils may not be suitable if they overlay a virtually impervious glacial till (hardpan) at 2-4 feet. The upper horizons may meet the criterion, but the till would not. The special case of till soils is discussed further under GL-2. If the soil borings reveal that the soil is layered, then this must be taken into account when sizing the BMP (sizing procedure is described in Section III-3.4).

For streambank erosion control the most suitable soils will generally be in Hydrologic Group A, though it is possible some Group B soils could also be used.

An example of a typical subsurface exploration program for basin design and for trench design is shown in Figures III-3.2 and III-3.3, respectively. The finished grade for the basin example in Figure III-3.2 and the trench example in Figure III-3.3 are less than four feet above the static water table in a sand and gravel unit.

The location of the seasonal high ground water table can be determined by field observation of static water elevation in borings, changes in soil moisture content, and changes in soil color (mottling, for example). It should be noted that the ground water table elevation fluctuates not only on a seasonal basis but also on an annual basis in response to prolonged periods of wet and dry precipitation cycles. Thus, the field work should be supplemented with consultation of the local government's health and public works departments to benefit from their long-term experience with local ground water conditions.

Ground water occurs under two types of conditions, water table and artesian. Water table conditions exist where the water-bearing materials that make up the ground water reservoir are not overlain by impervious strata and water from precipitation may directly enter the reservoir by downward percolation. The upper surface of the saturated zone, which is under atmospheric pressure is called the water table or ground water table. Its position is marked by the static water level in wells or borings. Figure III-3.4 presents a schematic cross-section showing the general pattern of flow under water table conditions. In nearly all cases, these conditions will prevail over artesian conditions in influencing the design of infiltration practices.

Artesian conditions are formed where the water that moves along the waterbearing bed passes beneath relatively impervious stratum and is confined under pressure other than atmospheric. If an artesian reservoir is penetrated by a well, the water level in the artesian well will rise above the elevation of the confining stratum. The water is artesian whether or not it rises to or above the land surface. The imaginary surface coinciding with the level to which the water rises in a well penetrating an artesian reservoir is called the piezometric surface. A typical artesian situation is depicted in Figure III-3.5.

The specific details of appropriate subsurface exploration techniques can be found in references number 1 through 12.

Developments which occur on sloping and rolling sites may use extensive cut and fill operations. The use of infiltration systems on fill material is not permitted because of the possibility of creating an unstable subgrade. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be aggravated if the fill material is allowed to become saturated by using infiltration practices.

Table III-3.1 Soil Properties Classified by Soil Texture

Texture Class	Infiltration Rate Hydrologic (inches/hr.)	Cation Exchange Capacity (milliequivalents/ 100 grams)	Effective Water Capacity (inches per inch)	Hydrologic Soil Group
Coarse Sands or Cobbles	20.00	<5.0	---	A
Sand	8.27	<5.0	0.35	A
Loamy Sand	2.41	5.0	0.31	A
Sandy Loam	1.02	>5.0	0.25	B
Loam	0.52	>5.0	0.19	B
Silt Loam	0.27	>5.0	0.17	C
Sandy Clay Loam	0.17	>5.0	0.14	C
Clay Loam	0.09	>5.0	0.14	D
Silty Clay Loam	0.06	>5.0	0.11	D
Sandy Clay	0.05	>5.0	0.09	D
Silty Clay	0.04	>5.0	0.09	D
Clay	0.02	>5.0	0.08	D

Source (except for cation exchange capacity): Rawls, Brakensiek, and Saxton, 1982 (16)

Cation exchange capacity values are estimated from Buckman and Brady, 1969, (23)



Figure III-3.1 U.S.D.A. Textural Triangle

### Textural Triangle U.S.D.A.

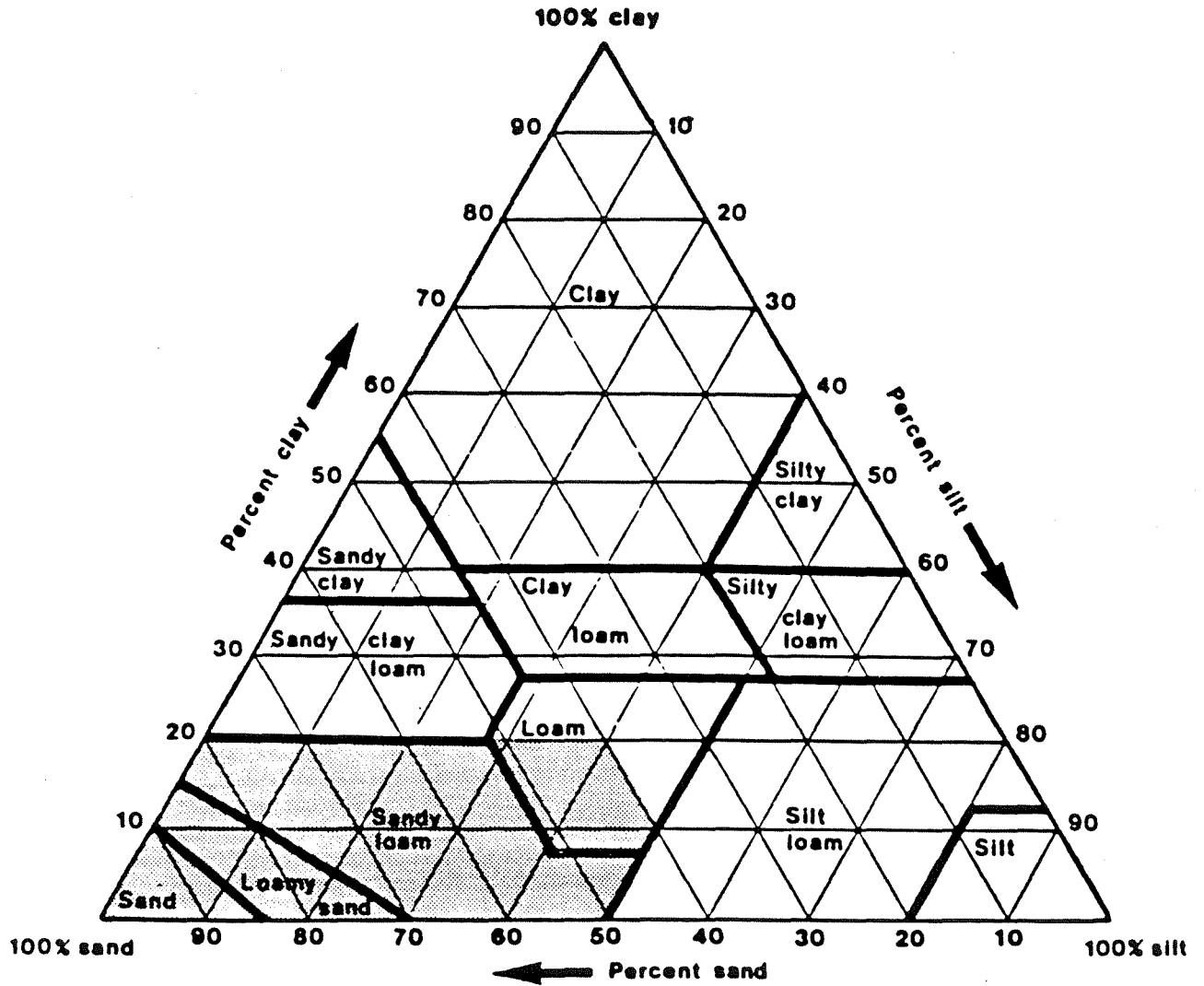


Table III-3.2  
Hydrologic Soil Groups for Soils in the Puget Sound Basin

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Agnew	C	Colter	C
Ahl	B	Custer	ND
Aits	C	Dabob	ND
Alderwood	C	Delphi	D
Arents, Alderwood	B	Dick	ND
Arents, Everett	B	Dimal	D
Ashoe	B	Dupont	D
Baldhill	B	Earlmont	C
Barneston	C	Edgewick	C
Baumgard	B	Eld	B
Beausite	B	Elwell	B
Belfast	C	Esquatzel	B
Bellingham	D	Everett	A
Bellingham variant	C	Everson	D
Boistfort	B	Galvin	D
Bow	D	Getchell	A
Briscot	D	Giles	B
Buckley	C	Godfrey	D
Bunker	B	Greenwater	A
Cagey	C	Grove	C
Carlsborg	ND	Harstine	C
Casey	ND	Hartnit	ND
Cassolary	C	Hoh	ND
Cathcart	B	Hoko	ND
Centralia	B	Hoodsport	ND
Chehalis	B	Hoogdal	C
Chesaw	A	Hoypus	ND
Cinebar	B	Huel	ND
Clallam	C	Indianola	ND
Clayton	B	Jonas	B
Coastal beaches	variable	Jumpe	ND
Kapowsin	C/D	Kalaloch	C
Katula	C	Renton	D
Kilchis	C	Republic	B
Kitsap	C	Riverwash	variable
Klaus	ND	Rober	C
Klone	ND	Salal	C
Lates	C	Salkum	B
Lebam	B	Sammamish	D
Lummi	ND	San Juan	ND
Lynnwood	ND	Scamman	D
Lystair	ND	Schneider	B
Mal	C	Seattle	D
Manley	B	Sekiu	ND
Mashel	B	Semiahmoo	D
Maytown	C	Shalcar	D
McKenna	D	Shano	B
McMurray	ND	Shelton	C
Melbourne	B	Si	C
Menzel	ND	Sinclair	C
Mixed Alluvial	variable	Skipopa	D
Molson	B	Skykomish	B
Mukilteo	C/D	Snahopish	ND
Naff	B	Snohomish	D
Nargar	A	Solduc	B
National	ND	Solleks	ND
Neilton	A	Sonoma	D

Table III-3.2  
Hydrologic Soil Groups for Soils in the Puget Sound Basin

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Newberg	B	Spanaway	A/B
Nisqually	B	Springdale	B
Nooksack	C	Sulsavar	B
Norma	C/D	Sultan	C
Ogarty	C	Sultan variant	B
Olete	ND	Sumas	C
Olomount	C	Swantown	ND
Olympic	B	Tacoma	D
Orcas	D	Tanwax	ND
Oridia	D	Tealwhit	ND
Orting	ND	Tenino	C
Oso	C	Tisch	D
Ovall	C	Tokul	ND
Pastik	C	Townsend	C
Pheeny	C	Triton	ND
Phelan	ND	Tukwila	D
Pilchuck	C	Tukey	ND
Potchub	C	Urban	variable
Poulsbo	C	Vailton	B
Prather	C	Verlot	C
Puget	D	Wapato	ND
Puyallup	B	Warden	B
Queets	ND	Whidbey	ND
Quilcene	ND	Wilkeson	B
Ragnar	B	Winston	A
Rainier	C	Woodinville	B
Raught	B	Yelm	C
Reed	ND	Zynbar	B

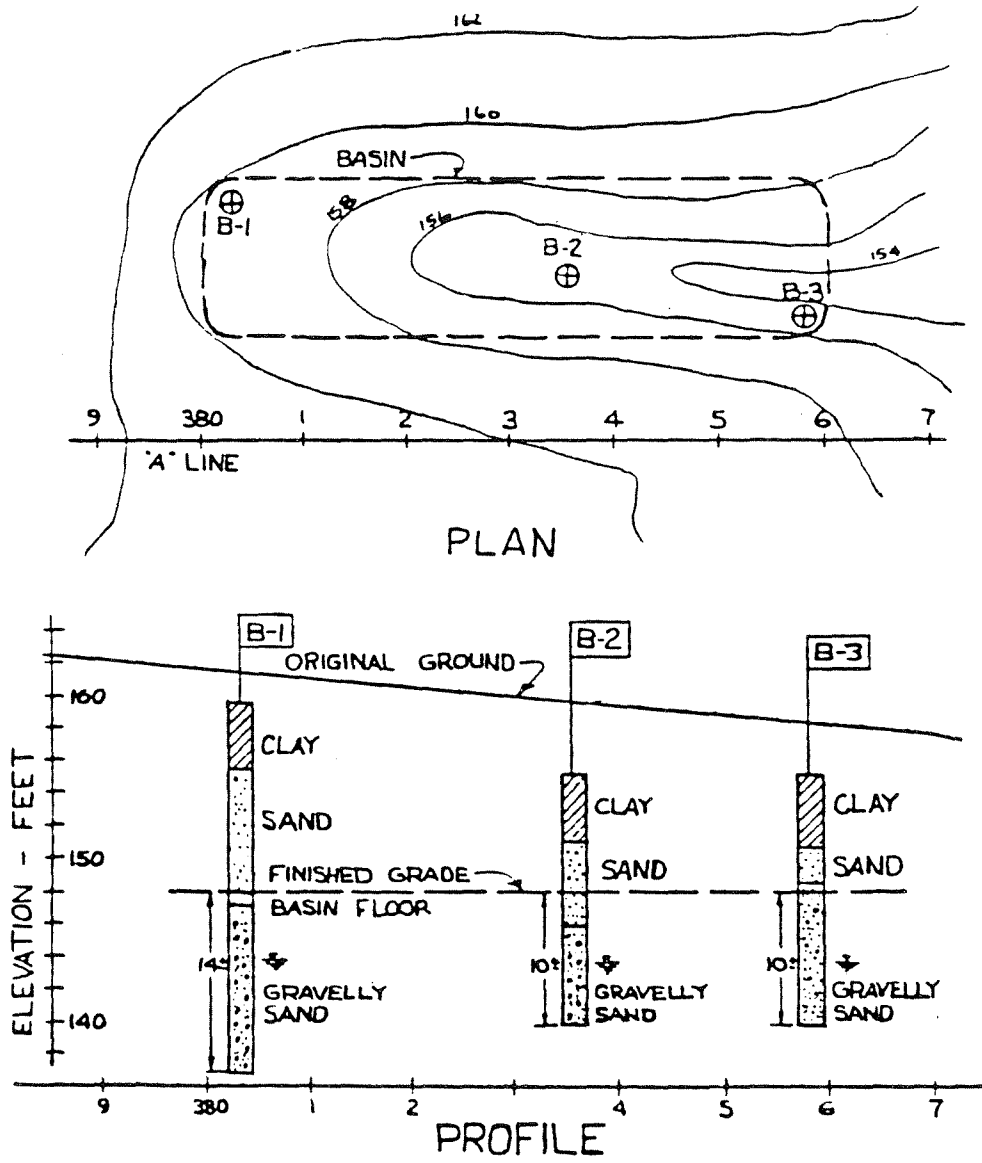
Hydrologic Soil Group Classifications

- A. (Low runoff potential). Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-to-excessively drained sands or gravels. These soils have a high rate of water transmission.
- B. (Moderately low runoff potential). Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
- C. (Moderately high runoff potential). Soils having slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
- D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

ND Data not currently available for this soil type.

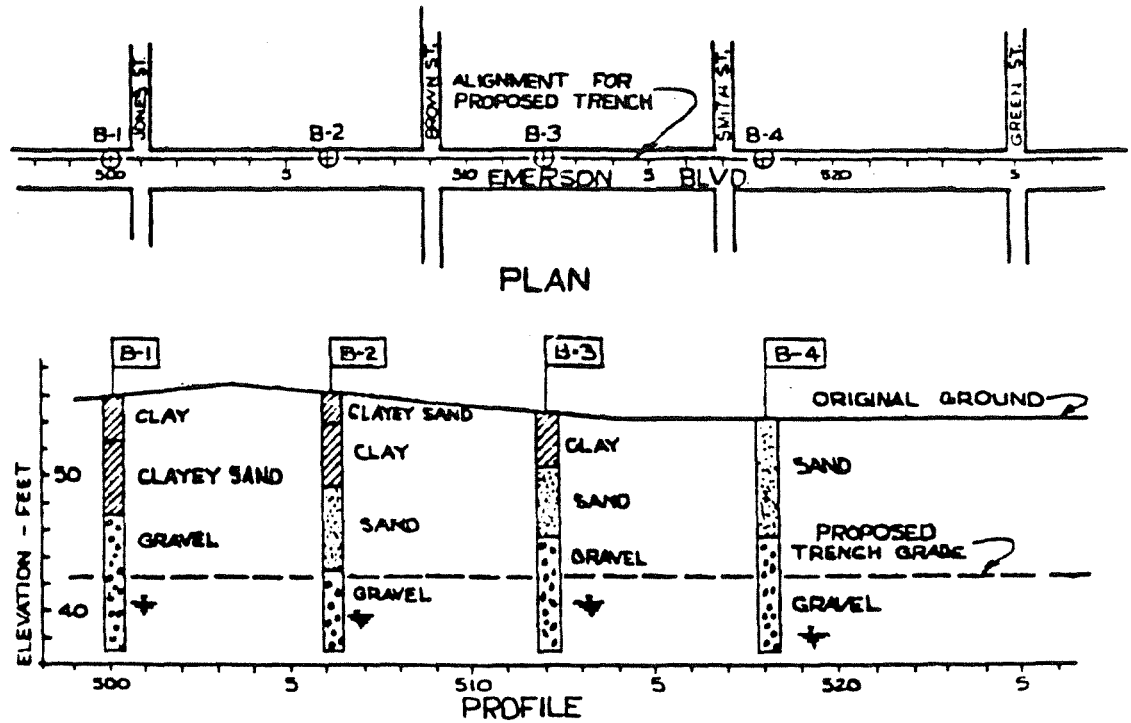
\*From SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form #5, September 1988 and various county soil surveys.

Figure III-3.2 Typical Exploration Program for Design of Infiltration Basins <sup>1</sup>



<sup>1</sup> Source: Hannon, 1980 (13)

Figure III-3.3 Typical Exploration Program for Design of Infiltration Trenches <sup>2</sup>



<sup>2</sup> Source: Hannon, 1980 (13)

Figure III-3.4 General Flow Pattern Under Water Table Conditions

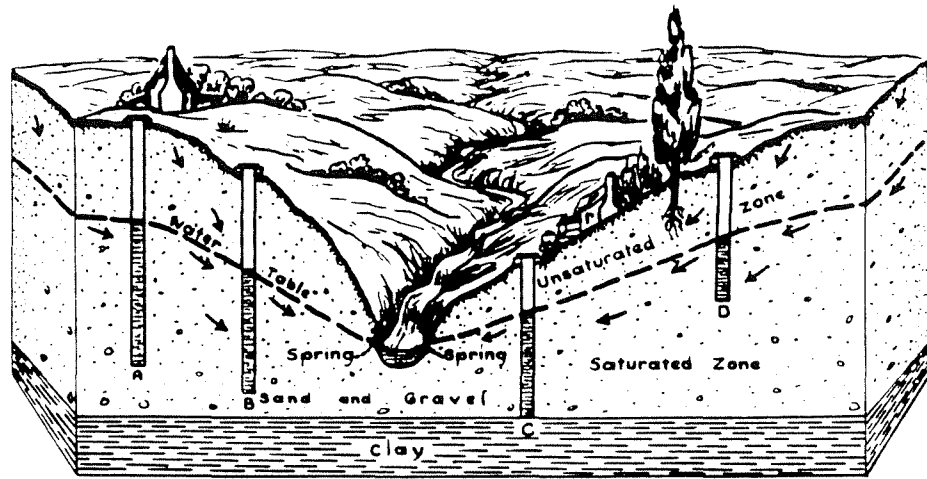
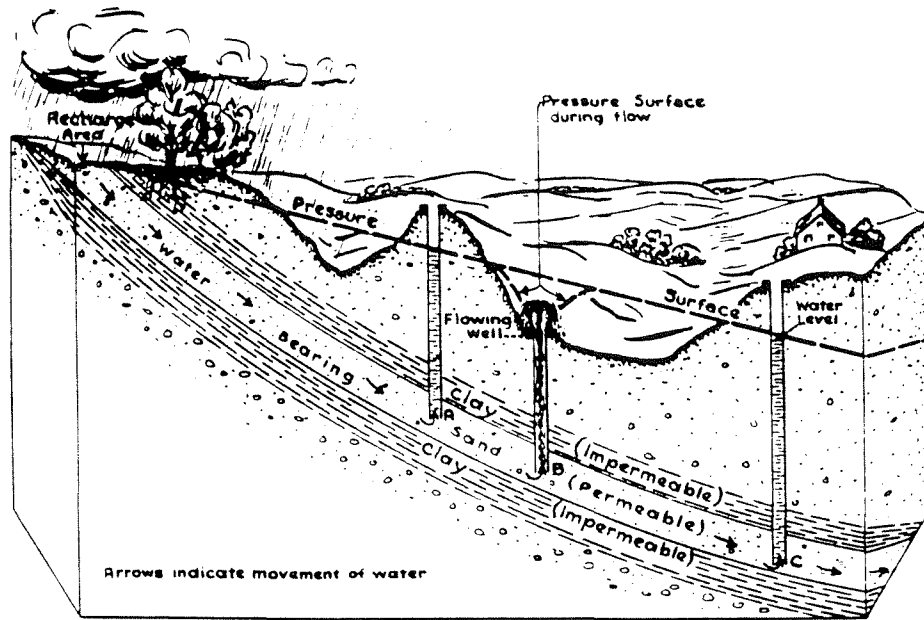


Figure III-3.5 Artesian System



In summary, the following procedure may be used for investigating the feasibility of using infiltration BMPs:

**Preliminary Screening** - Investigate soil characteristics and General Limitations based on published soil surveys, local studies, and field investigations of site. If the soil infiltration rate is less than 0.5 inches per hour, the site is not feasible for infiltration. If the soil infiltration rate is greater than 2.4 inches per hour it may be acceptable for streambank erosion control purposes but not runoff treatment.

**Soil Borings** - Soil borings will be required for two purposes:

(1) Collect soil samples so that a textural analysis can be conducted. The textural analysis is to be used to determine the following variables:

- infiltration rate,  $f$
- cation exchange capacity, CEC
- percent clay content

Soils identified by the textural analysis as Hydrologic Soil Group B are the most appropriate ones for providing *runoff treatment*; those which are Hydrologic Soil Group A are most appropriate for providing *streambank erosion control*.

If this analysis indicates that any of the conditions in General Limitation #1 are violated, then infiltration should not be pursued.

(2) Determine location and depth to the seasonal high water table, bedrock, impermeable layer, and/or dissimilar soil layers.

If this analysis indicates that any of the conditions in General Limitation #2 are violated, then infiltration should not be pursued.

At this point, the feasibility of infiltration should be clearly established. If feasible, the applicant may proceed to size and design the BMP as described in Sections III-3.4, III-3.6, and III-3.7 subject to meeting all other General Limitations.

### III-3.4 GENERAL DESIGN CRITERIA FOR INFILTRATION AND FILTRATION BMPs

A Darcy's Law approach is recommended for sizing both infiltration and filtration BMPs. Stage-storage and stage-discharge relationships can be developed and, through an iterative process, the final BMP size and geometry can then be determined by routing the appropriate design storm(s) through the facility. See Section III-1.4.3 for guidance on developing storage-discharge relationships.

Darcy's Law of ground water movement can be used to develop the stage-discharge relationship (Figure III-3.6 illustrates Darcy's Law):

$$Q = f * i * A_s, \text{ where}$$

- $Q$  = flowrate at which runoff is infiltrated/filtrated by BMP
- $f$  = infiltration rate of soil or filtration media
- $i$  = hydraulic gradient
- $A_s$  = Surface area of the infiltration or filtration BMP

Conservative values of "f" should be used. For infiltration BMPs, a factor of safety of two should be applied to the infiltration rate determined from the textural analysis and, hereafter, the design infiltration rate will be labeled " $f_d$ " where  $f_d = 0.5 * f$ . For sand filtration BMPs an "f" value of about 2 inches per



hour is recommended for design purposes. This appears to be a low value but reflects actual rates achieved by operating sand filtration systems treating urban runoff.

**NOTE:**  $A_s$  is not the cross-sectional area of the BMP, e.g., for a trench with length  $L_t$ , width  $W$ , and depth  $D$ , the bottom area of the trench is  $A_s = L_t * W$  while the cross-sectional area is  $W * D$ . The surface area  $A_s$  is determined from the basin geometry; it may be necessary to planimeter or otherwise compute the area (see Section III-1.4.4 for an example).

The hydraulic gradient is given by the equation:

$$i = \frac{h + L}{L}$$

where  $h$  is the height of the water column over the infiltration/filtration media and  $L$  is the distance from the top surface of the BMP to the water table, bedrock, impermeable layer, or soil layer of different infiltration rate (for latter applied to sand filtration BMPs it is the bottom of the filtration bed = 18").

If the approximate area available for the BMP is known then a preliminary stage-discharge relationship can be developed, i.e.,

$$Q = f_d * \frac{h + L}{L} * A_s$$

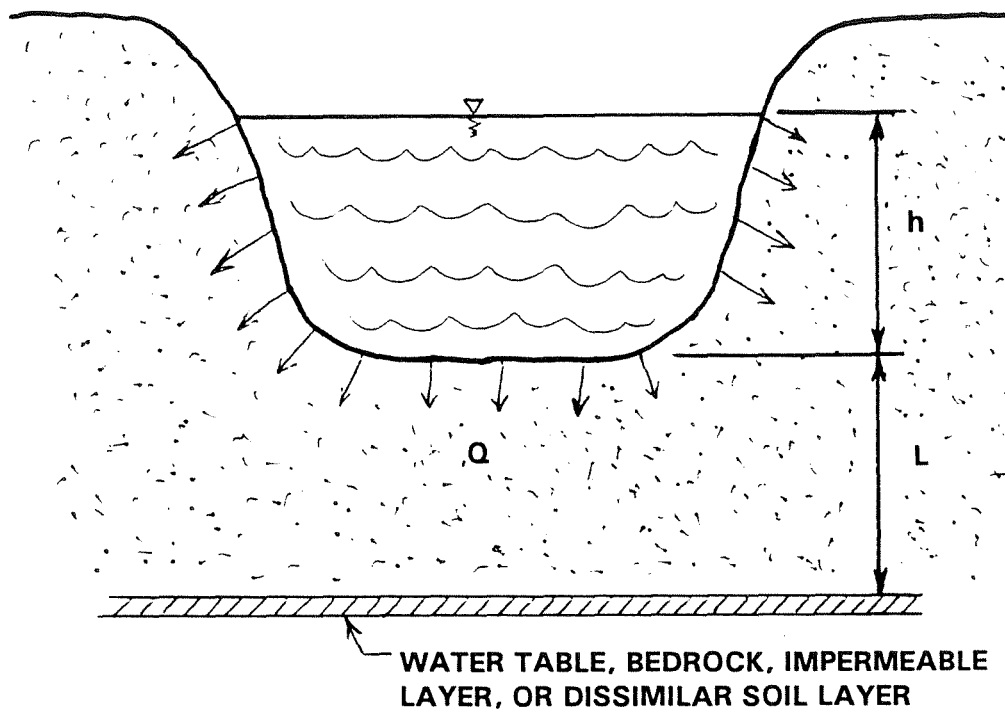
If the approximate depth available for the BMP is known then a stage-storage relationship can also be developed (see Section III-1.4). A minimum of one foot of freeboard is recommended when establishing the BMP depth.

The appropriate design storms can then be routed through the BMP using a level pool analysis (Section III-1.4.4) to finalize the BMP size and geometry. This will be an iterative process. The analysis must demonstrate that the BMP will completely percolate the design storm within 24 hours (or 48 hours for the 100-year event). If this is not the case the surface area and or depth of the BMP will have to be increased. If the analysis indicates that the design storms can only be partially infiltrated the BMP should still be utilized but the additional runoff must be conveyed to another BMP for runoff treatment and/or streambank erosion control. (Note: If a Water Quality Infiltration Basin or Trench (BMP RI.05 or RI.06, respectively) is preceded by a Presettling Basin (BMP RD.10) then the combination of both BMPs (i.e., the Presettling Basin and the Infiltration BMP) must be designed to drain the 6-month, 24-hour design storm within 24 hours. This is necessary to ensure that aerobic conditions are maintained in the infiltration BMP.)

#### Preliminary Sizing Example

An infiltration trench is proposed to treat the 6-month, 24-hour design storm for a development site. Soils investigations indicate that a sandy loam soil ( $f = 1.5$  in/hr) extends for at least 5 feet below the land surface. A BMP depth of about 3 feet is proposed. The surface area available for the BMP is approximately 100 square feet. The depth to the water table is estimated to be 75 feet. No impermeable soil layers were detected within 10 feet of the surface and none expected within at least 50 feet. For preliminary design purposes the trench is planned to be 30 feet long, 3 feet wide, and 2 feet deep. It will be filled with rocks such that the void ratio is 0.4. The following preliminary design is developed:

Figure III-3.6  
Darcy's Law of Ground water Movement



Stage-discharge Relationship

$$f = 1.5 \text{ inches/hour, thus } f_d = 0.5 * 1.5 = 0.75 \text{ inches/hour} \\ = 0.0625 \text{ ft/hr}$$

$h$  = variable - maximum of 2 feet

$L$  = assume 10 feet

$A_s$  = bottom surface area =  $30 * 3 = 90 \text{ sq. ft.}$

Solving for  $Q$  in Darcy's equation gives:

$$Q = f_d * \frac{h + L}{L} * A_s = 0.0625 * \frac{h + 10}{10} * 90 \quad \text{or,}$$

$$Q = (1.25 * h) + 12.5$$

Stage-storage Relationship

The stage-storage relationship would be:

$$S = A_s * h * \text{Void Ratio}$$

$$= 90 * h * 0.4, \text{ or}$$

$$S = 36 * h$$

Results of Preliminary Sizing

The tabular form of the stage-discharge and stage-storage relationships would be:

$h$ (ft)	$i$ (ft/ft)	$Q$ (cfs)	$S$ (cu.ft.)
0.0	1.0	5.6	0
0.5	1.05	5.9	18
1.0	1.1	6.2	36
1.5	1.15	6.5	54
2.0	1.2	6.8	72

Note that for design purposes it may be simpler to set the hydraulic gradient,  $i$ , equal to 1 thus making the discharge independent of stage.

At this point a level pool routing should be conducted to develop the final design dimensions of the BMP, ensuring, however, that the BMP will completely infiltrate the design storm(s) within 24 hours.

**III-3.5 CONSTRUCTION AND MAINTENANCE**

III-3.5.1 Overview

The failure of infiltration and filtration BMPs to function properly can often be traced back to construction and maintenance issues. By utilizing appropriate construction practices and conducting systematic and rigorous maintenance, infiltration/filtration BMPs should function properly.

### III-3.5.2 Construction

Regardless of the type of infiltration/filtration practice to be constructed, careful consideration must be given in advance of construction to the effects of the work sequence, techniques, and the equipment employed during construction of the facility. Serious maintenance problems can be averted, or in large part mitigated, by the adoption of relatively simple measures during construction.

Previous experience with infiltration and filtration practices in the States of Maryland and Texas has shown that these BMPs must not be put into use, or preferably even constructed, until the drainage areas that contribute runoff to the structure have been adequately stabilized. When this precaution is not taken, infiltration/filtration structures often become clogged with sediment from upland construction and thus fail to operate properly from the outset. It cannot be emphasized enough how important it is to protect these facilities from sediment deposition at all times.

Care must also be taken to not compact soils during the construction phase as this can seriously affect infiltration and filtration rates. If vehicles must be driven over the infiltration/filtration BMP during construction only those with large tracks shall be used.

Specific construction methods and specifications are provided for each infiltration and filtration BMP in Sections III-3.6 and III-3.7

### III-3.5.3 Maintenance

The maintenance requirements of infiltration and filtration BMPs are an important aspect which is often not addressed in the planning and design of these structures. Infiltration and filtration basins can be visually inspected and easily maintained. The surface of an infiltration/filtration trench or roof downspout system can also be visually inspected and maintained, but the subsurface storage area cannot. It is therefore a requirement to install an observation well in practices such as these in order to have an observation mechanism available.

Infiltration and filtration practices must be regularly inspected. Specific maintenance specifications and recommendations are provided for each infiltration and filtration BMP in Sections III-3.6 and III-3.7.

## **III-3.6 STANDARDS AND SPECIFICATIONS FOR INFILTRATION BMPs**

### III-3.6.1 Overview

This section presents detailed standards and specifications for the following infiltration best management practices:

- BMP RI.05 Water Quality (WQ) Infiltration Basin
- BMP RI.06 Streambank Erosion Control (SBEC) Infiltration Basin
- BMP RI.10 Water Quality (WQ) Infiltration Trench
- BMP RI.11 Streambank Erosion Control Infiltration Trench
- BMP RI.15 Roof Downspout System
- BMP RI.20 Water Quality (WQ) Porous Pavement
- BMP RI.21 Streambank Erosion Control (SBEC) Porous Pavement
- BMP RI.30 Water Quality (WQ) Concrete Grid and Modular Pavement
- BMP RI.31 Streambank Erosion Control (SBEC) Concrete Grid and Modular Pavement

The standards and specifications for each of the above BMPs contains, where appropriate, information on the following topics:

- Purpose and Definition
- Planning Considerations
- Design Criteria
- Construction and Maintenance Criteria

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**III-3.6.2 BMP RI.05 Water Quality (WQ) Infiltration Basin****Purpose and Definition**

This BMP is a vegetated open impoundment which is designed primarily for runoff treatment purposes and not streambank erosion control. Runoff conveyed to the basin is infiltrated into the underlying soil, where pollutant removal by the soil and vegetative root system takes place. The underlying soil will likely have insufficient permeability to be used for streambank erosion control. Infiltration basins are made by constructing a dam or an embankment, or by excavating a pit or a dugout.

Figure III-3.7 illustrates an infiltration basin.

**Planning Considerations**

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of the BMP. See Section III-3.3 for a description of General Limitations.*

*This BMP will typically be located off-line from the primary conveyance/detention system because streambank erosion control is generally not provided. Water Quality Infiltration BMPs must always be preceded by a pretreatment BMP to remove suspended solids that could clog the infiltration soils.*

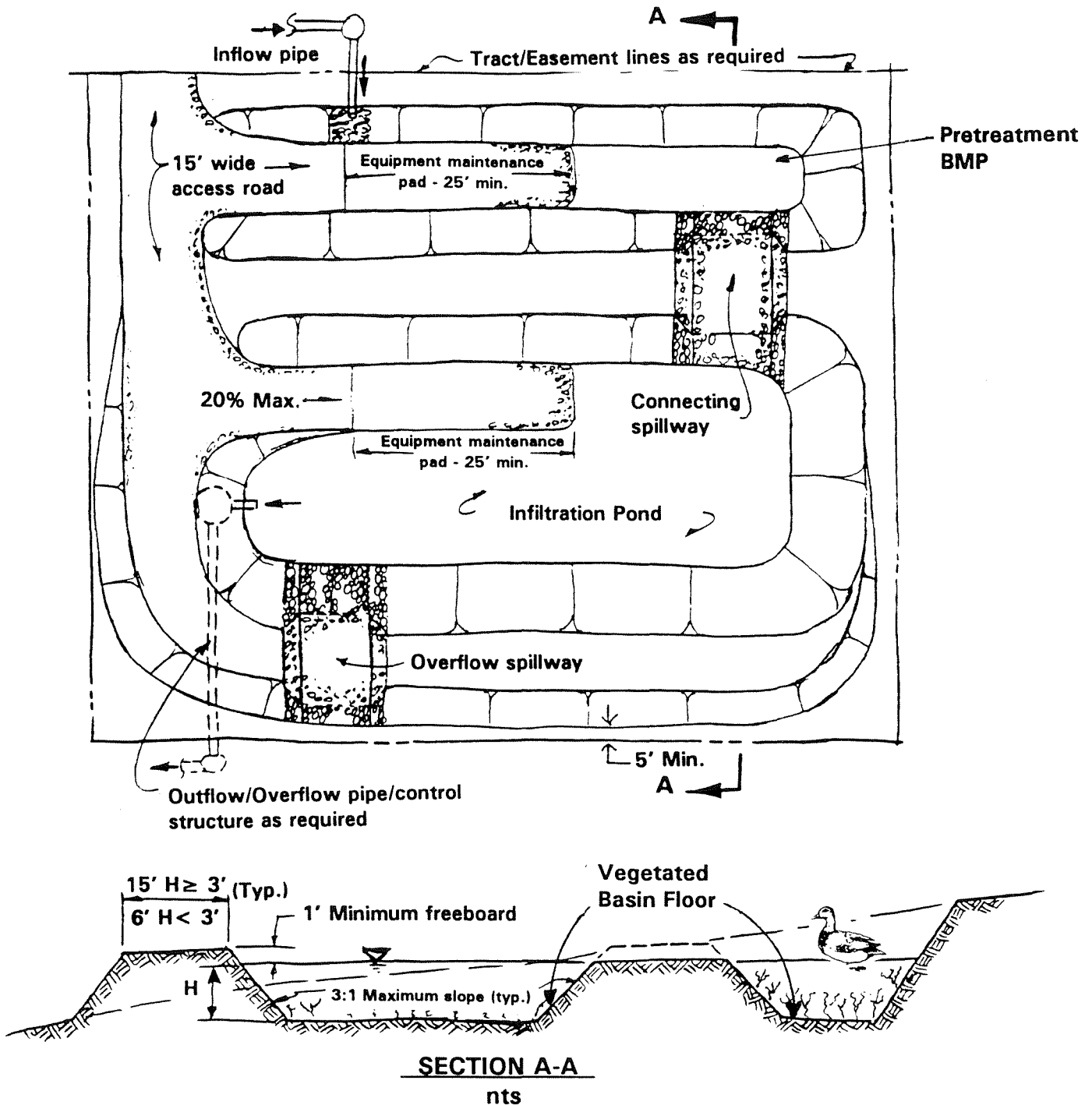
*Drainage areas can be up to 50 acres for Water Quality Infiltration Basins. Basin depths are generally from 3 - 12 feet.*

**Design Criteria**

The design procedure described in Section III-3.4 should be used to design an infiltration basin.

- **General** - The construction of structures, materials allowed, accessibility for maintenance, safety measures, easements, and hydraulic design methods shall be the same as those required for detention basins in Chapter III-4.
- **Soils Investigation** - A minimum of one soils log shall be required for each 5,000 square feet of infiltration basin area (plan view area) and in no case less than three soils logs per basin. Each soils log shall extend a minimum of 3 feet in depth below the bottom of the proposed basin, describe the SCS series of the soil, the textural class of the soil horizon(s) through the depth of the log, and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.
- **The design infiltration rate,  $f_d$** , will be equal to one-half the infiltration rate found from the soil textural analysis.
- **Pretreatment** - Water Quality Infiltration Basins must be preceded by a pretreatment BMP. See Chapter I-4 for selecting appropriate pretreatment BMPs.
- **Slopes** - Basins should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the potential impact of the basin infiltration upon the steep slope.

Figure III-3.7  
Infiltration Basin



Note: Detail is schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

- Buildings - Basins should be a minimum of 100 feet upslope and 20 feet downslope from any building.
- Surface Area - The infiltration surface area ( $A_g$ ) used for sizing the basin shall be computed by measuring the surface area (plan view area) below the maximum design water surface.
- Drawdown Time - Water Quality Infiltration basins shall be designed to completely drain stored runoff within one day following the occurrence of the 6-month, 24-hour design storm. Thus, a maximum allowable drawdown time of 24 hours shall be used. This will ensure that the necessary aerobic conditions exists in order to provide effective treatment of pollutants. If a Presettling Basin (BMP RD.10) precedes the infiltration basin, the *combined* drawdown time for both BMPs should be 24 hours.
- Vegetation - The basin floor and side banks are to be vegetated. See Volume II for criteria on establishing permanent vegetation.

#### Construction and Maintenance Criteria

##### Construction Schedule

The sequence of various phases of basin construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin could serve as a temporary sediment trap or pond in order to assist in erosion and sediment control during construction. However, basins near the final stages of excavation should never be used prematurely for runoff disposal. Drainage from untreated, freshly constructed slopes within the watershed area would load the newly formed basin with a heavy concentration of fine sediment. This could seriously impair the natural infiltration characteristics of the basin floor. Final grade of an infiltration basin shall not be attained until after its use as a sediment control basin is completed.

Specifications for basin construction should state the earliest point in construction progress when storm drainage may be directed to the basins, and the means by which this delay in use should be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.

##### Excavation

Initial basin excavation should be carried to within 1 foot of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

##### Lining Material

A healthy stand of vegetation is to be established on the basin floor and side slopes. This vegetation will not only prevent erosion and sloughing, but will also provide a natural means of maintaining infiltration rates and will provide additional pollution removal. Erosion protection of inflow points to the basin shall also be provided (e.g., riprap, flow spreaders, energy dissipators). Removal



of accumulated sediment is a problem only at the basin floor. Little maintenance is normally required to maintain the infiltration capacity of side slope areas.

Selection of suitable vegetative materials for the basin floor and side slopes to be stabilized, and application of correct amounts of fertilizer and mulches shall be done in accordance with Volume II, Standards and Specifications for Soil Erosion and Sediment Control. Local extension agencies should also be consulted.

#### Maintenance

##### Inspection Schedule

- When infiltration basins are first placed into use they should be inspected on a monthly basis, and more frequently if a large storm occurs in between that schedule. During the period October 1 through March 31 inspections shall be conducted monthly. Thereafter, once it is determined that the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semi-annual basis with additional inspections following the occurrence of a large storm. This inspection shall include investigation for potential sources of contamination.

##### Sediment Control

- The basin should be designed with maintenance in mind. Access should be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.
- Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass planted on basin side slopes will also prevent erosion.

##### Vegetation Maintenance

- Maintenance of vegetation established on the basin floor and side slopes is necessary in order to promote dense turf with extensive root growth which enhances infiltration, prevents erosion and consequent sedimentation, and prevents invasive weed growth. Bare spots are to be immediately stabilized and revegetated.
- The use of low-growing, stoloniferous grasses will permit long intervals between mowings. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to the pollution problems, including ground water pollution, that the infiltration basin is there to solve. Consult the local extension agency for appropriate fertilizer types and application rates.

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### III-3.6.3 BMP RI.06 Streambank Erosion Control (SBEC) Infiltration Basin

#### Purpose and Definition

This BMP is similar in design to the Water Quality Infiltration Basin (BMP RI.05) except that it is designed to provide only streambank erosion control; the soils underlying this BMP will be too coarse for runoff treatment purposes. Stormwater must always be treated prior to discharge to this BMP.

Figure III-3.7 illustrates an infiltration basin.

#### *Planning Considerations*

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of the BMP. See Section III-3.3 for a description of General Limitations.*

*Unlike the Water Quality Infiltration Basin, this basin will typically be located "on-line" and be an integral component of the primary conveyance/detention system. The 6-month, 24-hour design storm must be completely treated prior to runoff being discharged to this BMP.*

*Drainage areas can be up to 50 acres for Water Quality Infiltration Basins. Basin depths are generally from 3 - 12 feet.*

#### Design Criteria

The design procedure described in Section III-3.4 should be used to design an infiltration basin.

- General - The construction of structures, materials allowed, accessibility for maintenance, safety measures, easements, and hydraulic design methods shall be the same as those required for detention basins in Chapter III-4.
- Soils Investigation - A minimum of one soils log shall be required for each 5,000 square feet of infiltration basin area (plan view area) and in no case less than three soils logs per basin. Each soils log shall extend a minimum of 3 feet in depth below the bottom of the proposed basin, describe the SCS series of the soil, the textural class of the soil horizon(s) through the depth of the log, and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.
- The design infiltration rate,  $f_d$ , will be equal to one-half the infiltration rate found from the soil textural analysis.
- Overflow route - An overflow route must be identified in the event that the basin capacity is exceeded. This overflow route should be designed to meet Minimum Requirement #2 (Preservation of Natural Drainage Systems).
- Runoff Treatment - Runoff from the 6-month, 24-hour design storm is to be completely treated prior to discharge to this BMP.
- Slopes - Basins should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the potential impact of the basin infiltration upon the steep slope.
- Buildings - Basins should be a minimum of 100 feet upslope and 20 feet downslope from any building.

- The infiltration surface area ( $A_s$ ) used for sizing the basin shall be computed by measuring the surface area (plan view area) below the maximum design water surface.
- Spillways - The bottom elevation of the low-stage orifice should be designed to coincide with the one-day infiltration capacity of the basin. All other aspects of the principal spillway design and the emergency spillway shall follow the details provided for detention basins in Chapter III-4.
- Drawdown Time - Streambank Erosion Control Infiltration Basins shall be designed to completely drain stored runoff within one day following the occurrence of the 10-year, 24-hour design storm and within two days of the 100-year, 24-hour design storm (with appropriate correction factors as discussed in Chapter III-1). Thus, a maximum allowable drawdown time of 48 hours is permissible.
- Vegetation - The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas shall be stabilized and planted in accordance with Minimum Requirement #1 (Erosion and Sediment Control).

#### Construction and Maintenance Criteria

##### Construction Schedule

The sequence of various phases of basin construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin could serve as a temporary sediment trap or pond in order to assist in erosion and sediment control during construction. However, basins near the final stages of excavation should never be used prematurely for runoff disposal. Drainage from untreated, freshly constructed slopes within the watershed area would load the newly formed basin with a heavy concentration of fine sediment. This could seriously impair the natural infiltration characteristics of the basin floor. Final grade of an infiltration basin shall not be attained until after its use as a sediment control basin is completed.

Specifications for basin construction should state the earliest point in construction progress when storm drainage may be directed to the basins, and the means by which this delay in use should be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.

##### Excavation

Initial basin excavation should be carried to within 1 foot of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

##### Lining Material

Infiltration basins can be open or be lined with a 6 to 12-inch layer of filter material such as coarse sand or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when/if it becomes clogged. When a 6-inch layer of organic material is specified for disking or spading into the basin floor to increase the permeability

of the soil, the basin floor should be soaked or inundated for a brief period and then allowed to dry subsequent to this operation. This induces rapid decay in the organic material and prevents the organic matter from becoming hydrophobic, loosening the upper soil layer.

Establishing a healthy stand of vegetation on the basin side slopes and floor is recommended. This vegetation will not only prevent erosion and sloughing, but will also provide a natural means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin shall also be provided. Removal of accumulated sediment is a problem only at the basin floor. Little maintenance is normally required to maintain the infiltration capacity of side slope areas.

Selection of suitable vegetative materials for the side slopes and all other areas to be stabilized, and application of correct amounts of fertilizer and mulches shall be done in accordance with Volume II, Erosion and Sediment Control. Local extension agencies should also be consulted.

## Maintenance

### Inspection Schedule

- When infiltration basins are first placed into use they should be inspected on a monthly basis, and more frequently if a large storm occurs in between that schedule. During the period October 1 through March 31 inspections shall be conducted monthly. Thereafter, once it is determined that the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semiannual basis with additional inspections following the occurrence of a large storm (e.g. approximately 1 inch in 24 hours). This inspection shall include investigation for potential sources of contamination.

### Sediment Control Effect on Vegetated Basins

- The basin should be designed with maintenance in mind. Access should be provided for vehicles to easily maintain the forebay (presettling basin) area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.
- Cleanout frequency of infiltration basins will depend on whether they are vegetated or non-vegetated and will be a function of their storage capacity, recharge characteristics, volume of inflow, and sediment load.
- Grass bottoms in infiltration basins seldom need replacement since grass serves as a good filter material. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well established turf on a basin floor will grow up through sediment deposits forming a porous turf and preventing the formation of an impenetrable layer. Grass filtration works well with long, narrow, shoulder-type depressions (swales, ditches etc.) where highway runoff flows down a grassy slope between the roadway and the basin. Grass planted on basin side slopes will also prevent erosion.

### Sediment Removal From Non-Vegetated Basins

- Sediment is most easily removed when the basin floor (or presettling basin) is completely dry and after the silt layer has mud-cracked and separated from the basin floor. It is recommended that hand raking and removal be done if possible to avoid compaction of the infiltration media by equipment. Large-tracked vehicles should not be used in order to prevent compaction of the basin floor.

#### Tilling of the Non-Vegetated Basin Floor

- All accumulated sediment must be removed prior to tilling operations. As tilling is required periodically, and at least once annually, the frequency of sediment removal will be reduced to small operations on a regular basis.
- Tilling may be necessary to restore the natural infiltration capacity by overcoming the effects of surface compaction, and to control weed growth on the basin floor.
- Rotary tillers or disc harrows will normally serve this purpose. Light tractors should be employed for these operations. In the event that heavy equipment has caused deeper than normal compaction of the surface, these operations should be preceded by deep plowing. In its final condition after tilling, the basin floor should be level, smooth, and free of ridges and furrows to ease future removal of sediment and minimize the material to be removed during future cleaning operations. A levelling drag, towed behind the equipment on the last pass will accomplish this.
- In the spring the basin surface may be quite porous due to the effects of frost and subsequent thawing. The infiltration capacity diminishes rapidly thereafter. To enhance infiltration capacity, tilling should be done once each season from late June through September. To control vegetative growth, an additional light tillage may be necessary during the growing season. Precautions must be observed to avoid working any of the sediment accumulation into the basin floor as a part of a light cultivation for weed control. ANY cultivation or tilling operation must be preceded in all cases by careful sediment removal.

#### Side Slope Maintenance

- Maintenance of side slopes is necessary to promote dense turf with extensive root growth which enhances infiltration through the slope surface, prevents erosion and consequent sedimentation of the basin floor, and prevents invasive weed growth.
- Seed mixtures should be the same as those recommended in the Erosion and Sediment Control Volume.
- The use of low-growing, stoloniferous grasses will permit long intervals between mowings. Mowing twice a year is generally satisfactory. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to the pollution problems, including ground water pollution, that the infiltration basin is there to solve. Consult the local extension agency for appropriate fertilizer types and application rates.

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### III-3.6.4 BMP RI.10 Water Quality (WQ) Infiltration Trench

#### Purpose and Definition

This BMP is a shallow excavated trench designed primarily to provide runoff treatment but not streambank erosion control. The soils underlying this BMP must be capable of removing pollutants from runoff and will likely have insufficient permeability to be used for streambank erosion control. Trenches are generally 2 to 10 feet in depth backfilled with a coarse stone aggregate, allowing for temporary storage of storm runoff in the voids between the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered over with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet.

One alternative design is to install a pipe in the trench and surround it with coarse stone; this will increase the temporary storage capacity of the trench. A second alternative design is to build a vault or tank without a bottom (see BMP RD.15 for details). An infiltration vault/tank is equivalent to a detention vault with the bottom acting as the outlet, instead of having a control structure.

Figures III-3.8 illustrates a Water Quality Infiltration Trench, located off-line from the primary conveyance/detention system. Figure III-3.9 shows a schematic of a typical infiltration trench. Figures III-3.10 through III-3.15 illustrate other variations of trench designs.

#### Planning Considerations

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of this BMP. See Section III-3.3 for a description of General Limitations. One advantage of trenches is that they have less tendency to become clogged with sediment than do other infiltration BMPs.*

*This BMP will typically be located "off-line" from the primary conveyance/detention system in order to effectively treat pollutants and protect the infiltration soils from clogging. Water Quality Infiltration BMPs must always be preceded by a pretreatment BMP to remove sediments that could clog the infiltration soils.*

*An infiltration trench will generally be used in relatively small drainage areas (usually less than 15 acres). This practice can be used in residential lots, commercial areas, parking lots and open space areas. Trenches are one of the few BMPs that are relatively easy to fit into the margin, perimeter, and other less-utilized areas of developed sites, making them particularly suitable for retrofitting. A trench may also be installed under a swale to increase the storage of the infiltration system.*

#### Design Criteria

The procedure described in Section III-3.4 should be used to design an infiltration trench. Trenches are assumed to have rectangular cross-sections, thus the infiltration surface area (sides and bottom) can be readily calculated from the trench geometry. The storage volume of the trench must take into account the volume of backfill material placed in the trench (i.e., void ratio).

The same general criteria that were presented for Water Quality Infiltration Basins (BMP RI.05) shall apply to trenches; the following information is also provided for guidance:

- Soils Investigation - A minimum of one soils log shall be required for every 50 feet of trench length, and in no case less than two soils logs for each proposed

trench location. Each soils log should extend a minimum of 3 feet below the bottom of the trench, describe the SCS series of the soil, the textural class of the soil horizon(s) through the depth of the log, and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.

- The design infiltration rate,  $f_d$ , will be equal to one-half the infiltration rate found from the soil textural analysis.
- Pretreatment - Water Quality Infiltration Trenches must be preceded by a pretreatment BMP. See Chapter I-4 for selecting appropriate pretreatment BMPs.
- Drawdown Time - Infiltration trenches shall be designed to empty the 6-month, 24-hour storm event within one day (24 hours). This will ensure that the necessary aerobic conditions exists in order to provide effective treatment of pollutants. If a Presettling Basin (BMP RD.10) precedes the infiltration trench, the combined drawdown time for both BMPs should be 24 hours.
- Backfill Material - The aggregate material for the infiltration trench shall consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. The aggregate should be graded such that there will be few aggregates smaller than the selected size. Void space for these aggregates is assumed to be in the range of 30 percent to 40 percent.
- Filter Fabric - The aggregate fill material shall be completely surrounded as shown in Figure III-3.9 with an engineering filter fabric. In the case of an aggregate surface, filter fabric should surround all of the aggregate fill material except for the top one foot.
- Overflow Channel - In general, because of the small drainage areas controlled by an infiltration trench, an emergency spillway is not necessary. In all cases, the overland flow path of surface runoff exceeding the capacity of the trench should be evaluated to preclude the development of uncontrolled, erosive, concentrated flow. A nonerosive overflow channel leading to a stabilized watercourse shall be provided.
- Seepage Analysis and Control - An analysis shall be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. The use of infiltration trenches on fill sites is not permitted.
- Buildings - Infiltration trenches should be located 20 feet downslope and 100 feet upslope from building foundations.
- Observation Well - An observation well shall be installed for every 50 feet of infiltration trench length. The observation well will serve two primary functions: it will indicate how quickly the trench dewateres following a storm and it will provide a method of observing how quickly the trench fills up with sediments. Figure III-3.16 illustrates observation well details.

The observation well should consist of perforated PVC pipe, 4 to 6 inches in diameter. It should be located in the center of the structure and be constructed flush with the ground elevation of the trench as shown in Figure III-3.9. The top of the well should be capped to discourage vandalism and tampering.

## Construction and Maintenance Criteria

### Construction Timing

An infiltration trench shall not be constructed or placed into service until all of the contributing drainage area has been stabilized and approved by the responsible inspector.

### Trench Preparation

Excavate the trench to the design dimensions. Excavated materials shall be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic if it is to be left in place for more than 30 days (see BMP E1.20 in Volume II).

### Fabric Laydown

The filter fabric roll must be cut to the proper width prior to installation. The cut width must include sufficient material to conform to the trench perimeter irregularities and for a 12 inch minimum top overlap.

Place the fabric roll over the trench and unroll a sufficient length to allow placement of the fabric down into the trench. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the lined trench open during windy periods. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect. The overlap insures fabric continuity and allows the fabric to conform to the excavated surface during aggregate placement and compaction.

### Stone Aggregate Placement and Compaction

The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing potential soil piping, fabric clogging, and settlement problems.

### Overlapping and Covering

Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. The desired fill soil or stone aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

### Potential Contamination

Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

### Voids Behind Fabric

Voids may be created between the fabric and excavation sides and shall be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides. Soil piping, fabric clogging, and possible surface subsidence will be avoided by this remedial process.



#### Unstable Excavation Sites

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. These conditions require laying back of the side slopes to maintain stability; trapezoidal rather than rectangular cross-sections may result. This is acceptable, but any change in the shape of the stone reservoir needs to be taken into consideration in size calculations.

#### Traffic Control

Heavy equipment and traffic shall be restricted from travelling over the infiltration areas to minimize compaction of the soil. The trench should be flagged or marked to keep equipment away from the area.

#### Observation Well

An observation well, as described in the previous section on design criteria and shown in Figure III-3.16 shall be provided. The depth of the well at the time of installation will be clearly marked on the well cap.

#### Maintenance

##### Inspection Schedule

- The observation well should be monitored periodically. For the first year after completion of construction, the well should be monitored after every large storm (>1 inch in 24 hours), and, during the period October 1 through March 31 inspections shall be conducted monthly. From April 1 through September 30, the facility should be monitored on a quarterly basis. A log book shall be maintained by the responsible person designated by the local government indicating the rate at which the facility dewateres after large storms and the depth of the well for each observation. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis unless the performance data indicate that a more frequent schedule is required.

##### Sediment Removal

- Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate shall be required when the trench has a stone surface. Sediment deposits shall not be allowed to build up to the point where it will reduce the rate of infiltration into the trench.

Figure III-3.8  
Water Quality Infiltration Trench System

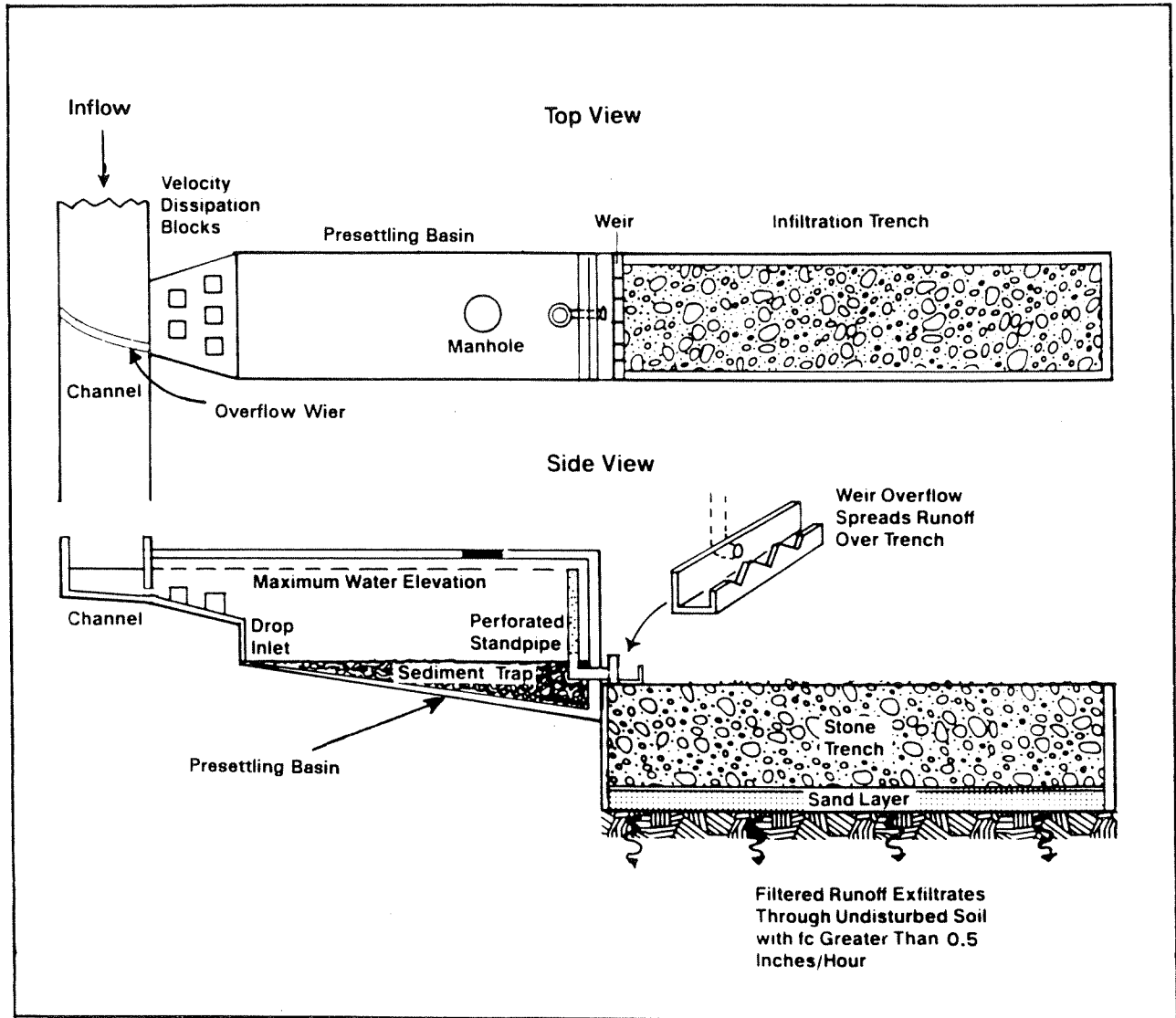


Figure III-3.9 Schematic of an Infiltration Trench  
(Reproduced with permission from Schueler (16))

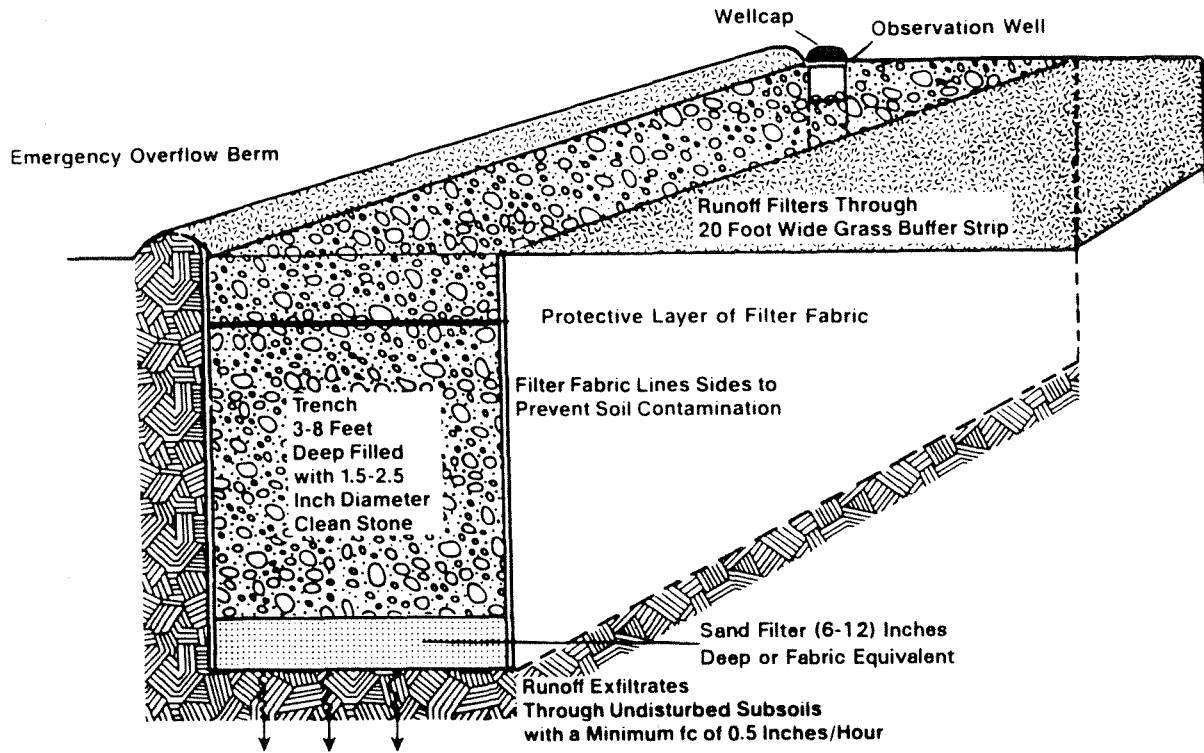


Figure III-3.10 Median Strip Trench Design  
 (Reproduced with permission from Schueler (16))

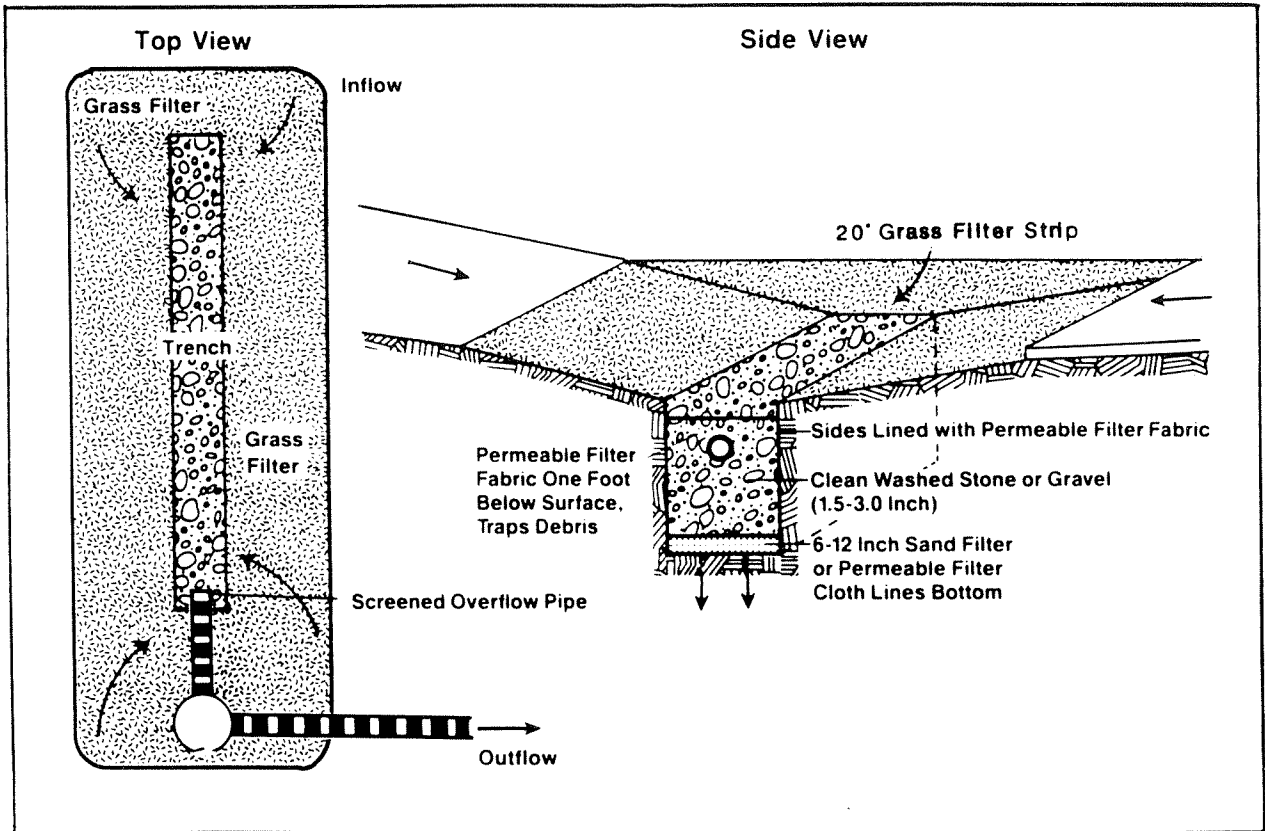


Figure III-3.11 Parking Lot Perimeter Trench Design  
(Reproduced with permission from Schueler (16))

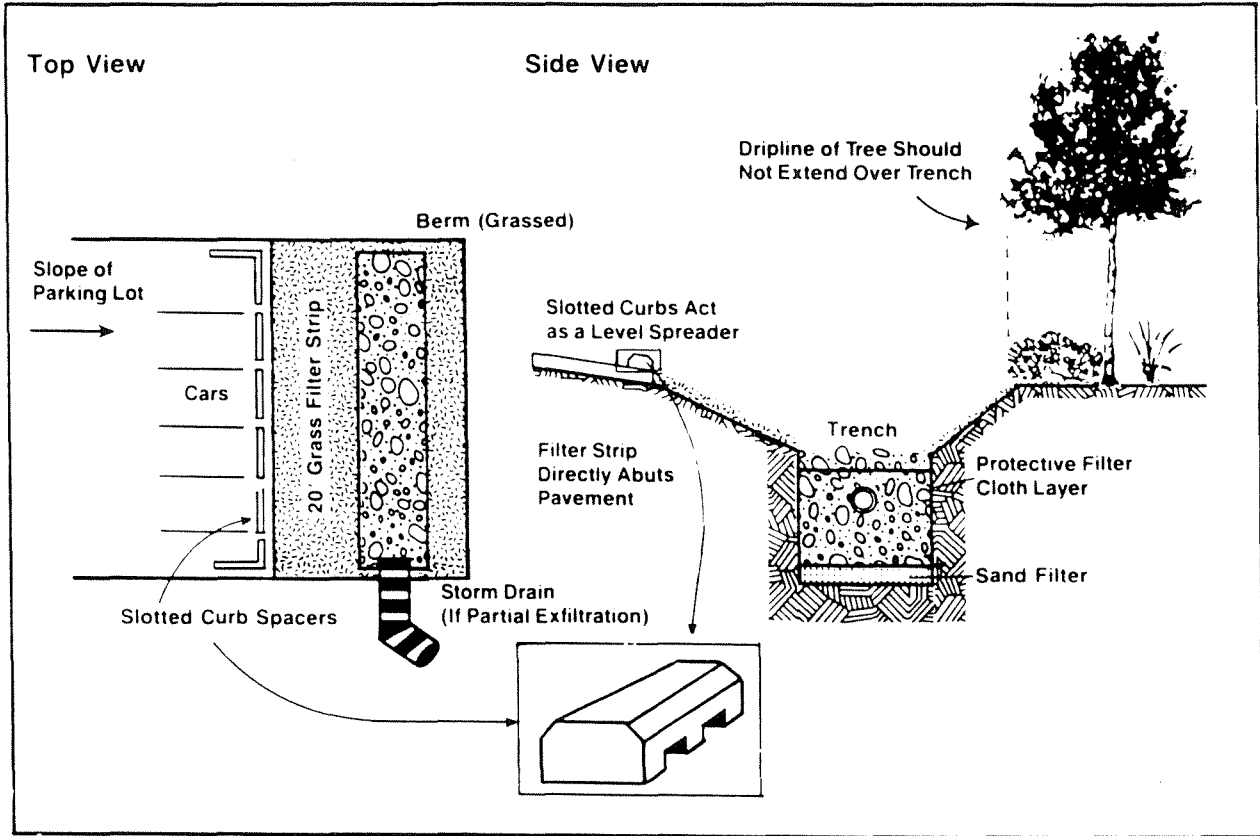


Figure III-3.12 Oversized Pipe Trench Design  
(Reproduced with permission from Schueler (16))

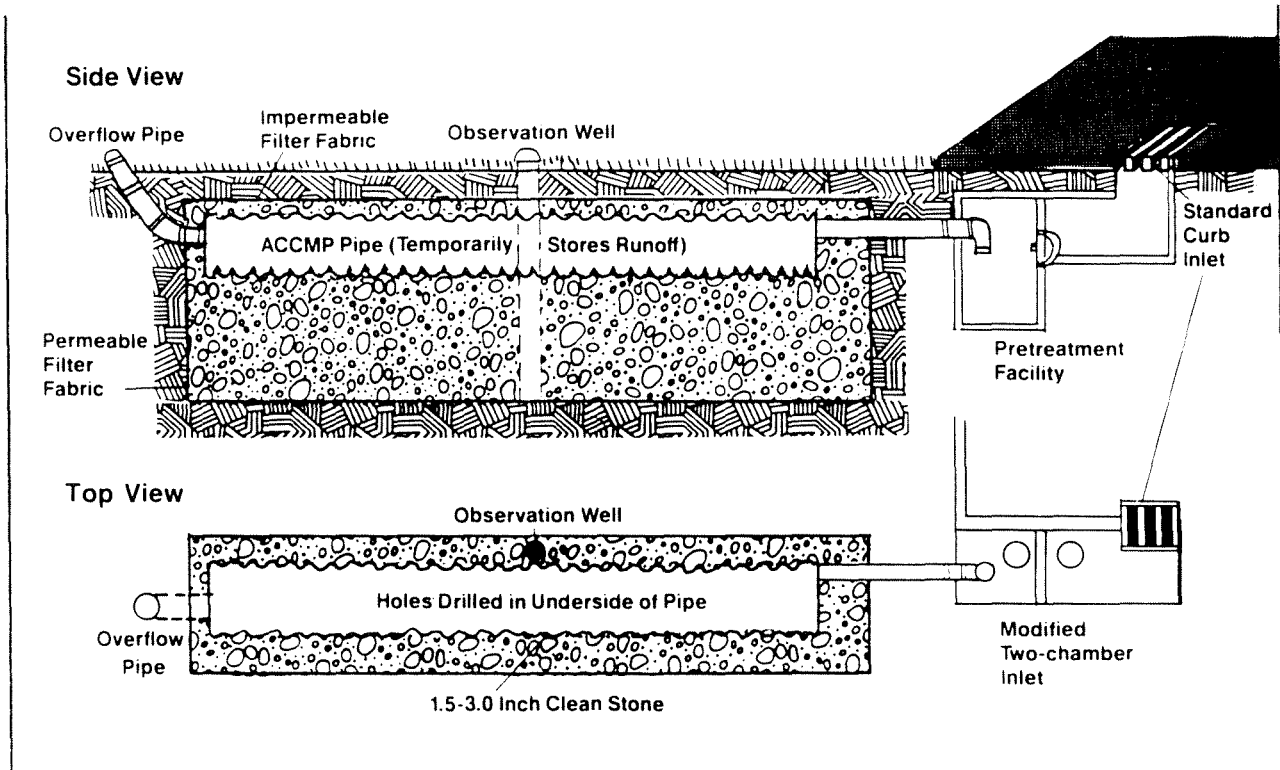


Figure III-3.13 Swale/Trench Design  
(Reproduced with permission from Schueler (16))

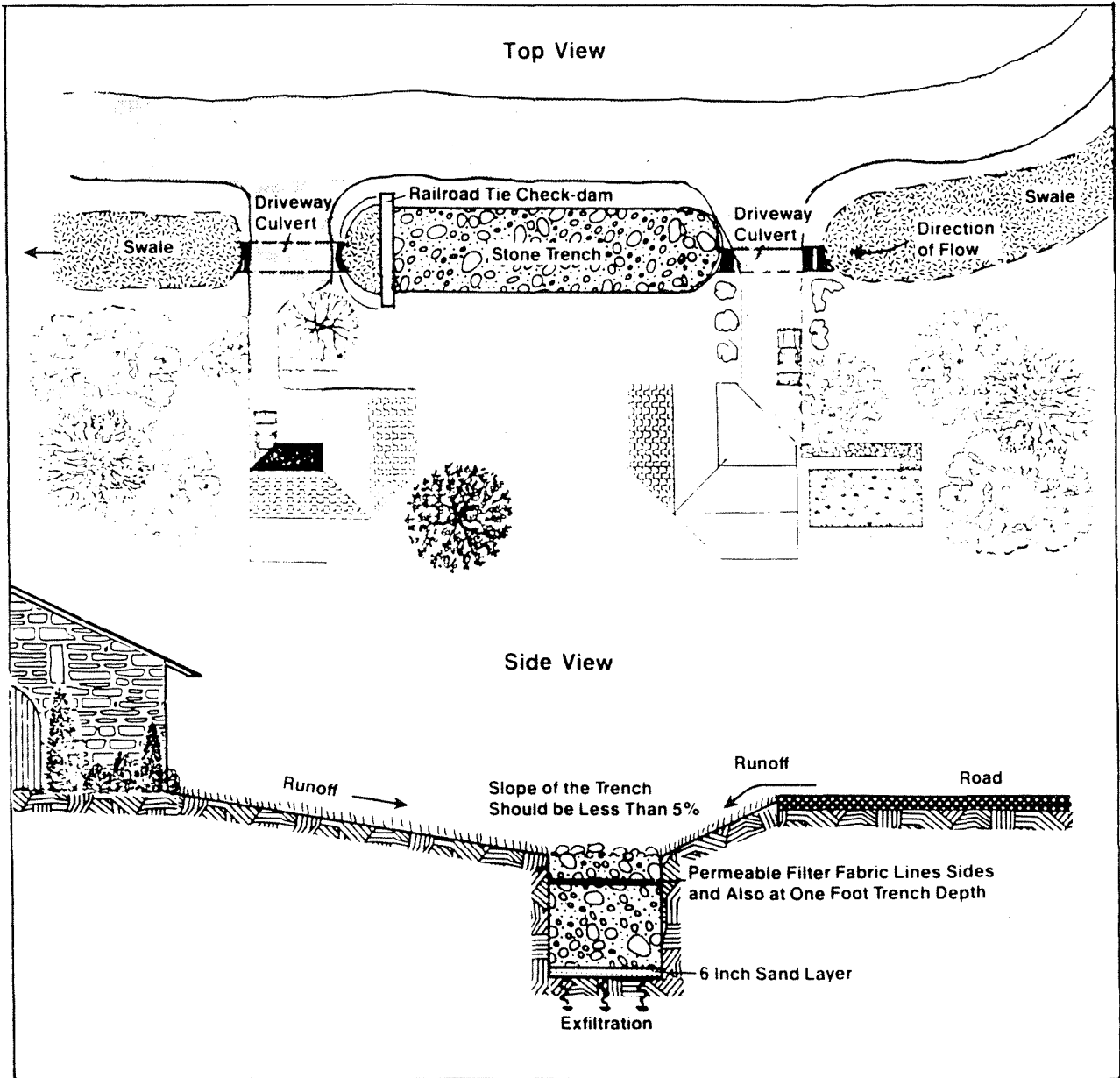


Figure III-3.14 Under-the-Swale Trench Design  
 (Reproduced with permission from Schueler (16))

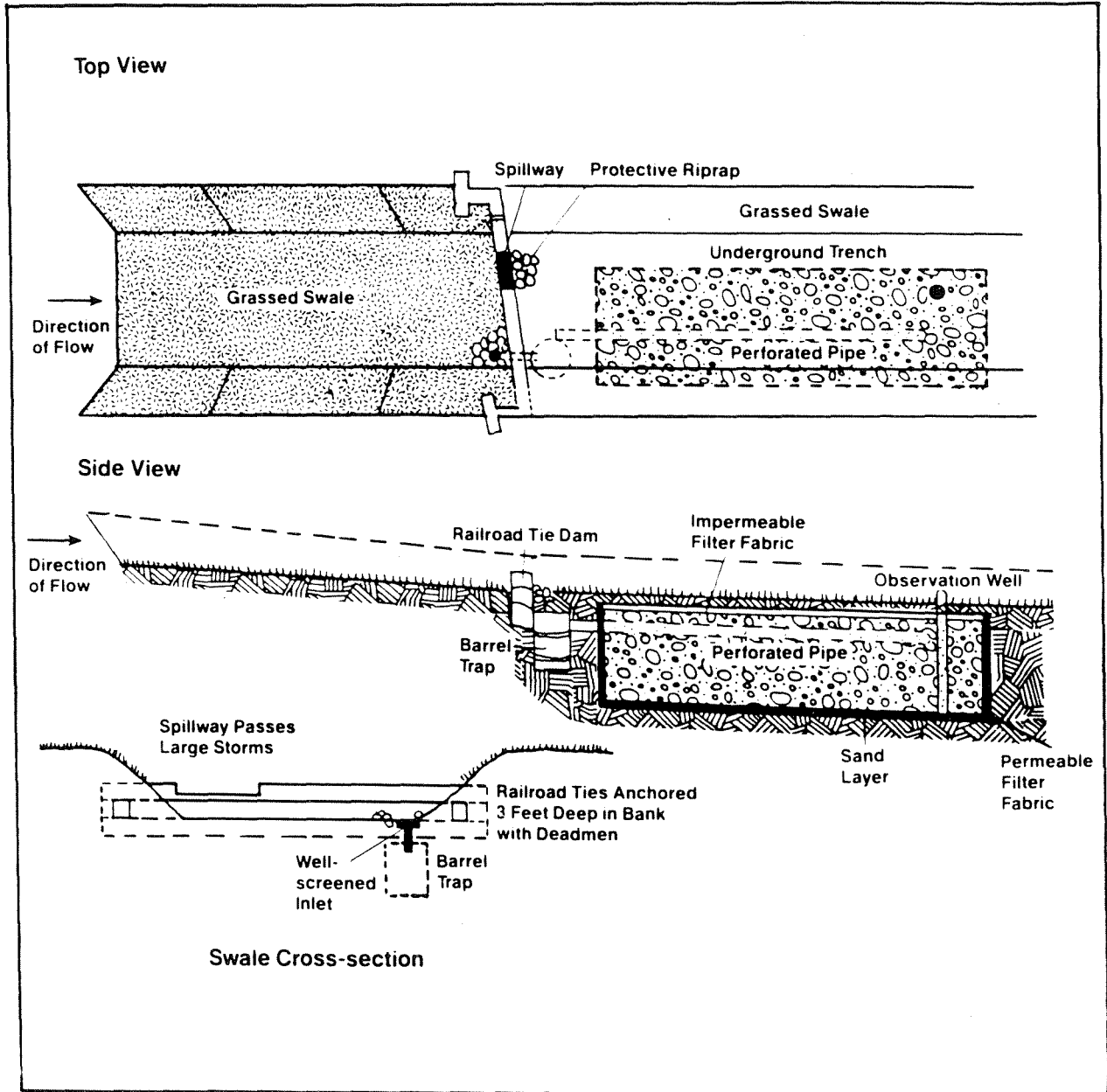




Figure III-3.15 Underground Trench with Oil/Grit Chamber  
(Reproduced with permission from Schueler (16))

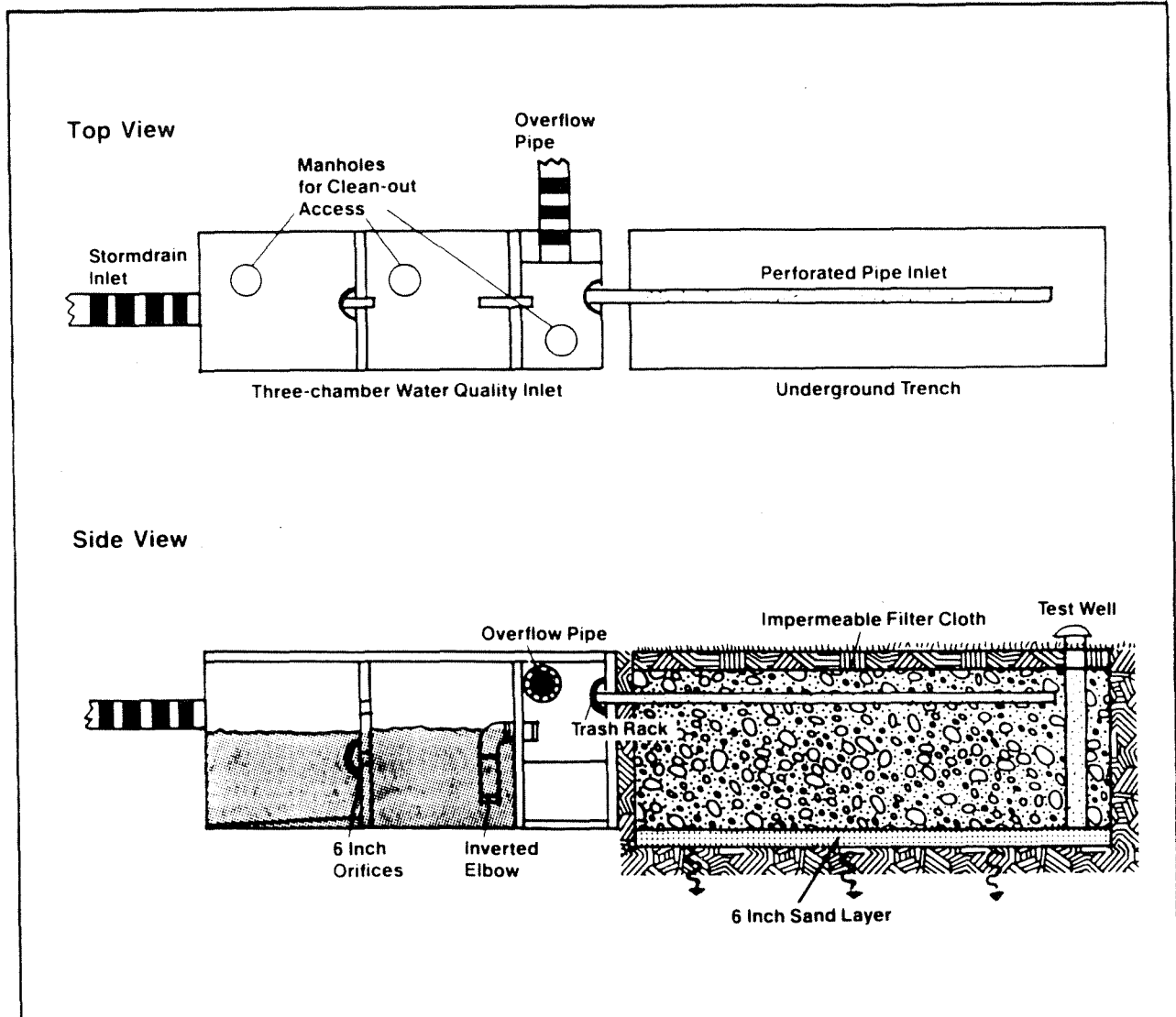
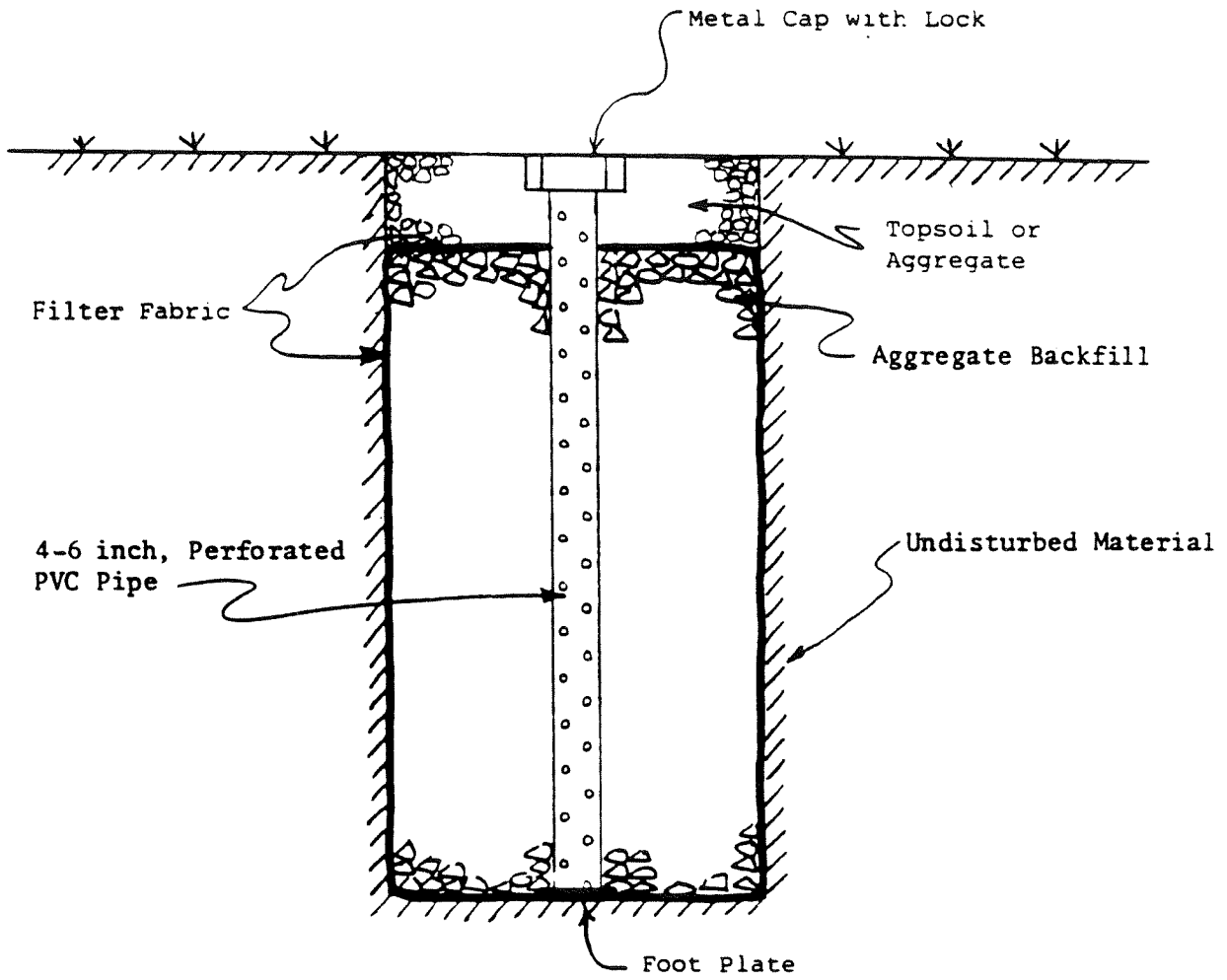


Figure III-3.16  
Observation Well Details



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### III-3.6.5 BMP RI.11 Streambank Erosion Control (SBEC) Infiltration Trench

#### Purpose and Definition

This BMP is a shallow excavated trench designed to provide streambank erosion control but not runoff treatment. The soils underlying this BMP will be too coarse for pollution removal and stormwater must be treated prior to discharge to this BMP. While physically resembling the Water Quality Infiltration Trench (BMP RI.10) the design criteria for this BMP more closely resembles that used for the Streambank Erosion Control Infiltration Basin (BMP RI.06).

Figures III-3.9 through III-3.15 illustrate infiltration trench designs.

#### Planning Considerations

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of this BMP. See Section III-3.3 for a description of General Limitations.*

*This BMP will typically be located on-line with the primary conveyance/detention system. The 6-month, 24-hour design storm must be completely treated prior to runoff being discharged to this BMP.*

*An infiltration trench will generally be used on relatively small drainage areas. This practice can be used in residential lots, commercial areas, parking lots and open space areas. Trenches are one of the few BMPs that are relatively easy to fit into the margin, perimeter, and other less-utilized areas of developed sites, making them particularly suitable for retrofitting. A trench may also be installed under a swale to increase the storage of the infiltration system.*

*Drainage areas are generally limited to less than 15 acres.*

*One advantage of trenches is that they have less tendency to become clogged with sediment than other infiltration BMPs.*

#### Design Criteria

The procedure described in Section III-3.4 should be used to design an infiltration trench. Trenches are assumed to have rectangular cross-sections, thus the infiltration surface area (sides and bottom) can be readily calculated from the trench geometry. The storage volume of the trench must take into account the volume of backfill material placed in the trench (i.e., void ratio).

#### General Criteria

- Soils Investigation - A minimum of one soils log shall be required for every 50 feet of trench length, and in no case less than two soils logs for each proposed trench location. Each soils log should extend a minimum of 3 feet below the bottom of the trench, describe the SCS series of the soil, the textural class of the soil horizon(s) through the depth of the log, and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.
- The design infiltration rate,  $f_d$ , will be equal to one-half the infiltration rate found from the soil textural analysis.
- Runoff Treatment - Runoff from the 6-month, 24-hour design storm is to be completely treated prior to discharge to this BMP.

- Drawdown Time - Streambank Erosion Control Infiltration Trenches shall be designed to completely drain stored runoff within one day following the occurrence of the 10-year, 24-hour design storm and within two days of the 100-year, 24-hour design storm (with appropriate correction factors as discussed in Chapter III-1). Thus, a maximum allowable drawdown time of 48 hours is permissible.
- Surface Area - The infiltration surface area ( $A_s$ ) used for sizing the trench shall be computed by measuring the surface area (plan view area) below the maximum design water surface.
- Slopes - Trenches should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the potential impact of the trench infiltration upon the steep slope.
- Backfill Material - The aggregate material for the infiltration trench shall consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. The aggregate should be graded such that there will be few aggregates smaller than the selected size. Void space for these aggregates is assumed to be in the range of 30 percent to 40 percent.
- Filter Fabric - The aggregate fill material shall be completely surrounded as shown in Figure III-3.9 with an engineering filter fabric. In the case of an aggregate surfaced trench, filter fabric should surround all of the aggregate fill material except for the top one foot, which is placed over the filter fabric. See Figure III-3.9 for details.
- Overflow route - An overflow route must be identified in the event that the trench capacity is exceeded. This overflow route should be designed to meet Minimum Requirement #2 (Preservation of Natural Drainage Systems).
- Spillways - The bottom elevation of the low-stage orifice should be designed to coincide with the one-day infiltration capacity of the trench. All other aspects of the principal spillway design and the emergency spillway shall follow the details provided for detention basins in Chapter III-4.
- Seepage Analysis and Control - An analysis shall be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. The use of infiltration trenches on fill sites is not permitted.
- Buildings - Infiltration trenches shall be located 20 feet downslope and 100 feet upslope from building foundations.
- Observation Well - An observation well shall be installed for every 50 feet of infiltration trench length. The observation well will serve two primary functions: it will indicate how quickly the trench dewateres following a storm and it will provide a method of observing how quickly the trench fills up with sediments. Figure III-3.16 illustrates observation well details.

The observation well should consist of perforated PVC pipe, 4 to 6 inches in diameter. It should be located in the center of the structure and be constructed flush with the ground elevation of the trench as shown in Figure III-3.9. The top of the well should be capped to discourage vandalism and tampering.

## Construction and Maintenance Criteria

### Construction Timing

An infiltration trench shall not be constructed or placed into service until all of the contributing drainage area has been stabilized and approved by the responsible inspector.

### Trench Preparation

Excavate the trench to the design dimensions. Excavated materials shall be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic if it is to be left in place for more than 30 days (see BMP E1.20 in Volume II).

### Fabric Laydown

The filter fabric roll must be cut to the proper width prior to installation. The cut width must include sufficient material to conform to the trench perimeter irregularities and for a 12 inch minimum top overlap.

Place the fabric roll over the trench and unroll a sufficient length to allow placement of the fabric down into the trench. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the lined trench open during windy periods. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect. The overlap insures fabric continuity and allows the fabric to conform to the excavated surface during aggregate placement and compaction.

### Stone Aggregate Placement and Compaction

The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing potential soil piping, fabric clogging, and settlement problems.

### Overlapping and Covering

Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. The desired fill soil or stone aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

### Potential Contamination

Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

### Voids Behind Fabric

Voids may be created between the fabric and excavation sides and shall be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides. Soil piping, fabric clogging, and possible surface subsidence will be avoided by this remedial process.

### Unstable Excavation Sites

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. These conditions require laying back of the side slopes to maintain stability; trapezoidal rather than rectangular cross-sections may result. This is acceptable, but any change in the size or the shape of the stone reservoir needs to be taken into consideration in size calculations.

### Traffic Control

Heavy equipment and traffic shall be restricted from travelling over the infiltration areas to minimize compaction of the soil. The trench should be flagged or marked to prevent drive-on.

### Observation Well

An observation well, as described in the previous section on design criteria and shown in Figure III-3.16 shall be provided. The depth of the well at the time of installation will be clearly marked on the well cap.

### Maintenance

#### Inspection Schedule

- The observation well should be monitored periodically. For the first year after completion of construction, the well should be monitored on a quarterly basis and after every large storm. During the period October 1 through March 31 inspections shall be conducted monthly. A log book shall be maintained by the responsible person designated by the local government indicating the rate at which the facility dewateres after large storms and the depth of the well for each observation. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis unless the performance data indicate that a more frequent schedule is required.

#### Sediment Removal

- Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate shall be required when the trench has a stone surface. Sediment deposits shall not be allowed to build up to the point where it will reduce the rate of infiltration into the trench.

### III-3.6.6 BMP RI.15 Roof Downspout System

#### Purpose and Definition

A roof downspout system is an infiltration trench system intended only for use in infiltrating runoff from roof downspout drains. This BMP is not designed to directly infiltrate any surface water that could transport sediment or pollutants such as from paved areas. Because runoff from rooftops is relatively clean, no treatment is required prior to its discharge to the soil. Figure III-3.17 illustrates a typical roof downspout system.

*Planning Considerations - none.*

#### Conditions Where Practice Applies

Roof downspout systems may be used in any situation where it is acceptable to dispose of this runoff by avoiding or replacing the use of direct connections to storm or sanitary sewers, or where such facilities do not exist. Because of their small size, they are well suited for a retrofit in areas where additional runoff control becomes necessary.

#### Advantages

- In areas where such practices can be used, they may cause a significant reduction in the need for installation of storm sewers and other stormwater runoff control facilities.
- Roof downspout systems are small and relatively simple to install and can be retrofit into subdivisions as necessary.

#### Disadvantages/Problems

- As with all underground infiltration systems, these systems are difficult to monitor, and may be difficult to replace if they are installed under paved areas.
- If used on single family residences, provisions should be made for maintenance responsibility, perhaps through the homeowner's association.

#### Specific Limitations

- Roof downspout systems are meant only to be used in areas where there is no significant depositional air pollution. Advice on this should be sought from Ecology or local agencies responsible for managing air quality if the residence is near major sources of air pollution.

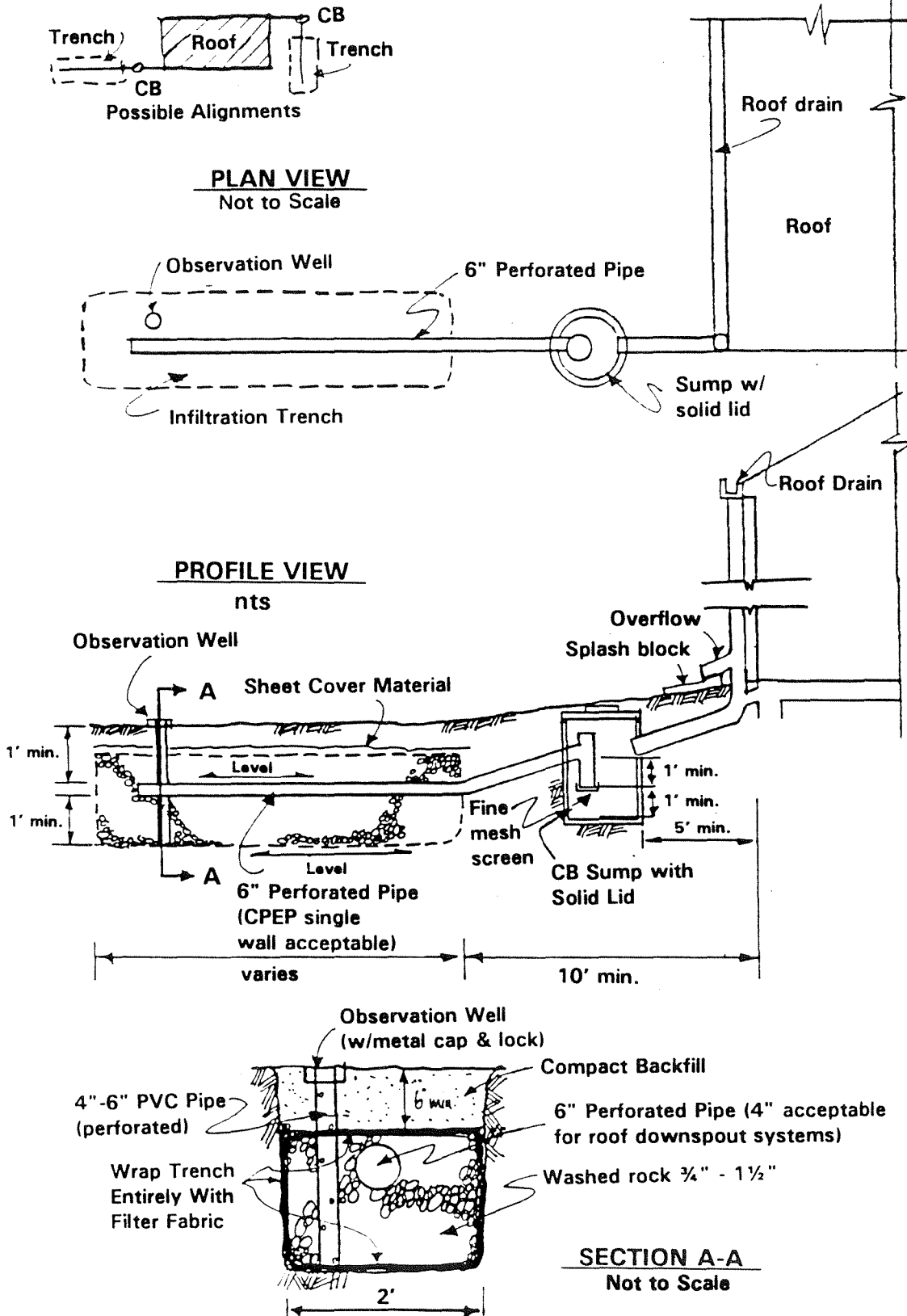
#### Design Criteria

The design criteria for infiltration trenches also applies to roof downspout systems with the following exceptions and/or additions:

#### Trenches Installed Under Pavement

- Trenches may be located under pavement provided that a small yard drain\ catchbasin with a grate cover is placed at the end of the trench pipe such that if the trench infiltration capacity is exceeded, the overflow would occur out of the catchbasin at an elevation at least 1 foot below that of any overlying pavement, and in a location which can accommodate the overflow and meet the requirements of Minimum Requirement #2 (Preservation of Natural Drainage Systems).

Figure III-3.17 Roof Downspout System





#### Other Requirements

- Roof downspout systems shall be a minimum of 10 feet from any structure, property line, or NGPE, and 30 feet from any septic tank or drainfield.
- Roof downspout systems shall be a minimum of 50 feet from any steep slope.
- The length of a roof downspout system should not exceed 100 feet from the inlet sump.
- Each roof downspout system shall have an observation well similar to that described for an infiltration trench. It should extend to the bottom of the trench and be located at a point approximately halfway in length.
- Filter fabric shall be wrapped entirely around the aggregate rock prior to backfilling.

#### Construction and Maintenance Criteria

##### Construction Specifications

Construction specifications are identical to those for infiltration trenches.

##### Maintenance

Maintenance procedures are identical for those of an infiltration trench. It is important to consider the fact that since these facilities are installed on individual structures, provision needs to be made for the maintenance of these structures, especially when the systems are installed on single family dwellings.

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### III-3.6.7 BMP RI.20 Water Quality (WQ) Porous Pavement

#### Purpose and Definition

This BMP is an open-graded asphaltic aggregate designed to primarily provide runoff treatment and not streambank erosion control and serves the same function as a Water Quality Infiltration Basin (BMP RI.05). The pavement is underlain by permeable soils capable of removing pollutants but which is unlikely to have sufficient permeability for streambank erosion control purposes. A typical porous asphalt paving cross section is presented in Figure III-3.18.

There are two types of porous pavement - porous asphalt pavement, and pervious concrete pavement.

Porous asphaltic paving material consists of an open graded coarse aggregate cemented together by asphalt cement into a coherent mass, with sufficient interconnected voids to provide a high rate of permeability to water. A typical porous asphalt paving cross section is presented in Figure III-3.18.

Pervious concrete consists of specially formulated mixtures of Portland Cement, uniform open graded coarse aggregate (WSDOT #8 or #89, 3/4 inch to no. 16 or no. 50 recommended), and potable water. This material may be combined with certain water reducing and retarding or accelerating admixtures along with air entraining agents. When properly handled and installed pervious concrete has a high percentage of void space which allows rapid percolation of liquids through the pavement. Figure III-3.20 illustrates a pervious concrete section.

#### Planning Considerations

*This BMP serves a similar function as a Water Quality Infiltration Basin (BMP RI.05) and has similar planning considerations.*

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of the BMP. See Section III-3.3 for a description of General Limitations.*

*This BMP will typically be located off-line from the primary conveyance/detention system because streambank erosion control is generally not provided. Water Quality Infiltration BMPs must always be preceded by a pretreatment BMP to remove suspended solids that could clog the infiltration soils. Drainage areas can be up to 15 acres for porous pavement. Additional information specific to porous pavement is provided below.*

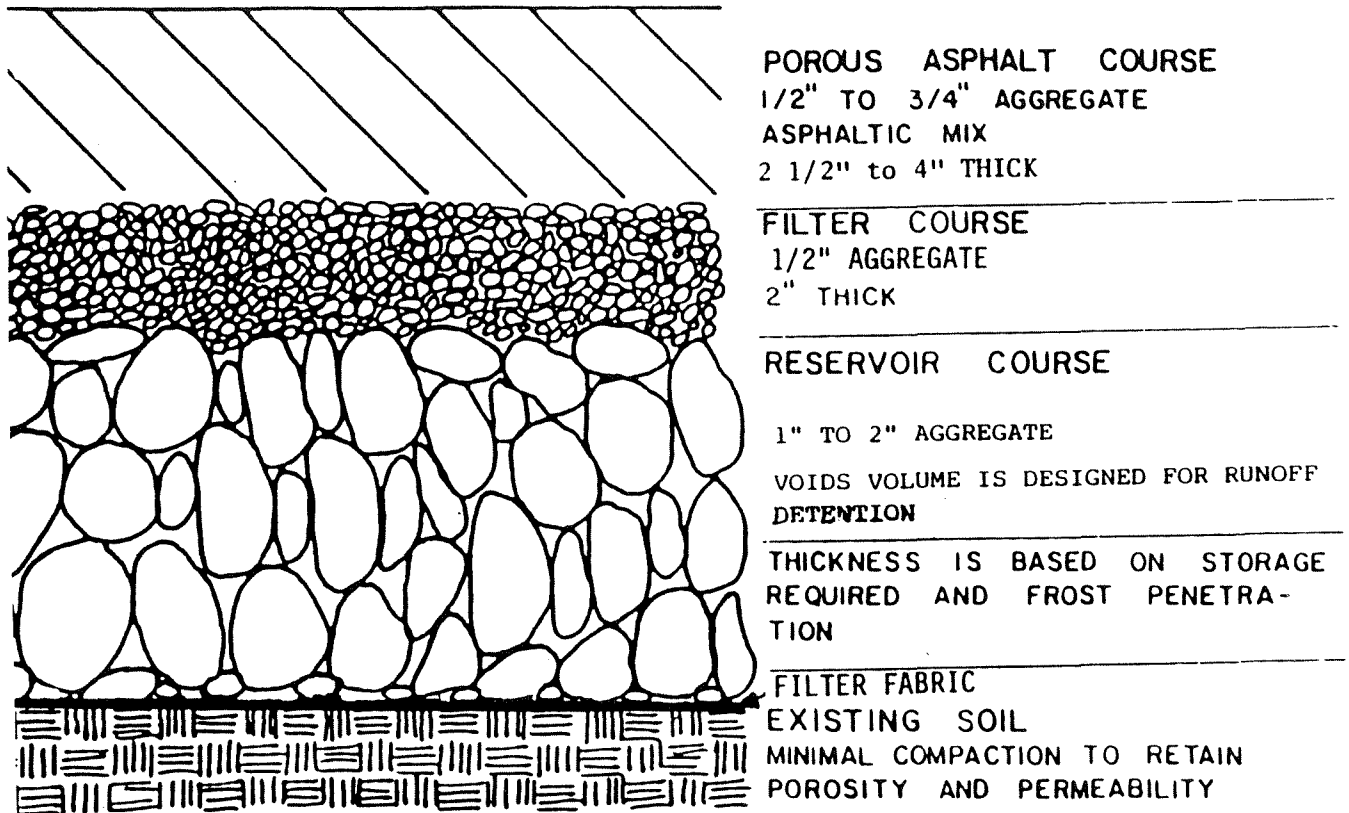
#### Conditions Where Practice Applies

This practice is applicable as a substitute for conventional asphalt pavement on parking areas and low-traffic volume roads provided that the grades, subsoil drainage characteristics and ground water table conditions are suitable for such use. In general the grades should be very gentle to flat, subsoil shall have moderately rapid permeability ( $f > 0.50$  in/hr) and the depth to the water table or bedrock shall be at least 3 feet.

Possible areas for use of this paving material include:

- (1) Parking lots, especially fringe or overflow parking areas;
- (2) Parking aprons, taxiways, and runway shoulders at airports;
- (3) Emergency stopping and parking lanes and vehicle cross-overs on divided highways; and
- (4) Low-traffic volume roads.

Figure III-3.18  
Typical Section of Porous Asphalt Paving  
(Modified after Diniz, 1980 and City of Rockville, Maryland, 1982)



#### Advantages

- Generally, ground water recharge rates are slightly higher under porous pavement than under natural conditions, as vegetation is absent and soil water is not transpired during the summer months. Up to 60-90 percent of the annual rainfall volume deposited on porous pavement sites is diverted to ground water.
- Tests have shown that there is up to 15% less hydroplaning and skidding on porous pavement surfaces. This decrease in hydroplaning is particularly important on airport runways. One test showed that the friction coefficient on porous pavement increased under wet conditions.
- Because water is rapidly transferred from the surface of the pavement, there is less puddling, which is an advantage to motorists in parking lots. Also because of the reduced puddling, there is less headlight reflectivity off the surface and pavement markings are more visible.
- Tire noise is less on porous pavement.
- Construction costs may be reduced because of the partial or complete elimination of curbs, drains and storm sewers.
- Porous pavement helps to maintain natural drainage boundaries and patterns, and roadside vegetation because of increased soil moisture.

#### Disadvantages

- A drawback of porous pavement is its tendency to clog if improperly maintained. Once it is clogged, it is difficult and costly to rehabilitate, and often must be completely replaced. Clogging can be prevented most easily by not installing it in areas where erosion is a concern, and by waiting until all other phases of construction are complete and vegetation is stabilized to install the pavement.
- Another concern is the lack of expertise of most pavement engineers and pavement contractors. A very high level of workmanship is required throughout the construction process, as porous asphalt needs to be handled with great care in order for it to retain its porous qualities.
- Some building codes may not allow for the installation of porous pavement, if for example, curbs and gutters are arbitrarily required.
- If spills occur, they must be immediately vacuumed up followed by a jet wash. This treatment will restore permeability to almost prespill levels (95%). Gasoline spillages will break down the asphalt binder to greater depths than in conventional pavements. Tar binders may work better than an asphalt binder to help prevent breaking down.
- Tests in Arizona showed that there was a slightly higher amount of wheel rut deformation in porous pavement than in conventional pavement, but this stabilized after the first few months. There is also the potential for areas of collapsed pores due to constant vehicle braking in one spot, for example at the beginning of curves or in the entry way of a parking lot.
- Narrow porous strips should not be placed between areas of impervious pavement. Often the edges become very clogged, and there is distress to the impervious pavement due to differential support caused by the additional moisture content of the pervious subgrade.
- A potential problem, especially in the Pacific Northwest, is the possibility of development of anaerobic conditions in the underlying soils as soils are unable

to dry out between storms. When this occurs, aerobic bacteria cannot reduce organic pollutants. Also in a wet subgrade, the soil may not support the design load. These problems can be solved by designing this BMP to drain the 6-month, 24-hour design storm within 24 hours and, if necessary, installing an underdrain system.

#### Design Criteria - General

As this BMP serves a similar function as the Water Quality Infiltration Basin (BMP RI.05) that BMP should be referenced for criteria. Basic design criteria is given in the following sections of this manual:

#### Hydrologic Analysis - Chapter III-1

#### General Infiltration Design Criteria - Section III-3.4

The following design criteria applies to all water quality infiltration BMPs:

- General - The construction of structures, materials allowed, accessibility for maintenance, safety measures, easements, and hydraulic design methods shall be the same as those required for detention basins in Chapter III-4.
- Soils Investigation - A minimum of one soils log shall be required for each 5,000 square feet of infiltration surface area (plan view area) and in no case less than three soils logs per basin. Each soils log shall extend a minimum of 3 feet in depth below the bottom of the proposed BMP, describe the SCS series of the soil, the textural class of the soil horizon(s) through the depth of the log, and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.
- The design infiltration rate,  $f_d$ , will be equal to one-half the infiltration rate found from the soil textural analysis.
- Pretreatment - Water Quality Infiltration BMPs must be preceded by a pretreatment BMP. See Chapter I-4 to select appropriate pretreatment BMPs.
- Slopes - This BMP should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the potential impact of the BMP infiltration upon the steep slope.
- Buildings - This BMP should be a minimum of 100 feet upslope and 20 feet downslope from any building.
- Surface Area - The infiltration surface area ( $A_s$ ) used for sizing the BMP shall be computed by measuring the surface area (plan view area) below the maximum design water surface.
- Drawdown Time - Water Quality Infiltration BMPs shall be designed to completely drain stored runoff within one day following the occurrence of the 6-month, 24-hour design storm. Thus, a maximum allowable drawdown time of 24 hours shall be used. This will ensure that the necessary aerobic conditions exists in order to provide effective treatment of pollutants. If a Presettling Basin (BMP RD.10) precedes the porous pavement, the combined drawdown time for both BMPs should be 24 hours.

The design procedures described in Sections III-3.4 and III-3.6.2 (Water Quality Infiltration Basin, BMP RI.05) should be used to design a Water Quality Porous Pavement system. A summary of several of the criteria is as follows:

- Soils investigation must be conducted.
- Design infiltration rate should be  $\frac{1}{2}$  of that found by the soils investigation
- Pretreatment of the 6-month, 24-hour storm is necessary to control siltation
- Drawdown time should be a maximum of 24 hours for the 6-month, 24-hour design storm.

The six General Limitations must be satisfactorily met before porous pavement can be utilized (Section III-3.3).

Additional criteria specific to porous asphalt paving and pervious concrete pavement is given below in separate sections.

#### Construction and Maintenance - General

##### Construction

See separate sections below for porous asphalt pavement and pervious concrete pavement.

##### Maintenance (for both types of porous pavement)

Routine maintenance involves removal of debris that is too coarse to be washed through the pavement system. Vacuuming pavement is required to remove particulates that are fine enough to be carried into the pavement but too large to pass through, thus clogging the void space. Porous pavements require no more repair maintenance than conventional pavements, so maintenance problems can generally be reduced to better "housekeeping" practices on the part of area residents and more efficient street cleaning procedure in municipalities.

To preserve the high filtration rate of pervious paving, routine inspection and maintenance is required. The surface should be routinely visually checked (preferably after a prolonged storm event) for evidence of debris, ponding of water, clogging of pores and other damage. Any debris should be immediately removed. An annual cleaning program should be instituted that requires a street sweeper with a vacuum to thoroughly cleanse the surface.

##### Cleaning

It has long been recognized that maintenance and cleaning of porous pavements to prevent or alleviate clogging would be a factor in the application of such pavements. Sections of porous pavement which have been clogged have been cleaned by various methods. No method has been found satisfactory on fully clogged pavements, however, and, only a superficially clogged section showing a water penetration rate of 0.1 inches per second compared to a normal water penetration of 0.38 inches per second can be restored to normal operation. The best method for cleaning is brush and vacuum sweeping followed by high pressure water washing of the pavement. In Maryland, it has been determined that vacuum cleaning alone, once the pavement is clogged, will be largely ineffective. The oils, especially in porous asphalt, bind dirt and only an abrading and washing technique can be effective in its removal. Clogging to a depth of 0.5 inch is sufficient to prevent water penetration.

If, during visual inspection, any ponding or clogging is noticed, the following program should be carried out to correct the problem. First, a street sweeper with a vacuum should be used. If ponding persists, steam cleaning with a biodegradable substance can be applied, then vacuuming done. If the clogging is at a depth greater than  $\frac{1}{2}$  inch,  $\frac{1}{4}$  inch diameter and one (1) foot on-center holes can be drilled through concrete pavement. Hand drilling or tandem drill rigs may be used. All drilling debris should be vacuumed from the pavement.

### Replacing Clogged Pavement

Once a large area of porous pavement is fully clogged and it cannot be adequately cleaned, the paving must be removed to a depth where the clogging is not evident and new porous paving filled in. In extreme cases, the affected area must be removed and new topping put down. Since these materials are relatively new, obtaining a patching mix suitable to match the installed pavement may be difficult. Available patching material is usually dense graded at present. If the subbase becomes clogged, the pavement must also be saw cut and removed. Six to twelve inches of the subbase will usually need to be replaced with clean sand, then proof rolled. Pervious paving will then need to be filled in.

### Porous Asphalt Paving - Additional Planning, Design, and Construction Criteria

The nature of each individual site will determine the design of the porous paving to be placed on it. A thorough prior examination of the site is of primary importance to the proper functioning of the porous pavement. Each case is different depending upon the site and particularly: soil and climate conditions; the wear expected on the surface itself; and the objectives of the particular use of the porous surface. An overview of the steps to be taken is provided below:

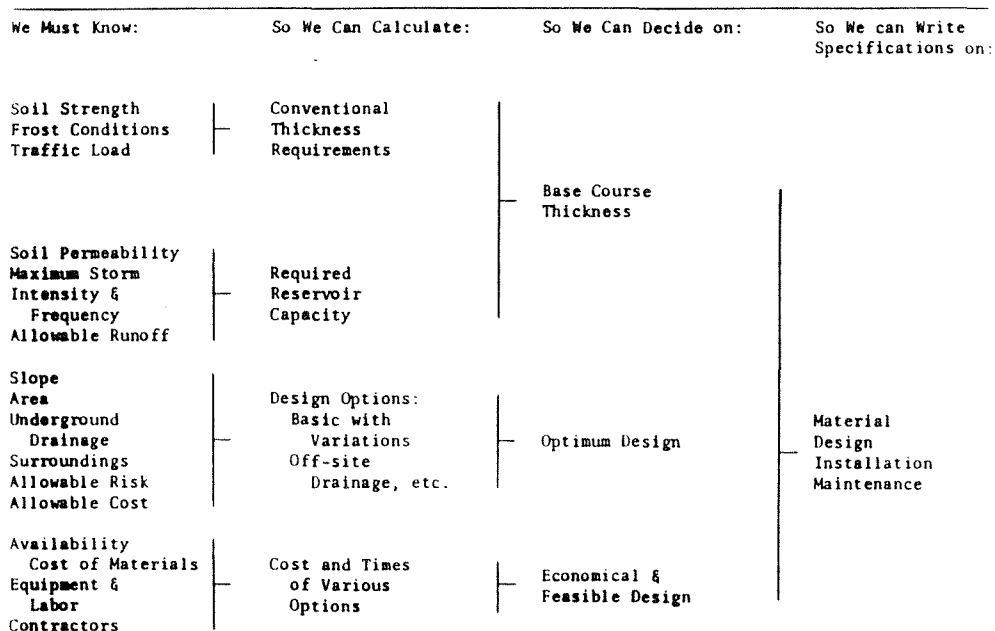
- Examine the site to determine its drainage. Walk over it and the surrounding area; examine the topographic and soil maps and take soil cores and examine the horizons.
- Examine the various soils to determine their permeability. Run gradation tests of the soil cores to determine textural classification and use values in Table III-3.1 to obtain infiltration rates.
- Determine the load bearing capability of the soil by lab test or categorically from soil maps. Design a pavement to carry the load and meet frost conditions. For each possible design, calculate the required base course thickness, considering grades.
- Determine the design storm volume.
- Evaluate the level of control provided by the porous asphalt paving.
- Consider ways to augment percolation or flow of water from the base course, if soil percolation is slow.
- Compare the most attractive options for probable cost, and complete the design using the most favorable one.
- Prepare specifications for materials, product installation, and maintenance and test.

The logic of the design steps listed above is shown in Table III-3.3.

### Soil Borings

Test soil borings should be taken to determine the character and permeability of the soil. The ability of the soil to percolate the water passing through the pavement will determine the thickness of the base reservoir required. In some cases where the infiltration rate is moderate, an alternate approach may be applicable for the removal of water from the base reservoir to the water table, such auxiliary drainage as described below under "Other Applications of Porous Asphalt Paving."

Table III-3.3  
Design Scheme for Porous Paving



Source: Thelen and Howe, 1978 (2)

Storage Time (Drawdown Time)

All porous paving installations shall be designed to drain the runoff from the 6-month, 24-hour storm within 24 hours.

Frost Heave

Soils capable of resisting frost heaving have been defined by a triangular chart, Asphalt Institute Publication MS-15 (1966); essentially the total clay and silt content of the subgrade soil must be less than 40 percent by weight. If a soil with a high susceptibility to frost heaving is being considered, for example a silt loam, the reservoir base course must extend below the frost line to allow for adequate drainage. This depth below the frost line may actually exceed the depth of storage required to control the runoff volume from the site.

Pavement Design

The design of porous asphalt pavements equivalent to conventionally constructed pavements will depend primarily on the load-bearing capacity of the subgrade, the expected traffic volume, and the storage capacity of reservoir and base. Specifications of the Franklin Institute Research Laboratories have been used to design the porous asphalt pavement roadways illustrated in Table III-3.4.

The traffic intensity will be a factor in the design depth requirement of the porous pavement. The traffic intensity is defined by the average daily Equivalent Axle Load (EAL), based on the equivalent of 18,000 pounds (18 Kips) axle load in the design lane. In most cases, the application of porous asphaltic pavement will be restricted to light traffic and parking lots. Thus, a minimum pavement thickness, from the top of the pavement to the subgrade soil, will generally be 9 inches to handle traffic intensity.



Table III-3.4 Minimum Thickness of Porous Paving for Various Loading Conditions

Traffic Group	General Character	15 +	10 - 14	6 - 9	<5*	EAL
1	Light Traffic	5"	7"	9"		5 - less
2	Medium Traffic (max 1000 VPD)	6"	8"	11"		6 - 20
3	Medium Traffic (max. 3000 VPD)	7"	9"	12"		21 - 75

\* Studies indicated that for all traffic areas (1,2,3) with a CBR of 5 or less, the subgrade was improved to CBR 6 with crushed stone 2" size  
 VPD = vehicles per day  
 EAL = equivalent axle load (18 kips) average daily

Source: Thelen and Howe, 1978 (2)

#### Factor of Safety in Design

Some pavement designers have suggested that because open graded mixes are not as strong as dense graded mixes, the pavement thicknesses suggested in Table III-3.4 might be insufficient and need to be increased. However, with normal and proper construction practices, sufficient subgrade compaction should be achieved so that with a well-drained subgrade, a minimum CBR of 6 or 7 could be used quite safely. These higher CBR values permit pavements to be considerably thinner, so it is assumed that there is an adequate safety factor built into the specifications given in Table III-3.4. Further refinement of these designs is anticipated as a result of increased use of these materials.

#### Calculation of Void Space

Void space should be calculated according to the testing procedure recommended in Federal Highway Administration Report No. FHWA-RD-74-2, Design of Open-Graded Asphalt Friction Courses (4). The volume of the sample should be measured mechanically rather than calculated from a water displacement method because a great deal of water is absorbed.

#### Aggregate Gradation

Porous asphaltic concrete pavement requires gradation of the "open" graded type as contrasted to the "dense" graded type which is capable of close packing. Aggregate specifications are given in Table III-3.5. Open graded mixes, due to their relatively high permeability to air and water, provided good resistance and durability to freeze/thaw conditions and to asphalt film oxidation.

#### Type and Quality of Aggregate

The aggregates selected for porous pavement construction should meet requirements of the standard specification for "Crushed Stone, Crushed Slag, Pavements," ASTM D 693-77, with two exceptions. First, the gradation test must be of the open graded type described here. Second, a soundness test is required, as specified in ASTM D 692-79, Coarse Aggregate for Bituminous Paving Mixtures," to determine if the aggregate is susceptible to disintegration by water.

Table III-3.5  
Aggregate Specifications for Porous Asphalt Paving

U.S. Sieve Series Size	Opening (mm)	Specification: Percent Passing by Weight
½ inch	12.70	100
¾ inch	9.51	95-100
#4	4.76	30-50
#8	2.38	5-15
#200*	0.074	2-5

\* Aggregate should be uniformly graded between the #8 and #200 sieves.

Asphalt Cement Grade in Mix

The suggested viscosity grade of asphalt cement to be used is AC-20 of AASHTO M-226-73 I. This grade is to be considered a tentative starting point because test results obtained from the design process may produce either an advantage or a necessity to alter the asphalt grade.

Mixing Temperature

To ensure that the individual aggregate particles are completely surrounded by asphalt, and that the asphalt is tightly bound to each particle, temperature of mixing at the hot mix plant shall be rigidly controlled. Too low a mixing temperature will result in inadequate asphalt binding and coverage of the aggregate, while too high a mixing temperature will allow asphalt to drain from the mix, resulting in a lower asphalt content and decreased strength. Suitable mixing temperatures range from 230 to 260 degrees Fahrenheit, but the lower end of that range (230° to 240° F) is recommended.

Asphalt Content in Mix

For road paving durability and to prevent too rapid hardening of the asphalt, it is desirable to have the highest asphalt content possible in the mix. Too much asphalt would separate out under traffic, so the maximum asphalt content is generally limited by that factor. Experience has shown that 5.5 percent by weight is the minimum recommended asphalt content. Asphalt content should be determined according to the testing procedure recommended in Federal Highway Administration Report No. FHWA-RD-74-2, already cited. The Marshall Design method for determining mix content is not recommended. Using a 5.5 percent asphalt content and the Asphalt Institute's recommended 4-inch minimum surface course, a 0.6-inch rainfall reservoir capacity is obtained with an infiltration rate of 176 inches per hour.

Hydrologic Note

It should be noted that when porous asphalt paving is designed without a positive drain, the design situation is analogous to an infiltration trench. The porous paving may be designed as a subsurface detention system with hydrologic soil groups that have a slow infiltration rate.

## Other Applications of Porous Asphalt Paving

On sites where the subgrade soil infiltration rate is slow, porous asphalt paving has been used to provide subsurface detention of stormwater runoff. There are a number of available drainage designs capable of adequately removing the water remaining in the reservoir base course. Several of these are illustrated in Figure III-3.19 and described below:

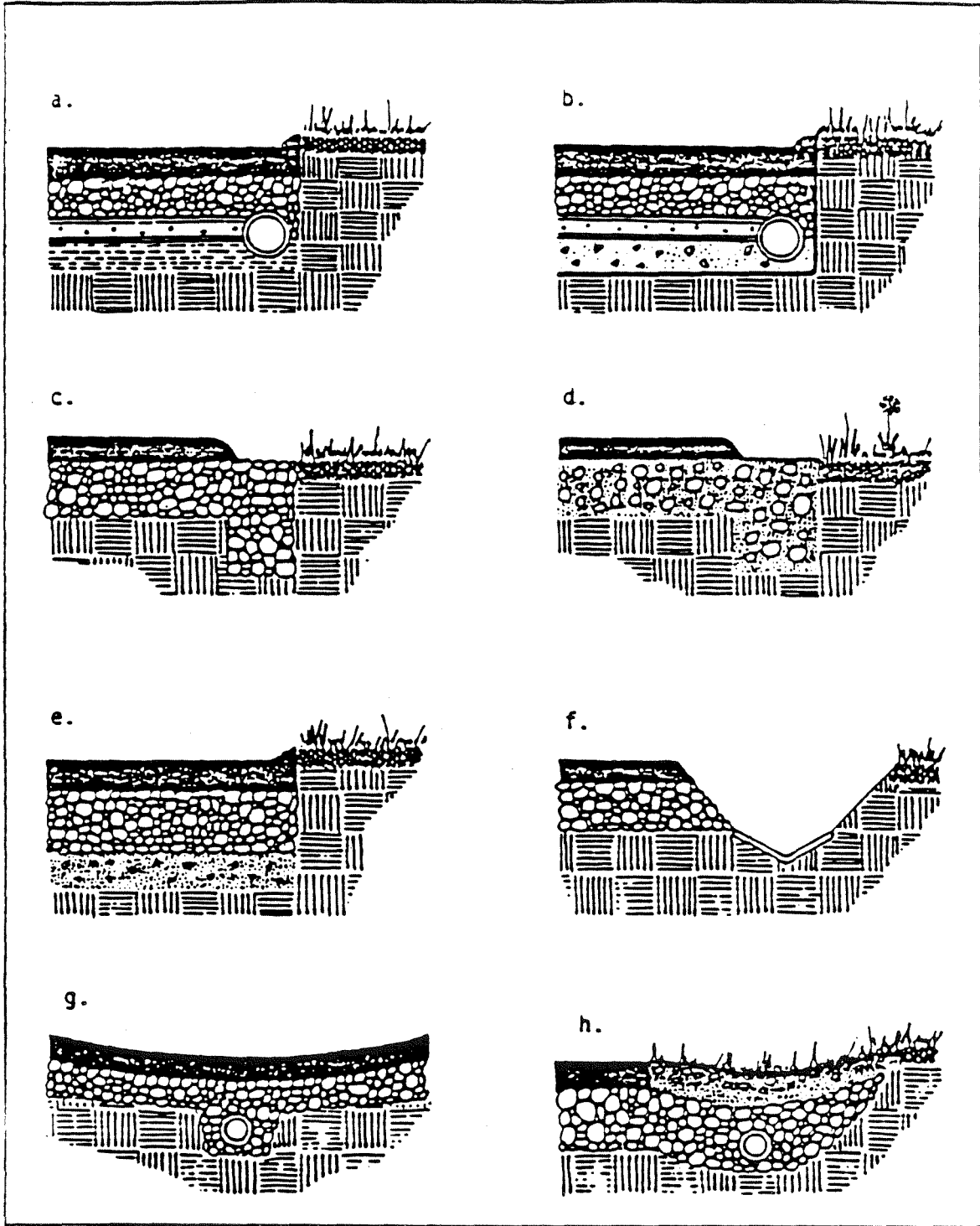
(a) French Drain. This system utilizes coarse open-graded rock in relatively deep pits or trenches. This type of drain can be expanded out at the lateral edges of a roadway to provide a deeper system with more water holding capacity, so that the water has more time to percolate through a less permeable subgrade. Such a system is shown in Figure III-3.19(c).

(b) Sand Drain. This system is similar to the French Drain, but the coarse open-graded rock also contains enough fines to prevent intrusion of adjacent soil which may tend to clog the drain. This clogging is dependent upon the nature of the subgrade soil. Again this system could be expanded to provide more water holding capacity (see Figure III-3.19(d)).

(c) Two-Layer Systems. With this type of system a subbase is provided as a filter medium. The coarse open rock drain layer (base) is protected by a suitable filter layer (subbase) such as clean concrete sand. This system should provide excellent resistance to clogging and excellent drainage capacity even after numerous years of service. This system is shown in Figure III-3.19(e).

(d) V-Trench Water Removal to Pond. A positive method of removal of water contained in a French Drain type system is to use the base material as a drain for transport to a relatively shallow V-trench at a low point in the cross section of the roadway. If a heavy volume of water is expected, it may be advisable to obtain greater drain capacity by construction of a 2-layer system. If an appreciable gradient is involved, a cross drain should be placed at the downhill end of the cut. This will intercept any water flowing longitudinally which if not drained could saturate the fills and cause slumping of the fill slopes. The V-trench shown in Figure III-3.19(f) could be emptied into a storage pond or other suitable drainage system. The profile of a road showing cross drains that empty into the V-trench is shown in Figure III-3.19(g).

Figure III-3.19 Porous Asphalt Paving Drainage Systems



Source: Thelen, et al. (3)

(e) Pipe Drains. Subgrade soils which are for all practical purposes impervious to water would necessitate the use of pipe drains. The pipe is generally perforated with  $\frac{1}{4}$  to  $\frac{3}{8}$ -inch diameter holes, placed in two or more double rows 90° to 120° apart running lengthwise on the bottom half of the pipe. Materials of construction include aluminum alloys, cast iron, clay, concrete and plastic. They are available in sizes ranging from 4 inches to 120 inches and larger in diameter. The sizes and type pipe to be used would be determined by the conditions set for drainage. Such a system is shown in Figures III-3.19(a), (b), and (h).

Alternative Construction Methods and Specifications Adapted from the Construction Specifications of the City of Rockville, Maryland

#### Stabilization

To preclude premature clogging and/or failure of this practice, porous asphalt paving structures shall not be placed into service until all of the surface drainage areas contributing to the pavement have been effectively stabilized in accordance with Erosion and Sediment Control Requirement (Minimum Requirement #1). See Chapter I-2.

#### Subgrade Preparation

Alter and refine the grades as necessary to bring subgrade to required grades and sections as shown in the drawings.

The type of equipment used in subgrade preparation construction shall not cause undue subgrade compaction. (Use tracked equipment or oversized rubber tire equipment; DO NOT use standard rubber tired equipment.) Traffic over subgrade shall be kept at a minimum. Where fill is required, it shall be compacted to a density equal to the undisturbed subgrade, and inherent soft spots corrected.

#### Aggregate Base Course

All stone used shall be clean, washed, crushed stone, meeting local highway department specifications.

Aggregate shall be of two sizes: the reservoir base course shall be to depth as noted on drawings of aggregate (maximum of 2-inch, minimum of 1 inch), and a 2-inch deep top course of  $\frac{1}{2}$ -inch aggregate (maximum of  $\frac{3}{4}$ -inch, minimum  $\frac{3}{8}$ -inch).

Aggregate base course shall be laid over a dry subgrade covered with engineering filter fabric to a depth shown in drawings, in lifts to lay naturally compacted. The stone base course shall be compacted lightly. Keep the base course clean from debris and sediment.

#### Porous Asphalt Surface Course

The surface course shall be laid directly over the  $\frac{1}{2}$ -inch aggregate base course and shall be laid in one lift.

The laying temperature shall be between 230° and 260°, with minimum air temperature of 50°F, to make sure that the surface does not cool prior to compaction.

Compaction of the surface course shall be done while the surface is cool enough to resist a 10-ton roller. One or two passes by the roller is all that is required for proper compaction. More rolling could cause a reduction in the surface course porosity.

Mixing plant shall certify the aggregate mix and abrasion loss factor and the asphalt content in the mix. The asphaltic mix shall be tested for its resistance to

stripping by water using ASTM D 1664. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

Transportation of mix to site shall be in clean vehicle with smooth dump beds that have been sprayed with a non-petroleum release agent. The mix shall be covered during transportation to control cooling.

Mix of asphalt shall be 5.5 to 6 percent of weight of dry aggregate.

Asphalt grade shall meet AASHTO Specification M-20 for 85 to 100 penetration road asphalt as a binder in the northern United States.

Aggregate grading shall be as specified in Table III-3.6.

Table III-3.6 Porous (Open-Graded) Asphalt Concrete Formulation

Probable Particle Data

Material	Screen	Weight (%)	Volume (%)	Width (mm)	Weight (g)	No. in 100g of asphalt concrete
Aggregate	Through ½	2.2	2.2	10.7	1.667	1.7
	Through ¼	59.6	46.3	8.0	0.697	85.5
	Through #1	17.0	13.3	4.0	0.087	195.4
	Through #6	2.8	2.2	2.0	0.0109	255.6
	Through #16	10.4	8.0	1.0	0.00136	7647.0
	Through #200	1.9	1.5	0.06	0.000294	6462.0
	Asphalt	5.5	10.5			
Air	0	16.0				
Sub-total Coarse Aggregate (½ - #1)		79.4	61.8			282.6
Sub-total Other		20.6	38.2			14364.6
<b>Total</b>		<b>100.0</b>	<b>100.0</b>			<b>14647.2</b>

Source: City of Rockville, Maryland

Protection

After final rolling, no vehicular traffic of any kind shall be permitted on the pavement until cooling and hardening has taken place, and in no case less than 6 hours (preferably a day or two).

Workmanship

Work shall be done expertly throughout and without staining or damage to other permanent work.

Make transition between existing and new paving work neat and flush.

Finished paving shall be even, without pockets, and graded to elevations shown.

Iron smoothly to grade, all minor surface projections and edges adjoining other materials.

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### Certification

A professional engineer, registered in the State of Washington, shall certify compliance with these specifications.

### Pervious Concrete - Additional Planning, Design, and Construction Criteria

#### Introduction

Figure III-3.20 illustrates a typical pervious concrete pavement section.

Pervious concrete contains a large percentage by weight of aggregate larger than a number four sieve (0.185 inches). Pervious concrete is also referred to by several other names such as open graded mix, gap graded mix, draincrete, popcorn mix, no fines mix or porous concrete. Pervious concrete has a high void space, at least 15% is required and a coarse surface texture. The water-cement ratio is low, 0.20 - 0.40, and the slump is extremely low, often zero.

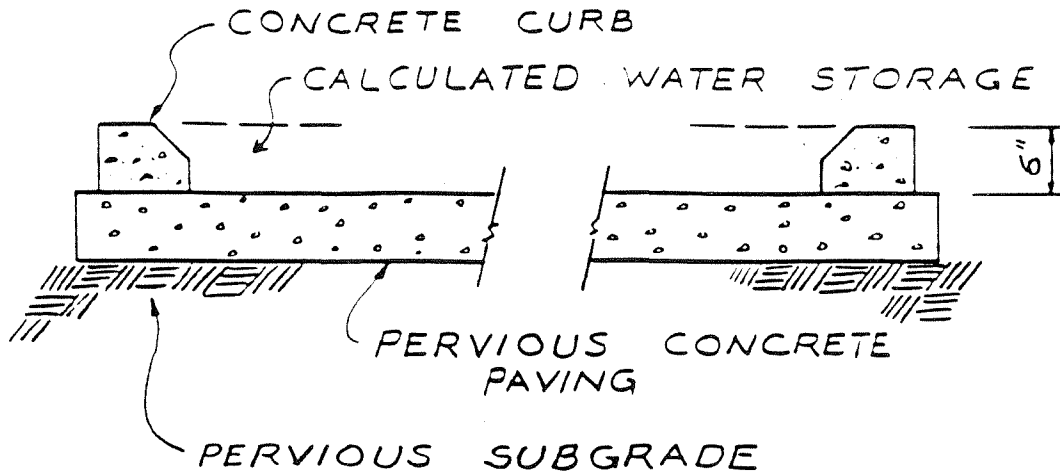
Excessive amounts of water yield a paste which is too fluid and flows off the aggregate particles, reducing cohesion and filling the voids in the lower part. Too little water results in a paste which does not adhere to the aggregate particles, leading to insufficient cohesion. The quantity of cement paste and water is considered sufficient when it coats the coarse aggregate with a shiny film, giving it a metallic gleam. A typical mix provides a permeability of about 2.3 gallons per minute per square foot. Higher percolation rates are possible with higher void contents, but higher void contents also produce lower strengths.

Compressive and flexural strengths of pervious concrete are somewhat lower than those of conventional portland cement concrete, due to the higher void content and lower unit weight. Compressive and flexural strengths are dependent on the water-cement ratio, aggregate-cement ratio, unit weight, void content and aggregate shape and size. The flexible nature of this pavement means that the subgrade condition is extremely important to the performance of the pavement.

The method of handling and placing are different from other types of concrete. Only concrete firms and contractors familiar with the intricacies of porous concrete should be used and then only if a Professional Engineer, with training and experience in porous concrete, is present during paving. Pervious concrete is placed into location and not poured as is conventional concrete. The time lapse between batching and placement should be kept as short as possible. Due to its low water-cement ratio, hydration of the cement will proceed faster and strengths may be impaired from delays in placement. Pervious concrete is placed with a minimum of handling. Best results have been obtained by using a vibratory screed, or vibratory bullfloat for small jobs. These may have to be modified by adding extra weight. For uniform compaction it is advisable to have an inch of material along the base of the screed, while moving it over the concrete surface. Hand troweling or finishing is neither required nor desirable, as this will close up the voids and impair the drainage characteristics.

When a vibratory screed is used, its forward movement over the concrete should not be stopped unless the vibrating mechanism is also stopped. Otherwise, there will be variations in the surface texture of the concrete. A straightedge for manual screeding should be available on jobs using a vibratory screed. In the event of machine breakdown, this will permit uninterrupted unloading of the mixer trucks and avoid extended mixing with attendant loss in voids and change in consistency.

Figure III-3.20 Pervious Concrete Pavement Typical Section



A close-up view of no-fines concrete



The screeding operation must be followed by two passes with a garden roller. This is to assure that any loose particles become well embedded in the pavement surface. Curing is a very important factor with pervious concrete. With the high void percentage, rapid drying is a far more serious problem because the dry paste fails to bond the aggregate particles together. Therefore, adequate moist curing is essential. The pervious concrete should be sprayed shortly after screeding with a light mist so as not to wash the cement paste off the aggregate. It is then covered with impervious sheets for at least the first three days, and preferably for a longer period.

A typical cross-section of pervious concrete is illustrated by Figure III-3.20. These installations are different from porous asphaltic pavement, primarily due to the type of cementing agent that is used in the surface course (e.g., portland cement as opposed to asphalt). However, it is also noticeable that the pavement may be placed directly on the shaped and graded existing sandy soil (pervious subgrade).

Retention storage of up to six inches maximum depth is provided on the surface of the pavement as well as within the voids in the concrete. The load bearing  $\frac{1}{2}$ -inch aggregate base, the open graded coarse aggregate subbase, and filter fabric that were shown with the porous asphalt cross-section (Figure III-3.18) are often not used. When a subbase is required for stability, up to six inches of clean durable quartz sand (WSDOT 902 Fine Aggregate) or equivalent is substituted for crushed stone. The concrete is then placed directly on this lightly compacted subbase.

However, the manufacturer of the patented porous concrete paving process includes both the  $\frac{1}{2}$ -inch bearing course and the open graded subbase in their design. A layer of compacted sand is used between the subbase and the existing soil to prevent the migration of fine material in the surrounding media from migration into the subbase. Certainly this design would provide for more strength and stability and would be preferred in anything exceeding light duty applications.

#### Design Manual

A manual relating to mixing, hauling, placing, testing and suggested design procedures for use of pervious concrete is available through the Florida Concrete and Products Association, 649 Vassar St., Orlando, FL, 32804 at a nominal fee. This comprehensive manual will assist material suppliers, contractors, specifying agencies and design professionals in the proper procedures used to place portland cement pervious pavements.

At a minimum, the following interim specifications should be followed for the manufacture and placement of pervious concrete pavement.

#### 1) Materials

Locally available materials having a record of satisfactory performance are recommended.

- a) The cement used for these facilities shall be Portland Cement Type I or II conforming to ASTM C-150 or Portland Cement Type IP or IS conforming to ASTM C-595. Fly ash conforming to ASTM C-618 may be used in amounts not to exceed 20% of total cementitious material. Ground iron blast-furnace slag conforming to ASTM C-989 may be used in amounts not to exceed 50% by weight of total cementitious material.
- b) Use Washington Department of Transportation (WSDOT) No. 8 coarse aggregate ( $\frac{3}{8}$  inch to No. 16) ASTM C-33 or No. 89 coarse aggregate ( $\frac{3}{8}$  inch to No. 50) ASTM D-448. For designs incorporating fine aggregate, it shall conform to WSDOT Specifications 902. Other gradation of aggregate may be used, subject to approval of the local government.

- c) Air Entraining Agent: Shall comply with ASTM C-260.
- d) Admixture: Type A water reducing; Type D water reducing and retarding; Type E water reducing and accelerating; In accordance with ASTM C-494
- e) Water: Potable

2) Proportions

- a) For pavements subjected to other than light vehicular traffic, the total cementitious material shall not be less than 600 lbs. per unit.
- b) The volume of aggregate per unit shall be equal to 27 cu.ft. when calculated as a function of the rodded unit weight determined in accordance with ASTM C-29.

Fine aggregate, if used, should not exceed 3 cu.ft. (rodded unit weight in accordance with ASTM C-29) and shall be included in total aggregate volume.

- c) Admixtures shall be used in accordance with the manufacturer's instructions and recommendations.
- d) The quantity of mix water shall be such that the cement paste displays a "wet-metallic" sheen, without causing the paste to flow from the aggregate. Insufficient water will result in a dull appearing paste of inadequate consistency.

3) Subgrade Preparation and Formwork

- a) The top 6 inches of the subgrade shall be composed of granular or gravelly soil that is predominantly sandy with no more than a moderate amount of silt or clay.
- b) Prior to placement of Portland Cement Pervious Pavement, the subgrade shall be tested for rate of permeability by double ring infiltrometer, or another suitable test of subgrade soil permeability.
- c) Subgrade Support: Material shall be placed and compacted in layers of a thickness that can be compacted to a minimum density of  $94 \pm 2\%$  of maximum density as determined by AASHTOT-180.
- d) Subgrade Moisture: The subgrade shall be in a moist condition with no free standing water prior to pavement placement.
- e) Forms: Forms may be of wood or steel and shall be the depth of the pavement. Forms shall be of sufficient strength and stability to support mechanical equipment without deformation of plan profiles following spreading, strike-off and compaction operations.

4) Mixing, Hauling and Placing

- a) Truck mixers shall be operated at the speed designed as mixing speed by the manufacturer for 75 to 100 revolutions of the drum.
- b) The portland cement aggregate mixture may be transported or mixed on site and should be used within one (1) hour of the introduction of mix water, unless otherwise approved by an engineer.
- c) Each mixer truck should be inspected for appearance of concrete uniformity according to preceding Section (2d). Water may be added to obtain the

required mix consistency. A minimum of 20 revolutions at the manufacturer's designated mixing speed shall be required following any addition of water to the mix. Discharge shall be a continuous operation and shall be completed as quickly as possible.

- d) **Placing and Finishing Equipment:** Unless otherwise approved by the Owner or Engineer in writing, the Contractor shall provide mechanical equipment of either slipform or form riding with a following compactive unit that will provide a minimum of 10 psi vertical force. The pervious concrete pavement will be placed to the required cross-section and shall not deviate more than  $\pm \frac{1}{4}$ -inch in 10 feet from profile grade. If placing equipment does not provide minimum specified unit weight, a full width roller or other compaction device that will provide a compactive effort to meet unit weight requirement will be used immediately following strike-off operations. After mechanical or other approved strike-off and compaction operations, no other finishing operation will be allowed. If vibration, internal or surface applied, is used, it shall be shut off immediately when forward progress is halted for any reason. The Contractor will be restricted to pavement placement widths of a maximum of fifteen (15) feet unless the Contractor can demonstrate competence to provide pavement placement widths greater than the maximum specified to the satisfaction of the Engineer.
- e) Curing procedures shall begin within twenty minutes after final placement operations. A fog mist shall be applied prior to covering all surfaces and exposed edges with a 6-mil thick polyethylene sheet for a period of five days. The covering shall be held down securely to prevent dislocation due to high winds or adjacent traffic conditions.
- f) If required, control (contraction) joints shall be installed at 60 foot intervals to a depth of  $\frac{1}{4}$  the pavement thickness. No raveling of the surface will be permitted during the joint installation procedure. Isolation (expansion) joints will not be used, except when pavement is abutting building slabs or other adjoining structures.

#### 5) Testing and Inspection

- a) It is strongly suggested that the owner retain an independent testing laboratory. The testing laboratory shall conform to the applicable requirements of ASTM E-329 "Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction" and ASTM C-1077 "Standard Practice for Testing Concrete and Concrete Aggregates for Use in Construction, and Criteria for Laboratory Evaluation" and shall be inspected and accredited by the Concrete Materials Engineering Council, Inc., or by an equivalent recognized national authority.

The agent of the testing laboratory performing field sampling and testing of concrete shall be certified by the American Concrete Institute as a concrete field testing technician Grade I or by a recognized state or national authority for an equivalent level of competence.

- b) A minimum frequency of one (1) test for each day of placement shall be conducted to verify the rodded weight of material as delivered. The test shall be conducted in accordance with ASTM C-172 and C-29. The mix shall be within (+5) five pcf of design unit weight. If outside this range, mix proportions shall be modified to comply.
- c) At seven (7) days from placement, a minimum of three (3) cores for each placement shall be taken in accordance with ASTM C-42. The cores shall be used for verification of pavement thickness. Subsequent to thickness verification, core ends shall be trimmed to facilitate volume determination.

Core unit weight shall be calculated based on weight results when tested in accordance with ASTM C-140 paragraph 14.1 (disregard suspended weight).

Pavement acceptance shall be based on the average unit weight of cores being within  $\pm 5$  pcf of design weight. The thickness of the pavement recommended is five (5) inches for light traffic loadings. Additional thickness will be required for pavement subjected to frequent heavy axle loadings.

**Porous Pavement References**

- (1) Virginia State Water Control Board, Best Management Practices Handbook: Urban, Planning Bulletin 321, Richmond, Virginia, 1979.
- (2) Thelen, E. and L.F. Howe, Porous Pavement, The Franklin Institute Press, Philadelphia. PA, 1978.
- (3) Thelen, E. et al., Investigation of Porous Pavements for Urban Runoff Control, prepared by the Franklin Institute Research Laboratories for the U.S. Environmental Protection Agency, NTIS PB-227-5, Springfield, VA, 1972.
- (4) Smith, R.W., J.M. Rice and S.R. Spelman, Design of Open Graded Asphalt Friction Courses, Federal Highway Administration, U.S. Department of Transportation, FHWA-RD-74-2, 1974.

III-3.6.8 BMP RI.21 Streambank Erosion Control (SBEC) Porous Pavement

## Purpose and Definition

This BMP is similar to the Water Quality Porous Pavement (BMP RI.20) but is designed to provide only streambank erosion control. Thus, while it physically resembles Water Quality Porous Pavement its function more closely resembles that of the Streambank Erosion Control Infiltration Basin (BMP RI.06). The soils underlying this BMP will be too coarse for pollution removal and stormwater must be treated prior to discharge to this BMP. There are two types of porous pavement; porous asphalt pavement and pervious concrete pavement.

Porous asphalt paving is presented in Figures III-3.18 and Figures III-3.19. Figure III-3.20 illustrates pervious concrete pavement.

*Planning Considerations*

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of this BMP. See Section III-3.3 for a description of General Limitations.*

*This BMP will typically be located "on-line" and be an integral part of the primary conveyance/detention system. The 6-month, 24-hour design storm must be completely treated prior to being discharged to this BMP.*

*Drainage areas up to 15 acres can be served by this BMP.*

## Design Criteria

See Water Quality Porous Pavement (BMP RI.20) for design criteria keeping in mind, however, that this BMP serves a different function than BMP RI.20 (i.e., no runoff treatment; streambank erosion control only). As this BMP serves a similar function as the Streambank Erosion Control Infiltration Basin (BMP RI.06), that BMP should be referenced for criteria. Basic design criteria are given in the following sections of this manual:

Hydrologic Analysis - Chapter III-1

General Infiltration Design Criteria - Section III-3.4

The following design criteria applies to all streambank erosion control infiltration BMPs:

- General - The construction of structures, materials allowed, accessibility for maintenance, safety measures, easements, and hydraulic design methods shall be the same as those required for detention basins in Chapter III-4.
- Soils Investigation - A minimum of one soils log shall be required for each 5,000 square feet of infiltration surface area (plan view area) and in no case less than three soils logs per BMP. Each soils log shall extend a minimum of 3 feet in depth below the bottom of the proposed BMP, describe the SCS series of the soil, the textural class of the soil horizon(s) through the depth of the log, and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.
- The design infiltration rate,  $f_d$ , will be equal to one-half the infiltration rate found from the soil textural analysis.
- Overflow route - An overflow route must be identified in the event that the BMP capacity is exceeded. This overflow route should be designed to meet Minimum

Requirement #2 (Preservation of Natural Drainage Systems).

- Runoff Treatment - Runoff from the 6-month, 24-hour design storm is to be completely treated prior to discharge to this BMP.
- Slopes - This BMP should be a minimum of 50 feet from any slope greater than 15 percent. A geotechnical report should address the potential impact of the BMP infiltration upon the steep slope.
- Buildings - the potential impacts of infiltration on building foundations must be evaluated.
- The infiltration surface area ( $A_i$ ) used for sizing the BMP shall be computed by measuring the surface area (plan view area) below the maximum design water surface.
- Spillways - The bottom elevation of the low-stage orifice should be designed to coincide with the one-day infiltration capacity of the BMP. All other aspects of the principal spillway design and the emergency spillway shall follow the details provided for detention basins in Chapter III-4.
- Drawdown Time - Streambank Erosion Control Infiltration BMPs shall be designed to completely drain stored runoff within one day following the occurrence of the 10-year, 24-hour design storm and within two days of the 100-year, 24-hour design storm (with appropriate correction factors as discussed in Chapter III-1). Thus, a maximum allowable drawdown time of 48 hours is permissible.

Additional criteria specific to porous asphaltic paving and pervious concrete pavement is given above under "Water Quality Porous Pavement."

Construction and Maintenance Criteria

Same as for Water Quality Porous Pavement (BMP RI.20).

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III-3.6.9 BMP RI.30 Water Quality (WQ) Concrete Grid and Modular Pavement**Purpose and Definition**

Concrete grid and modular pavement are primarily intended to provide runoff treatment in low-volume traffic areas. This BMP must be underlain by soils which have the capability of removing pollutants from runoff. These soils will likely have insufficient permeability to be used for streambank erosion control. Concrete grid and modular pavement consists of strong structural materials having regularly interspersed void areas which are filled with pervious materials, such as sandy loam. Types of concrete grid and modular pavement sections are illustrated in Figure III-3.21.

**Planning Considerations**

*This BMP serves a similar function as the Water Quality Porous Pavement (BMP RI.20) and has similar planning considerations.*

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of the BMP. See Section III-3.3 for a description of General Limitations.*

*This BMP will typically be located off-line from the primary conveyance/detention system because streambank erosion control is generally not provided. Water Quality Infiltration BMPs must always be preceded by a pretreatment BMP to remove suspended solids that could clog the infiltration soils.*

*Drainage areas up to 15 acres can be served by this BMP.*

**Conditions Where Practice Applies**

Where pavement is desirable or required for low-volume traffic areas and the underlying soils allow for rapid drainage. This practice is most applicable for new construction, but it can be used in existing developments to expand a parking area or even to replace existing pavement if that is a cost-effective measure, or for aesthetic reasons.

Possible areas for use of these paving materials include:

- Parking lots, especially fringe or overflow parking areas.
- Parking aprons, taxiways, blast pads, and runway shoulders at airports (heavier loads may demand the use of reinforced grid systems).
- Emergency stopping and parking lanes and vehicle cross-overs on divided highways.
- On-street parking aprons in residential neighborhoods.
- Recreational vehicle camping area parking pads.
- Private roads, easement service roads and fire lanes.
- Industrial storage yards and loading zones (heavier loads may demand the use of reinforced grid systems).
- Driveways for residential and light commercial use.
- Bike paths, walkways, patios and swimming pool aprons.

#### Advantages

- Normally impervious areas are able to accept stormwater runoff and infiltrate it.

#### Disadvantages

- Modular pavement costs are approximately double the cost of conventional pavement.
- Without good maintenance, the voids in the pavement may become plugged.
- If the soil is only marginally permeable, pollutants may build up near the soil surface, especially in an area such as a parking lot.

#### Design Criteria - General

For General Design Criteria see Water Quality Porous Pavement (BMP RI.20). Hydrologic design procedures described are in Section III-3.4. A summary of basic design criteria is as follows:

- Soils investigation must be conducted.
- Design infiltration rate should be  $\frac{1}{2}$  of that found by the soils investigation
- Pretreatment of the 6-month, 24-hour storm is necessary to control siltation
- Drawdown time should be a maximum of 24 hours for the 6-month, 24-hour design storm. If a Presettling Basin (BMP RD.10) precedes the modular pavement discharge area, the *combined* drawdown time for both BMPs should be 24 hours.

The six General Limitations must be satisfactorily met before this BMP can be utilized (Section III-3.3).

#### Additional Planning and Design Criteria

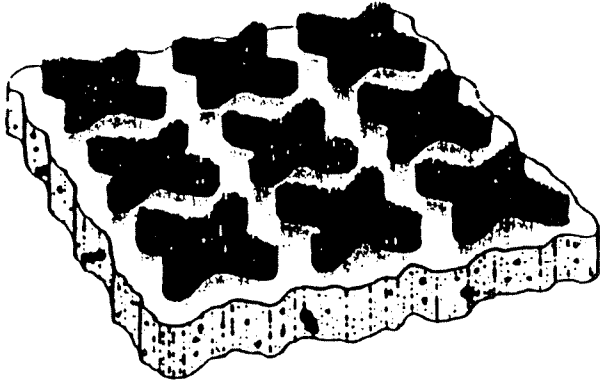
##### Pavement Types (see Figure III-3.21)

Modular pavement systems vary considerably in configuration. Categories include:

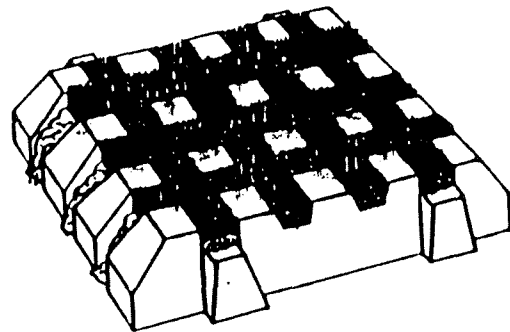
1. Poured-in-Place Concrete Slabs -- Reinforced concrete slabs covering large areas are poured in place on the ground to be covered. Special forms are used to shape the void areas, and a flat surface results. Because the slab is reinforced with steel, this pavement is suitable for heavy loads and has maximum resistance to movement caused by frost heave or settling.
2. Pre-Cast Concrete Grids -- Concrete paving units incorporating void areas are usually precast in a concrete products plant and trucked to a job site for placement on the ground. However, for large jobs these units can be formed and cast at the site. There are two types of grid pavers:
  - a. Lattice Pavers -- generally flat and grid-like in surface configuration.
  - b. Castellated Pavers -- distinguished by a more complex surface configuration characterized by crenels and merlons that are exposed when pervious materials are added. These units show a higher percentage of grass surface.
3. Modular Unit Pavers -- Smaller pavers which may be clay bricks, granite sets, or cast concrete of various shapes. These pavers are monolithic units which do not have void areas incorporated into their configuration. They are installed on the ground to be covered with pervious material placed in the gaps between the units.



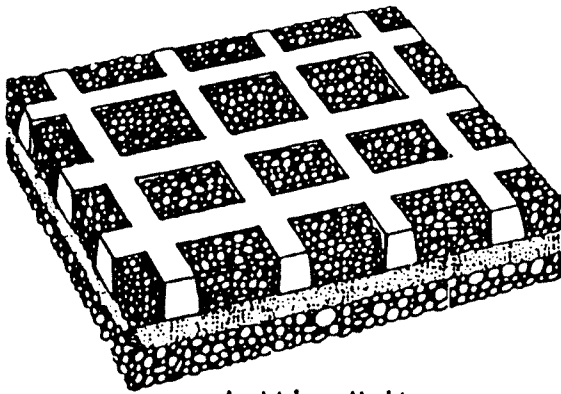
Figure III-3.21 Types of Grid and Modular Pavements



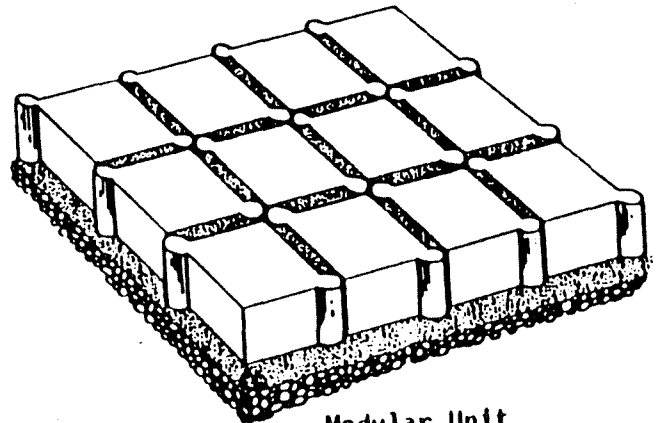
Poured-in-Place Slab



Castellated Unit



Lattice Unit



Modular Unit

Source: Virginia Soil and Water Conservation Commission

### Production of Units

There are a number of manufacturers of precast concrete grids and unit pavers, and various styles can be purchased from distributors. Forms are required for poured-in-place systems. These systems should be installed by contractors who have been trained in the use of the forms.

### Site Characteristics

To determine the suitability of the types of paving materials and to plan and design their installation, the following information about the site should be known:

1. Environmental data: Soil permeability and bearing capacity; slope; depth, direction of movement, natural quality, and confined or unconfined condition of ground water; and surface drainage conditions.
2. Pollution information: Types of pollutants generated by the prevailing and intended land uses and the effect of the practice on pollutants, generally and specifically. Pollution control effectiveness is not currently documented for these products, and applied research is needed.
3. The intended use of the area: This is a key determinant of the choice of paving material. Is the installation temporary or permanent? What type of maintenance will be necessary? Is pavement coloring desired? What type of performance will be required of the paving surface? Can the practice be coupled with other BMPs for increased effectiveness?
4. Pre-development and projected post-development runoff determinations and other hydrologic data: To determine the need for overflow or back-up stormwater facilities, when required by local agencies for flood control. Few manufacturers list runoff or infiltration coefficients for their products, and research on these factors is needed.

### Construction and Maintenance Criteria

#### Construction

All installations of modular pavement should be designed and constructed according to the manufacturer's specifications. To be consistent with other forms of treatment, stored water must be percolated prior to the time limit specified for other on-site retention systems. However, facilities using vegetative cover in combination with pavers must be capable of disposing of stored waters within time limits necessary to avoid damage to the ground cover (24 to 36 hours for most grasses). Parking areas should avoid extensive ponding for periods exceeding more than an hour or two.

In the design of these systems, experience shows a definite potential for large margins of error involved in estimating the infiltration rate of the underlying soils for the purpose of evaluating the storage recovery period. Consequently the use of a safety factor of two or more is normally recommended. This allowance may be accomplished by reducing the percolation rate by one-half its original value.

#### Maintenance

Where turf is incorporated into these installations, normal turf maintenance -- watering, fertilizing and mowing -- will be necessary. Mowing is seldom required in areas of frequent traffic. It is documented that the hard surfaces in these installations require very little maintenance. However, fertilizers, pesticides and other chemicals may have adverse effects on concrete products. The use of such chemicals should be restricted as much as possible.

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III-3.6.10 BMP RI.31 Streambank Erosion Control (SBEC) Concrete Grid/Modular Pavement**Purpose and Definition**

Concrete grid and modular pavement is designed to provide streambank erosion control by infiltrating runoff into the soil. It is not to be used for runoff treatment purposes and should only be used in low-volume traffic areas. Concrete grid and modular pavement is a pavement consisting of strong structural materials having regularly interspersed void areas which are filled with pervious materials, such as sod, gravel, or sand. Types of concrete grid and modular pavement are illustrated in Figure III-3.21.

**Planning Considerations**

*Appropriate soil conditions and the protection of ground water are among the important considerations which may limit the use of this BMP. See Section III-3.3 for a description of General Limitations.*

*This BMP will typically be located "on-line" and be an integral part of the primary conveyance/detention system. The 6-month, 24-hour design storm must be completely treated prior to being discharged to this BMP.*

*Drainage areas up to 15 acres can be served by this BMP.*

**Design Criteria**

For General Design Criteria see Streambank Erosion Control Porous Pavement (BMP RI.21). Hydrologic design procedures described are in Section III-3.4.

A summary of basic design criteria is as follows:

- Soils investigation must be conducted.
- Design infiltration rate should be  $\frac{1}{2}$  of that found by the soils investigation
- Runoff Treatment - Runoff from the 6-month, 24-hour design storm is to be completely treated prior to discharge to this BMP.
- Overflow route - An overflow route must be identified.
- Drawdown time should be a maximum of 24 hours for the 2-year and 10-year, 24-hour design storms; 48 hours for 100-year, 24-hour design storm (with appropriate correction factors).
- Slopes - potential effect of infiltration on slopes is to be evaluated.
- Buildings and facilities - potential effects of infiltration are to be evaluated.

The six General Limitations must be satisfactorily met before this BMP can be utilized (Section III-3.3).

**Construction and Maintenance Criteria**

See Water Quality Concrete Grid and Modular Pavement (BMP RI.30).

**III-3.7 STANDARDS AND SPECIFICATIONS FOR FILTRATION BMPs**

**III-3.7.1 Overview**

This section presents detailed standards and specifications for the following filtration best management practices:

BMP RF.05	Sand Filtration Basin
BMP RF.10	Sand Filtration Trench
BMP RF.15E	Aquatard System (Experimental)

The standards and specifications for each of the above BMPs contains, where appropriate, information on the following topics:

- Purpose and Definition
- Planning Considerations
- Design Criteria
- Construction and Maintenance Criteria

### III-3.7.2 BMP RF.05 Sand Filtration Basin

#### Purpose and Definition

Sand filtration basins are open impoundments which filter runoff through a layer of sand into an underdrain system. Sand filtration provides runoff treatment, but not streambank erosion control and these basins are to be located off-line from the primary conveyance/detention system. While effective at treating conventional pollutants, sand filtration is not effective at removing nutrients. It's use for treating oil is being allowed on an interim basis and sand filtration may substitute for API and CPS-type oil/water separators.

The sand bed filtration system consists of an inlet structure, sand bed, underdrain piping and basin liner. The basin liner will only be required if the treated runoff is not to be allowed to percolate into the soil underlying the filtration basin. A liner would be necessary if the filtered runoff required additional treatment, such as in a wet pond for further nutrient removal, or in cases where additional ground water protection was mandated. Figures III-3.22 and III-3.23 illustrates sand filtration basin systems.

#### Planning Considerations

*To improve the effectiveness of sand filtration basins and to protect the media from clogging, these basins are to be located off-line from the primary conveyance/detention system and must be preceded by a pretreatment BMP. Disturbed areas that are sediment sources in the contributing drainage area should be identified and stabilized to the maximum extent practicable. Because of the potential for clogging, sand filtration BMPs must never be used as sediment basins during construction.*

*If a sand filtration basin is used as a substitute for an API or CPS-type oil/water separator, then pretreatment may not be necessary if the contributing drainage area is small and completely impervious (the restrictions which apply to oil/water separators will also apply to sand filtration basins in this case - see Chapter III-7 for further details).*

#### Design Criteria

Sand filtration BMPs are to be designed according the procedure described in Section III-3.4, using a Darcy's Law approach. Important design considerations are discussed below.

#### Off-line Isolation/Diversion Structure

By locating sand filtration systems off-line from the primary conveyance/detention system the long-term effectiveness of the treatment system can be maintained. Off-line systems are designed to capture and treat the 6-month, 24-hour design storm; this is typically achieved by using isolation/diversion baffles and weirs. A typical approach for achieving isolation of the water quality volume is to construct an isolation/diversion weir in the stormwater channel such that the height of the weir equals the maximum height of water in the filtration basin during the 6-month, 24-hour design storm. When additional runoff greater than the water quality storm enters the stormwater channel, it will spill over the isolation/diversion weir and mixing with already-isolated water quality volume will be minimal. Figures III-3.24 and III-3.25 illustrate two types of isolation/diversion structures which have been successfully used.

Source: City of Austin, 1988

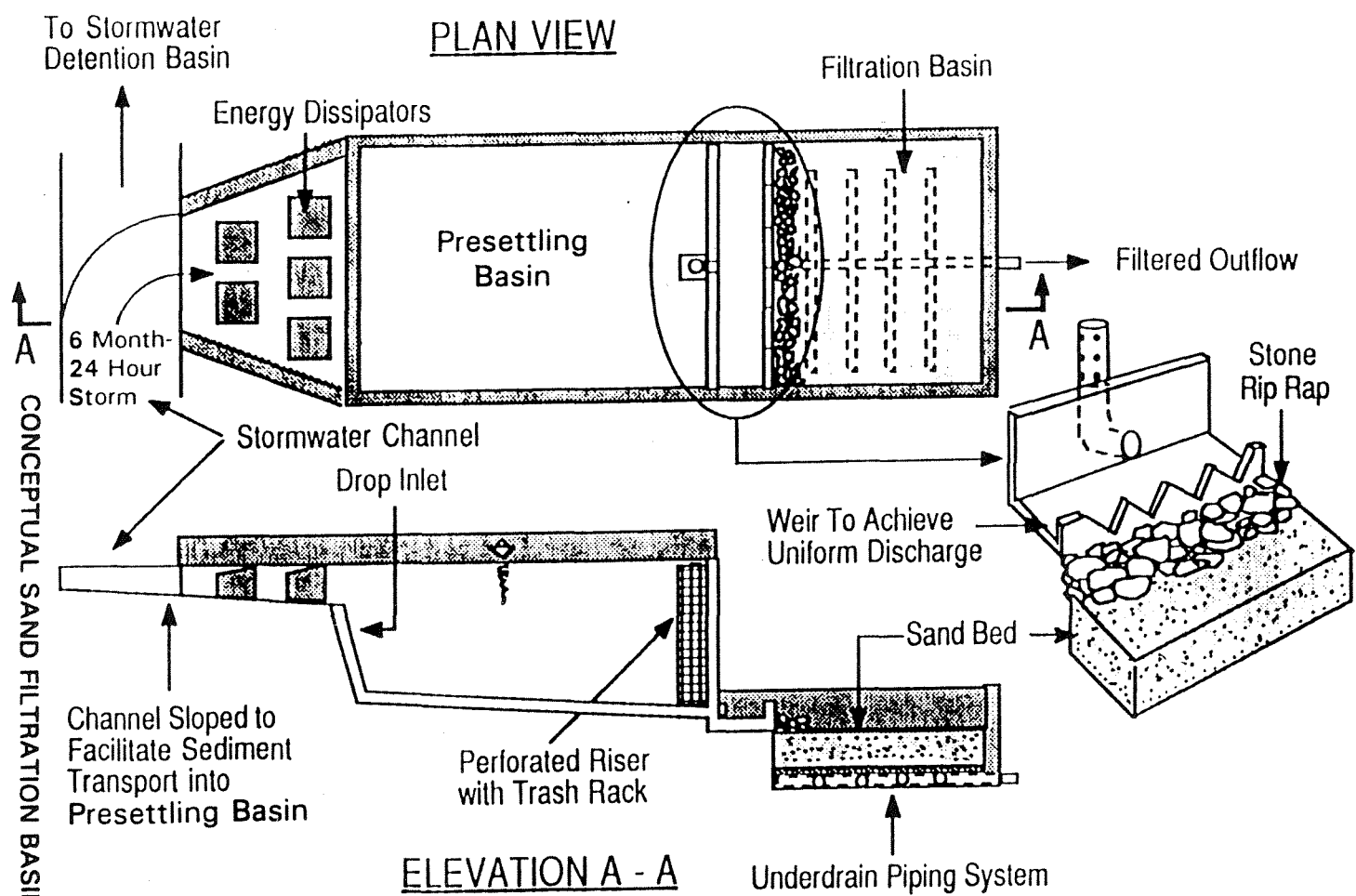
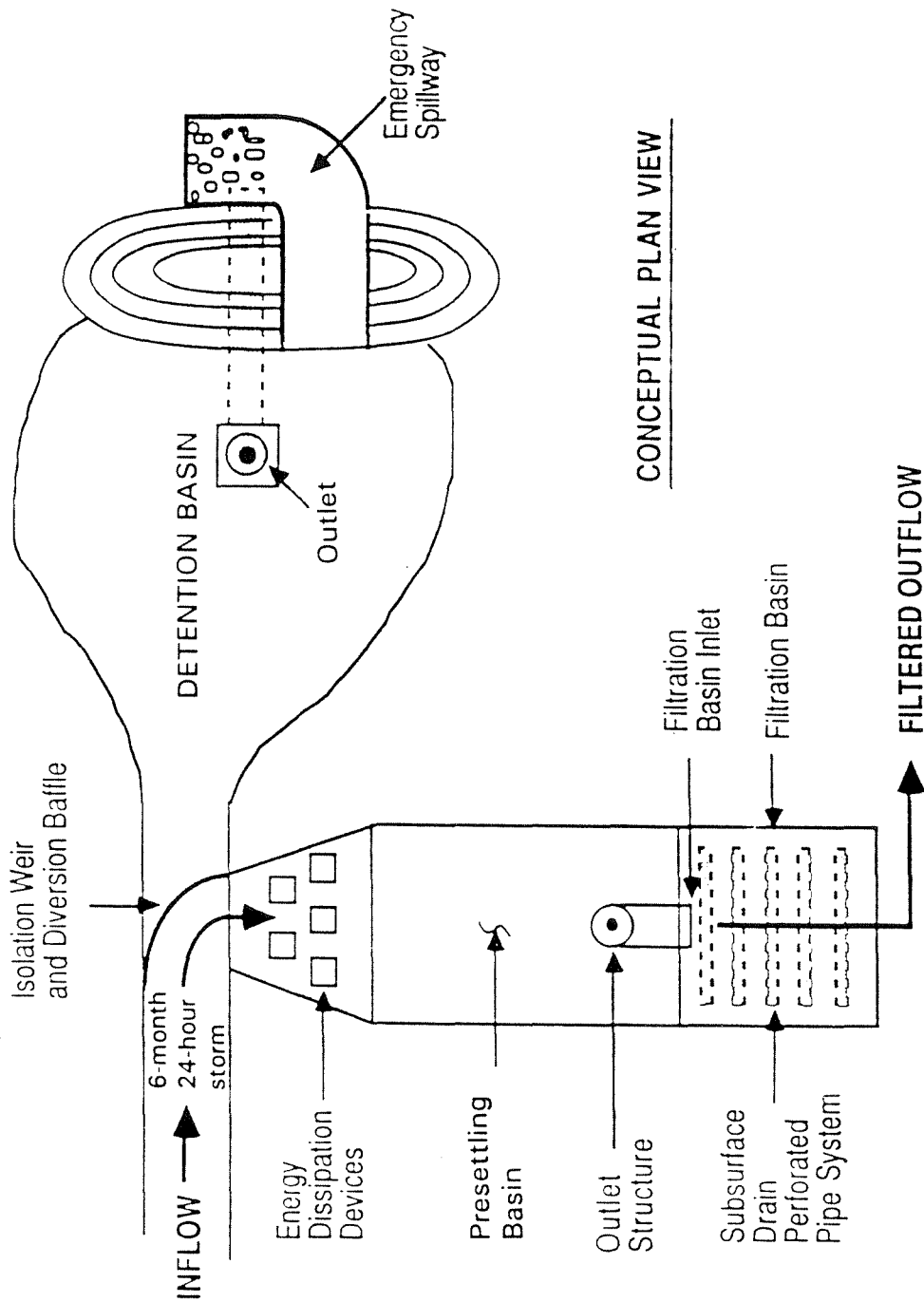


Figure III-3.22  
Conceptual Sand Filtration Basin System

Figure III-3.23  
Sand Filtration Basin Preceded by Presettling Basin



**SAND FILTRATION BASIN PRECEDED BY PRESETTLING BASIN**

Source: City of Austin, 1988

## Sizing Sand Filtration BMPs

The Darcy's Law method for sizing the BMP should be used:

$$Q = f * i * A_s$$

where  $f$  is the sand filtration rate,  $i$  is the hydraulic gradient, and  $A_s$  is the filtration bed surface area. The hydraulic gradient is given by the equation:

$$i = \frac{h}{h + L}$$

where  $h$  is the height of the water column over the top of the sand bed and  $L$  is the thickness of the sand bed (typically 18 inches).

A conservative value for the filtration rate ( $f$ ) should be used. Design filtration rates of about two inches/hour are used in Austin, Texas, which are much lower than published values for sand but reflect actual field permeability rates. The lower rates reflect the effects of suspended solids and sediment on the sand's permeability.

## Drainage Area

A maximum contributing drainage area of 50 acres is recommended for sand filtration basins.

## Drawdown Time

Sand filtration basins are to be designed to completely empty (drawdown time) in 24 hours or less.

## Inlet Structure

The inlet structure should spread the flow uniformly across the surface of the filter media. Flow spreaders, weirs or multiple orifice openings are recommended. Stone riprap or other dissipation devices should be installed to prevent gouging of the sand media and to promote uniform flow. The inset in Figure III-3.23 illustrates this.

## Sand Bed

A sand bed depth of 18 inches is recommended. This is the final bed depth; consolidation of the sand is likely during construction.

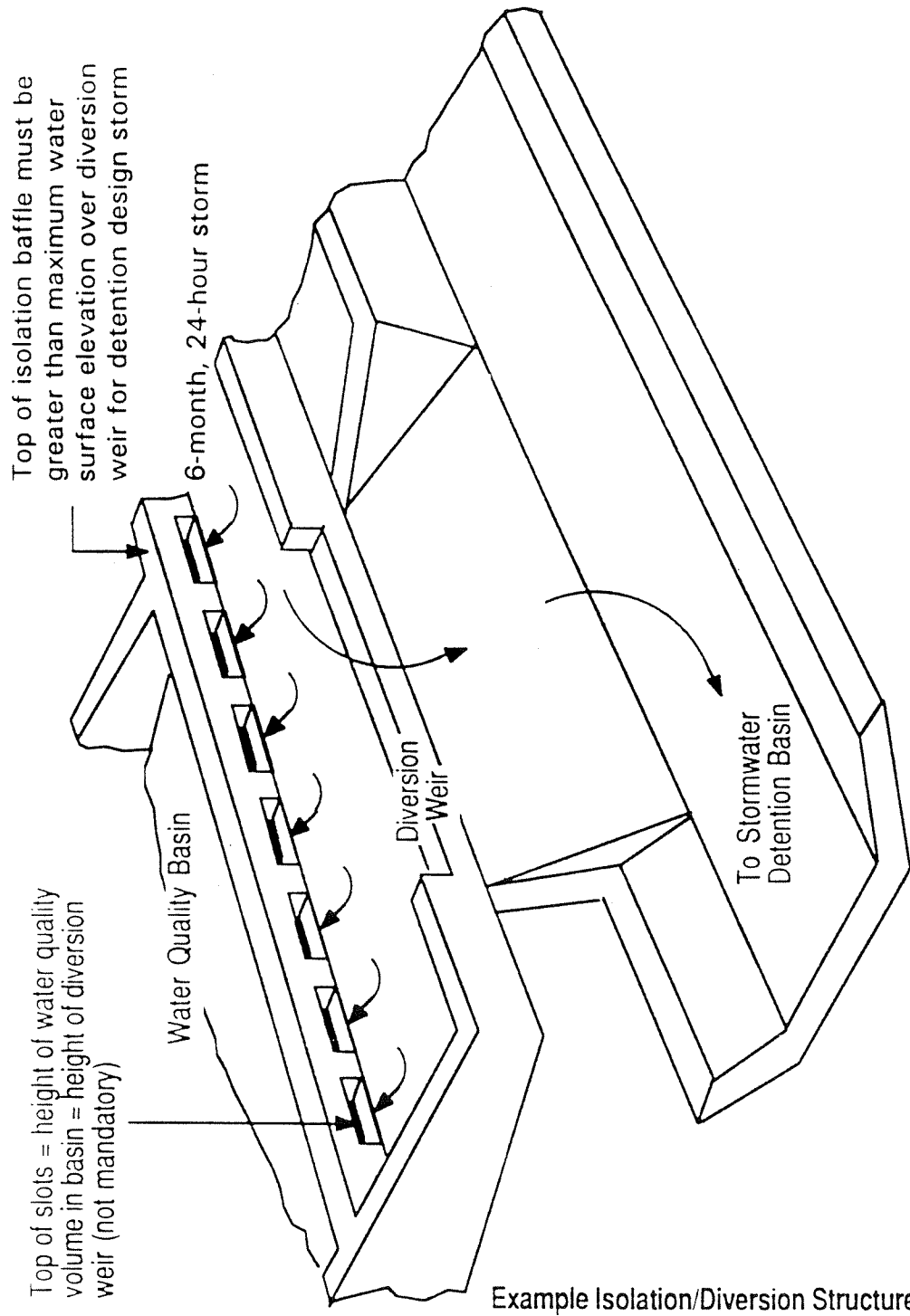
Two sand bed configurations can be selected from; one with a gravel layer and the other a trench design which utilizes drainage matting as a substitute for the gravel layer. The top surface layer should be level so that equal distribution of runoff will be achieved in the basin.

## 1. Sand Bed with Gravel Layer (Figure III-3.26a)

The top layer is to be a minimum of 18 inches of 0.02-0.04 inch diameter sand (smaller sand size is acceptable). Under the sand shall be a layer of ½ to two (2) inch diameter gravel which provides a minimum of two (2) inches of cover over the top of the underdrain lateral pipes. No gravel is required under the lateral pipes. The sand and gravel must be separated by a layer of geotextile fabric meeting the specifications listed in Table III-3.7.

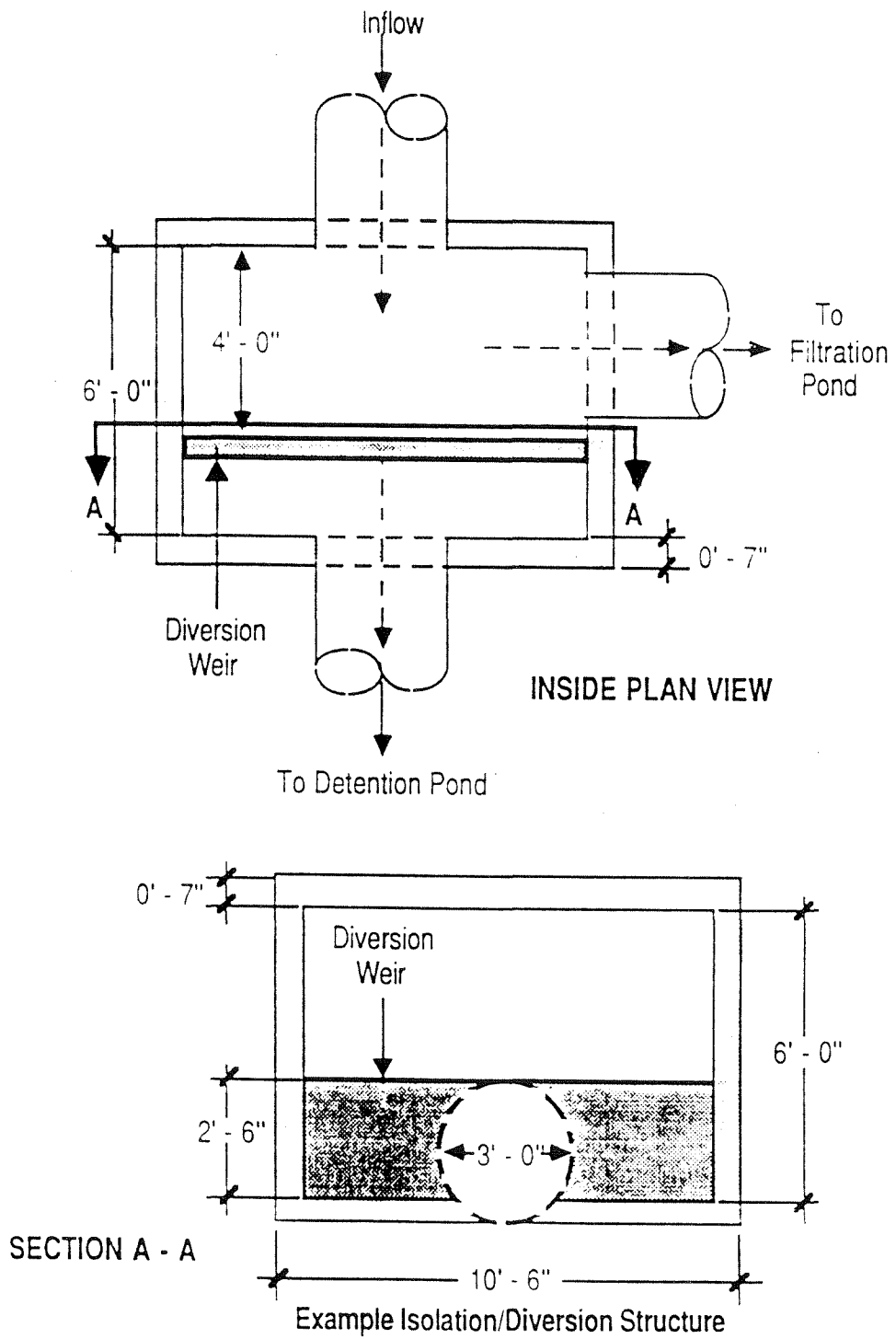


Figure III-3.24  
Example Isolation/Diversion Structure



Source: City of Austin, 1988

Figure III-3.25  
Example Isolation/Diversion Structure



Source: City of Austin, 1988

## 2. Sand Bed with Trench Design (Figure III-3.26b)

This configuration can be used on flatter sites which may restrict the applicability of the previous design. The top layer shall be 12-18 inches of 0.02-0.04 inch diameter sand (smaller sand size is acceptable). Laterals shall be placed in trenches with a covering of  $\frac{1}{2}$  to two (2) inch gravel and geotextile fabric. The lateral pipes shall be underlain by a layer of drainage matting. The geotextile fabric is needed to prevent the filter media from infiltrating into the lateral piping. The drainage matting is needed to provide adequate hydraulic conductivity to the laterals. Table III-3.7 provides the specifications for the geotextile fabric. Table III-3.8 provides the specifications for the drainage matting.

Table III-3.7  
Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile
Unit Weight		oz/sq.yd.	8 (min.)
Filtration Rate		in/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (modified)	lbs.	125 (min.)
Mullen Burst Strength	ASTM D-751	psi	400 (min.)
Tensile Strength	ASTM D-1682	lbs.	300 (min.)
Equiv. Opening Size	US Standard Sieve	No.	80 (min.)

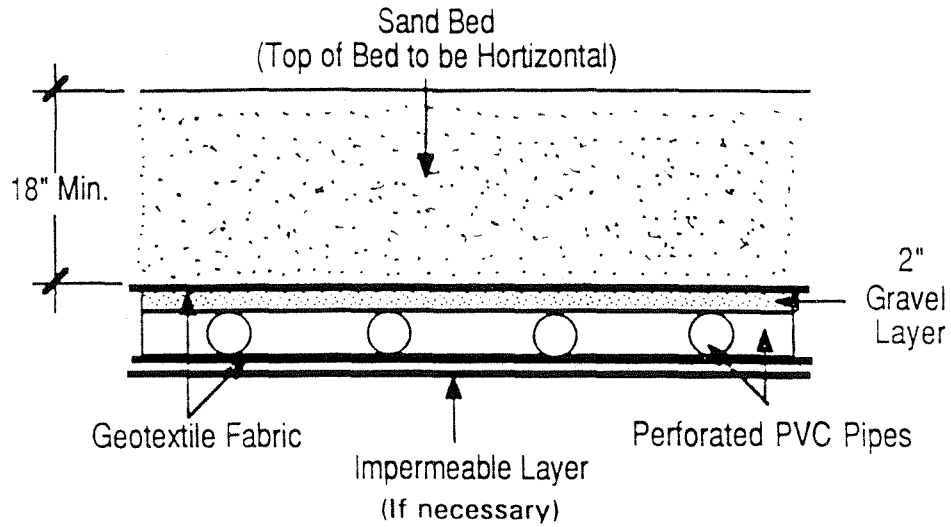
Source: City of Austin, 1988

## Underdrain Piping

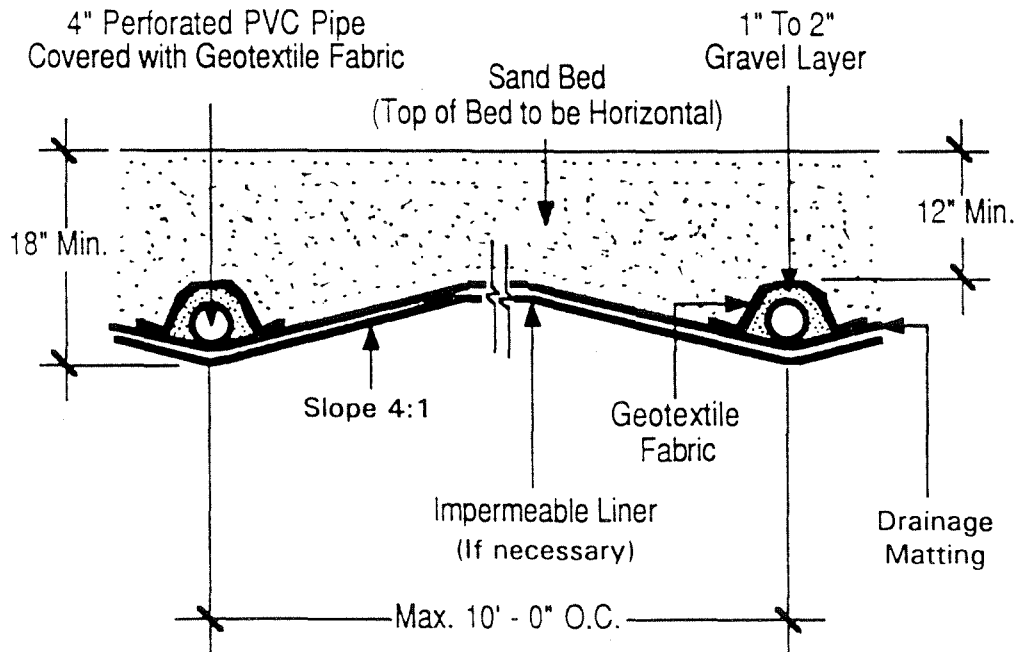
The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be four (4) inches or greater and perforations should be  $\frac{3}{8}$  inch. All piping is to be schedule 40 polyvinyl chloride or greater strength. A maximum spacing of ten (10) feet between laterals is recommended. Lesser spacings are acceptable. The maximum spacing between rows of perforations should not exceed six (6) inches.

The minimum grade of piping shall be  $\frac{1}{8}$  inch per foot (one (1) percent slope). Access for cleaning all underdrain piping is needed; this can be provided by installing cleanout ports which tee into the underdrain system and surface above the top of the sand filtration media.

Figure III-3.26a Sand Bed Profile with Gravel Layer



A. SAND BED PROFILE (WITH GRAVEL LAYER)



B. SAND BED PROFILE (TRENCH DESIGN)

Sand Bed Filtration Configurations

Figure III-3.26b Sand Bed Profile with Trench Design  
Source: City of Austin, 1988

Table III-3.8  
Drainage Matting Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		oz./sq.yd.	20
Flow Rate (fabric)		GPM/ft <sup>2</sup>	180 (min.)
Permeability	ASTM D-2434	cm/sec	12.4 x 10 <sup>-2</sup>
Grab Strength (fabric)	ASTM D-1682	lbs.	Dry lg. 90 Dry wd. 70 Wet lg. 95 Wet wd. 70
Puncture Strength (fabric)	COE CW-02215	lbs.	42 (min.)
Mullen Burst Strength	ASTM D-1117	psi	140 (min.)
Equiv. Opening Size	US Standard Sieve	No.	100 (70-120)
Flow Rate (drainage core)	Drexel Univ. Test Method	GPM/ft. width	14

Source: City of Austin, 1988

#### Basin Liner

If an impermeable liner is required it should meet the specifications below. If an impermeable liner is not required then a geotextile fabric liner shall be installed which meets the specifications listed above in Table III-3.7 unless the basin has been excavated to bedrock. Impermeable liners may be either clay, concrete or geomembrane. Clay liners should meet the specifications give in Table III-3.9:

Table III-3.9  
Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	1 x 10 <sup>-6</sup>
Plasticity Index of Clay	ASTM D-423 & D-424	percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	percent	Not less than 30
Clay Particles Passing	ASTM D-422	percent	Not less than 30
Clay Compaction	ASTM D-2216	percent	95% of Standard Proctor Density

Source: City of Austin, 1988

The clay liner should have a minimum thickness of 12 inches.

If a geomembrane liner is used instead of clay, it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane fabric should be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane (see Table III-3.7 for geotextile fabric specifications).

Equivalent methods for protection of the geomembrane liner will be considered. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing, and abrasion.

Concrete liners may also be used for sedimentation chambers and for sedimentation and filtration basins less than 1,000 square feet in area. Concrete shall be five (5) inch thick Class A or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be six (6) gage wire or larger and six (6) inch by six (6) inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete shall have a minimum six (6) inch compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to one (1) inch. Where visible, the concrete shall be inspected annually and all cracks shall be sealed.

#### Pretreatment BMP

It is recommended that a presettling basin (BMP RD.10) and/or biofiltration swale (BMP RB.05) be used to pretreat runoff discharging to the sand filter. Descriptions of these two BMPs are provided in Chapters III-4 and III-6, respectively.

If a presettling basin is used for pretreatment, careful attention must be given to designing the inlet and outlet structures. The presettling basin consists of an inlet structure, outlet structure and basin liner if permeable soils underlay the basin. The presettling basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. This will improve basin performance and reduce maintenance requirements.

- Inlet Structure - The inlet structure design must be adequate for isolating the water quality volume from the larger design storms and to convey the peak flows for the larger design storms past the basin. The water quality volume should be discharged uniformly and at low velocity into the presettling basin in order to maintain near quiescent conditions which are necessary for effective treatment. It is desirable for the heavier suspended material to drop out near the front of the basin; thus a drop inlet structure is recommended in order to facilitate sediment removal and maintenance. Energy dissipation devices may be necessary in order to reduce inlet velocities which exceed three (3) feet per second.
- Outlet Structure - The outlet structure conveys the water quality volume from the presettling basin to the filtration basin. The outlet structure shall be designed to provide for a residence time of 24 hours for the 6-month, 24-hour storm. See Chapter III-4 for calculating residence time. A perforated pipe or equivalent is the recommended outlet structure. The residence time should be achieved by installing a throttle plate or other flow control device at the end of the riser pipe (the discharges through the perforations should not be used for drawdown time design purposes). The perforated riser pipe can be selected from Table III-3.10:

Table III-3.10  
Perforated Riser Pipe Specifications

Riser Pipe Nominal Dia. (inches)	Vertical Spacing Between Rows (center to center - inches)	Number of Perforations per Row	Diameter of Perforations (inches)
6	2.5	9	1
8	2.5	12	1
10	2.5	16	1

Source: City of Austin, 1988. This information is based on commercially available pipe. Equivalent designs are acceptable.

A trash rack shall be provided for the outlet. Openings in the rack should not exceed  $\frac{1}{4}$  the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations it is recommended that geotextile fabric be wrapped over the pipe's bottom rows and that a cone of one (1) to three (3) inch diameter gravel be placed around the pipe. If a geotextile fabric wrap is not used then the gravel cone must not include any gravel small enough to enter the riser pipe perforations. Figure III-3.27 illustrates a perforated riser outlet structure with trash rack.

#### - Basin Liner

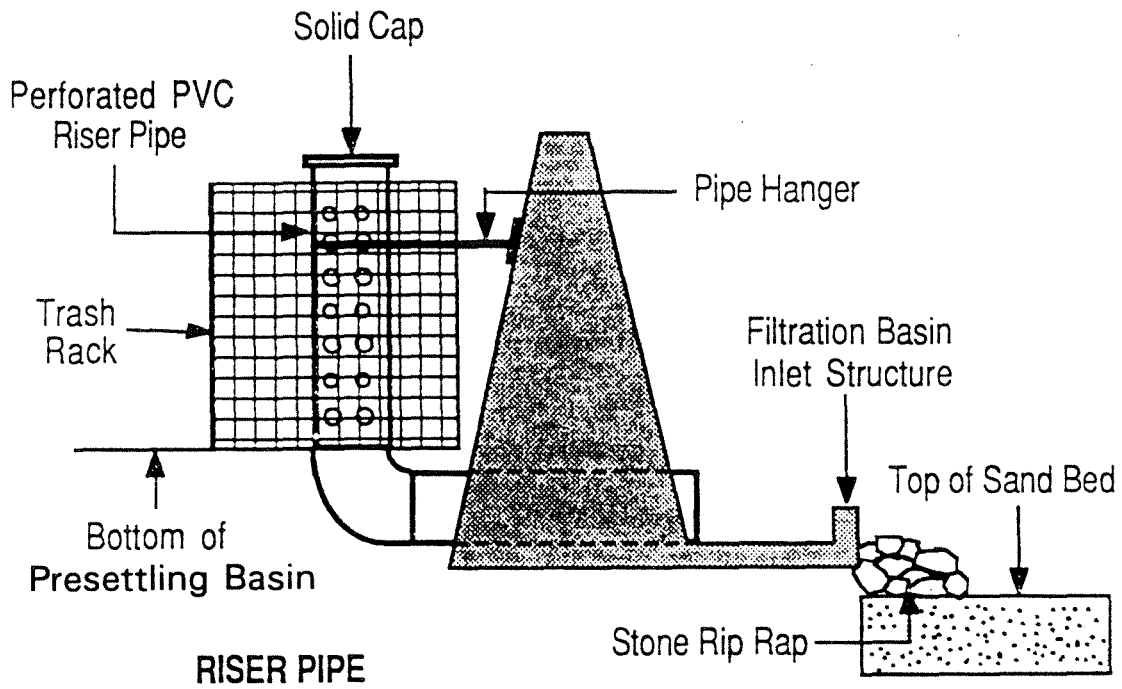
The pretreatment BMP may need to have a basin liner to prevent runoff from being lost to soil infiltration prior to treatment by the filtration basin. If a basin liner is required then it shall meet the specifications in Table III-3.9 or equivalent, as discussed above.

### Construction and Maintenance Criteria

#### Construction Requirements

- The final sand bed depth must be 18 inches; consolidation of sand will likely occur during installation and this must be taken into account. The sand should be periodically wetted, allowed to consolidate, and then extra sand added. Repeat this procedure until the bed depth has stabilized at 18 inches.
- Provisions must be made for access to the basin for maintenance purposes. A maintenance vehicle access ramp is necessary. The slope of the ramp should not exceed 4:1.
- The design should minimize susceptibility to vandalism by use of strong materials for exposed piping and accessories.
- Side slopes for earthen embankments should not exceed 3:1 to facilitate mowing.
- The erosion and sediment control plan must be configured to permit construction of the pond while maintaining erosion and sediment control. No runoff is to enter the sand filtration basin prior to completion of construction and site revegetation. Construction runoff may be routed to the sediment basin/chamber but outflow from this structure shall by-pass the sand filter basin.

Figure III-3.27 Perforated Riser Outlet Structure



Perforated Riser Outlet Structure



#### Maintenance Requirements

- Removal of silt when accumulation exceeds  $\frac{1}{2}$  inch.
- Removal of accumulated paper, trash and debris every six (6) months or as necessary.
- Corrective maintenance is required any time drawdown does not occur within 36 hours after the sedimentation basin has emptied.
- Annual inspection and, as necessary, repair of the structure.

#### Sand Media Rehabilitation and Replacement

Over time, a layer of sediment will build up on top of the filtration media which can inhibit the percolation of runoff. Experience has shown that this sediment can be readily scraped off during dry periods with steel rakes or other devices. Once sediment is removed the design permeability of the filtration media can typically be restored by then striating the surface layer of the media. Eventually, however, finer sediments which have penetrated deeper into the filtration media will reduce the permeability to unacceptable levels, thus necessitating replacement of some or all of the sand. The frequency in which the sand media must be replaced is not well established and will depend on the suspended solids levels entering the system (thus, the effectiveness of the pretreatment BMP can be a significant factor). Drainage areas which have disturbed areas containing clay soils will likely necessitate more frequent replacement. Properly designed and maintained sand filtration BMPs in Austin, Texas have functioned effectively, without complete replacement of the sand media, for at least five years and should have design lives of 10 to 20 years.

### III-3.7.3 BMP RF.10 Sand Filtration Trench

#### Purpose and Definition

A sand filtration trench is similar to a Water Quality Infiltration Trench (BMP RI.10) except that it is designed according to the same criteria used for a Sand Filtration Basin (BMP RF.05). Sand filtration trenches are generally used for smaller drainage areas than sand filtration basins. A typical use of a trench is along the perimeter of a parking lot. As with basins, pretreatment must be provided in order to protect the sand media from premature clogging. Trenches have experienced fewer problems with clogging than basins, perhaps because their use has been limited more to high impervious cover sites which may generate less suspended solids.

Figures III-3.8 through III-3.15 illustrate trench designs which can be adapted for use as sand filtration systems.

Sand filtration provides runoff treatment but not streambank erosion control, and trenches are to be located off-line from the primary conveyance/detention system. While effective at treating conventional pollutants sand filtration is not effective at removing nutrients. Its use for treating oil is being allowed on an interim basis and sand filtration may substitute for API and CPS-type oil/water separators.

The sand bed filtration system consists of an inlet structure, sand bed, underdrain piping and trench liner. The trench liner will only be required if the treated runoff is not to be allowed to percolate into the soil underlying the filtration basin. A liner would be necessary if the filtered runoff required additional treatment, such as in a wet pond for further nutrient removal, or in cases where additional ground water protection was mandated.

#### *Planning Considerations*

*See Water Quality Infiltration Trench (BMP RI.10) and Sand Filtration Basin (BMP RF.05).*

#### Design Criteria

See Water Quality Infiltration Trench (BMP RI.10) and Sand Filtration Basin (BMP RF.05).

#### Observation Well

An observation well should be installed every 50 feet for the length of the infiltration trench. See the Water Quality Infiltration Trench, BMP RI.10 for detailed specifications of the observation well.

#### Construction and Maintenance Criteria

See Water Quality Infiltration Trench (BMP RI.10) and Sand Filtration Basin (BMP RF.05).

III-3.7.4 BMP RF.15E Aquatard System (Experimental)

Aquatard systems are filtration BMPs which utilize different treatment media than sand. These BMPs will likely provide runoff treatment but not streambank erosion control. Ecology is aware of at least two alternative treatment mediums being tested. One is a compost system which is described in Section I-1.12. The other is a peat-sand filter being tested by the State of Maryland. One of the primary objectives of these experimental filtration systems is to develop a treatment media capable of removing nutrients and other difficult-to-treat pollutants. Ecology will notify the public as developments occur.

**III-3.8 REFERENCES**

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## CHAPTER III-4 DETENTION FACILITIES

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## CHAPTER III-4

## DETENTION FACILITIES

## III-4.1 INTRODUCTION

III-4.1.1 Background

Detention facilities, by design, provide storage of runoff resulting from development. Properly designed detention facilities can provide effective treatment of pollutants contained in stormwater, especially particulates which can settle out during quiescent conditions. In addition, detention BMPs can reduce streambank erosion and flooding by temporarily detaining runoff before releasing it at flowrates and frequencies similar to those occurring under natural hydrologic conditions. Detention facilities include ponds, vaults, and tanks.

III-4.1.2 Purpose and Scope

The purpose of this chapter is to present general and specific criteria for the evaluation, design, construction, and maintenance of detention facilities. In particular, this chapter provides guidance on how BMPs can be designed to accomplish two primary stormwater management objectives, *runoff treatment* and *streambank erosion control* (recall that *source control* is another objective which is required in all cases).

Sections III-4.2 and III-4.3 should be read first as they discuss important concepts and design criteria applicable to detention BMPs. Sections III-4.4 and III-4.5 provide detailed standards and specifications for the following detention BMPs:

BMP RD.05	Wet Pond (Conventional Pollutants)
BMP RD.06	Wet Pond (Nutrient Control)
BMP RD.09	Constructed Wetland
BMP RD.10	Presettling Basin
BMP RD.11	Extended Detention Dry Pond
BMP RD.15	Wet Vault/Tank
BMP RD.20	Extended Detention Dry Vault/Tank

## III-4.2 RUNOFF TREATMENT AND STREAMBANK EROSION CONTROL

III-4.2.1 Background

Minimum Requirements #4 and #5 require development sites to provide runoff treatment and control streambank erosion, respectively (see Chapter I-2). The runoff treatment design storm is the 6-month, 24-hour event. The streambank erosion control standard is to limit peak flows discharged from the *developed* site to 50 percent of the *existing* condition 2-year, 24-hour event and maintain the *existing* condition peak flow rates for the 10-year and 100-year, 24-hour design storms, with appropriate correction factors (see Chapter III-1 for further details).

## Runoff Treatment

Runoff treatment is accomplished by detention BMPs using a variety of pollutant removal mechanisms, including sedimentation, biological uptake, and vegetative filtration. Runoff treatment is to be provided for up to the 6-month, 24-hour design storm. The rationale for selecting this storm is that over 90 percent of the annual runoff events will be captured and treated by BMPs sized for this event. The 6-month, 24-hour storm is determined by multiplying the 2-year, 24-hour event by a factor of 0.64. The size of the 6-month storm averages about 2 inches in the Puget

Sound Basin but will vary from about 0.65 inches to over 3 inches, depending on where a site is located (see the isopluvial maps in the appendix of Chapter III-1).

#### Streambank Erosion Control

Streambank erosion control is accomplished in detention BMPs by detaining runoff and then releasing it back to stream systems at reduced flowrates. The goal is to replicate, to the extent possible, the pre-development hydrologic regime. Streambank erosion control is required whenever discharges are made, directly or indirectly, to a stream system.

A typical detention BMP configuration maintains a permanent pool of water as a "dead storage" area for treatment purposes and a "live storage" area above the permanent pool in order to temporarily detain runoff for streambank erosion control purposes. Figure III-4.1 illustrates this configuration.

Limiting streambank erosion and the destruction of fish habitat can be achieved by limiting the rate of release of runoff from the 2-year design storm to 50 percent of the existing condition rate. This criterion is based on advice from the Washington Department of Fisheries. For further technical details, please contact the Habitat Management Division of that Department. The rationale for this release rate is prevention of both the frequency and duration of flows at the highly erosive bankfull stage. This would occur if the runoff was released at 100 percent of the existing condition rate because of the increased volume of runoff associated with development. If all of the 2-year, 24-hour storm can be infiltrated the restrictive release rate is no longer necessary.

Note that a coincident benefit of this detention requirement is extended detention in many instances. Releasing the runoff from the 2-year storm at 50 percent of the existing condition rate may result in this runoff being detained for approximately 40 hours, or longer. Longer detention periods will be achieved on sites that have higher ratios of pre-developed to post-developed peak flows, lower SCS curve numbers, and longer times of concentration.

The rationale for controlling the large, infrequent storms (i.e., the 10-year and 100-year events) is to provide additional streambank erosion protection as well as flood protection.

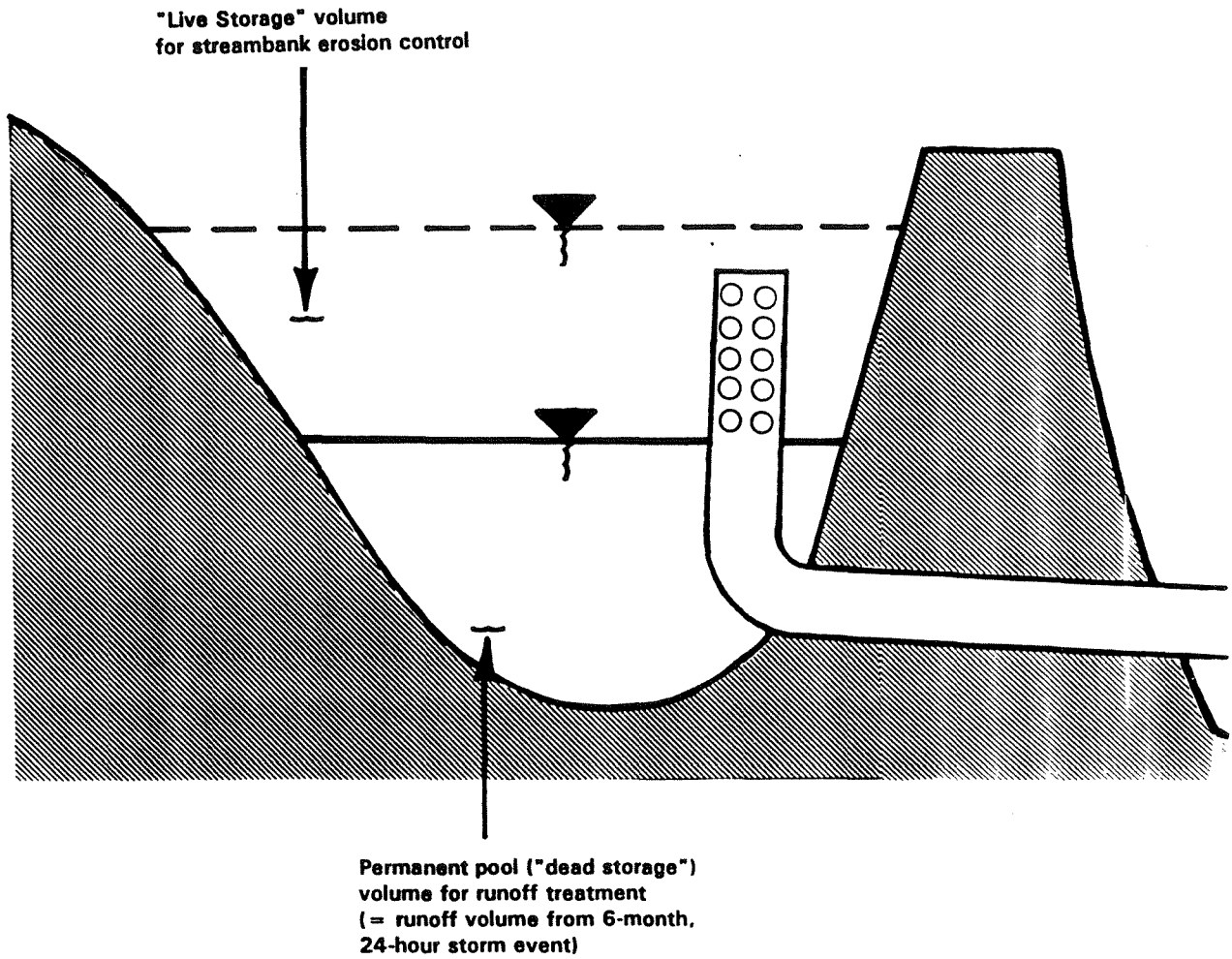
*Note: A correction factor must be applied to the detention volume for streambank erosion control in order to account for weaknesses in current hydrologic analysis methods. When using SCS hydrologic analysis methods to estimate runoff for 24-hour duration storms, the correction factor should vary from 20% for residential areas up to 50% for commercial areas. Until the work on the 7-day design storm, or other alternative methods for estimating runoff is complete the design engineer is advised to apply a correction factor. The correction factor is to be applied to the volume of the BMP without changing the BMP depth or design of the outlet device. See Chapter III-1 for a further discussion of this issue.*

**(Note: An adopted and approved basin plan (Minimum Requirement #9 in Chapter I-2) may be used to develop streambank erosion control requirements that are tailored to a specific basin).**

#### Additional Requirements

Additional requirements may apply if a development discharges into a natural or created (mitigated) wetland, lake, and other sensitive waterbodies (see Minimum Requirements #4 - #7 in Chapter I-2).

Figure III-4.1  
Typical Wet Pond-type Detention BMP





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### III-4.2.2 Mechanisms of Pollutant Removal

Detention BMPs utilize a variety of mechanisms to remove pollutants from stormwater. A primary mechanism is the removal of particulate pollutants using sedimentation; some detention BMPs may also remove particulates using filtration by vegetation. Biological uptake of dissolved pollutants is another mechanism which can be important for controlling nutrients. The type of facility used and the way it is designed will determine the degree to which each process operates, and its efficiency. The pollutants of concern in stormwater include heavy metals (such as lead, copper, zinc, and cadmium), nutrients (nitrogen and phosphorus), certain bacteria and viruses, organics (such as hydrocarbons and pesticides) and sediment. They may be present in water in both dissolved and particulate form. The particulate fraction includes sediment itself, as well as heavy metals, organics and nutrients that may be bound to it. Many of the pollutants of greatest concern are associated with smaller sediment sizes, such as silt and clay. Since the smaller size fractions are of most concern, conditions which promote quiescent settling and extended detention times will be the most effective in removing particulate pollutants. Similarly, long detention times will be necessary to reduce soluble pollutants by biological assimilation.

Detention BMPs which utilize a permanent pool of water are considered the most effective treatment BMPs. These BMPs are known as "wet" ponds, vaults, or tanks. The permanent pond improves the removal efficiency of particulate pollutants by:

- dissipating the inflow energy of the stormwater as it enters the basin
- preventing scour of material settled to the bottom
- allowing exchange of incoming stormwater with previously captured water, thus providing additional time between storms to settle pollutants

"Wet" detention BMPs which establish vegetation within the permanent pool volume can provide additional pollutant removal. The vegetation in such "shallow marsh" areas serves as a filtration media for removing particulate pollutants. Aquatic plants in the permanent pool can assimilate dissolved pollutants. Biological uptake and/or transformation of pollutants into less toxic materials can be an important method of pollutant removal.

*Note: The effectiveness of "shallow marsh" detention BMPs at treating nutrients is under investigation. Because the majority of rainfall in the Northwest occurs in the winter months, when biological activity is low, wet pond BMPs which utilize biological removal mechanisms may not function as effectively as in other regions of the country. The need to control nutrients and other "non-conventional" pollutants may require changes in the current BMP selection strategy and design criteria. Many of the design details given below have been taken from work on the East Coast and elsewhere and will be subject to refinement after further experience is gained in this region. Nevertheless, the details presented in this manual represent the currently available information and should provide a sound basis for design of detention BMPs. For further details on the literature sources, see Stockdale (Reference 1 in Section III-4.4.3, "Constructed Wetlands").*

In cases where a permanent pool cannot be established, the pollutant removal efficiency of detention facilities can be improved by extending the detention period of the runoff from the smaller, more frequent storms (up to the 6-month, 24-hour storm in the Puget Sound basin). Such facilities are called "extended detention" facilities. Some literature recommends that this detention period be from 32 to 40 hours in order to settle out substantial quantities of the common pollutants. However, this may not apply as well to the Pacific Northwest because of the rainfall characteristics of this region. Pollutant removal from runoff from larger storms is not necessary because these infrequent storms only account for a small percentage of the long-term, average annual runoff volume (see Appendix AI-2.1).

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### III-4.2.3 Classification of Detention BMPs

Detention BMPs designed for runoff treatment are classified according to whether they provide *pretreatment* or *primary* treatment of pollutants. Pretreatment BMPs utilize sedimentation as the removal mechanism; runoff is temporarily detained in order to settle out particulate pollutants. Where detention is used to provide *primary* treatment, a permanent pool of water ("dead storage") is established that is more effective at removing pollutants than the temporary detention mechanism used by pretreatment BMPs. Primary treatment BMPs are further classified as either those that provide treatment of "conventional" pollutants or those that treat nutrients in addition to conventional pollutants. Conventional pollutants tend to be particulate in nature whereas nutrients can exist in both particulate and dissolved form. Examples of nutrients are nitrogen and phosphorus. The primary difference between a detention BMP which controls "conventional" pollutants as compared to one that treats nutrients is that a nutrient control BMP has a shallow marsh system established within the permanent pool volume. The permanent pool in the conventional treatment BMP does not have to be vegetated. The determination as to when nutrient control is required, in addition to control of conventional pollutants, is made by the local Plan Approval Authority.

Detention facilities may be either "wet" or "dry," and be either above ground (ponds), or below ground (tanks or vaults). A wet pond, as the name implies, maintains a permanent pool of water (dead storage) for runoff treatment purposes. If streambank erosion control is required then a "live storage" volume is detained. In contrast, a "dry" facility, does not contain this dead storage (except for a few inches for sediment storage) and hence tends to dry out between storms. BMPs labeled as "extended detention" are "dry" facilities, as is the presettling basin (BMP RD.10).

Some detention BMPs can provide either runoff treatment or streambank erosion control while others can be designed to provide both. In general, "wet pond" BMPs can provide both while pretreatment BMPs cannot. Vaults are not considered to be as effective as basins for runoff treatment because the only treatment mechanism utilized by vaults is sedimentation. It should be noted that only "wet" vaults can be used for runoff treatment. The only application where a "dry" vault is permitted is to control streambank erosion after treatment has been provided, i.e., a *dry* vault (BMP RD.20) is always preceded by a treatment BMP.

The presettling basin (BMP RD.10) is a pretreatment BMP that is designed to treat runoff but not control streambank erosion. It will typically precede infiltration and filtration BMPs in order to protect the treatment media of those BMPs from siltation. The extended detention dry pond (BMP RD.11) is essentially a presettling basin that also has a live storage volume in order to control streambank erosion. This BMP may have limited application for new development as it cannot provide an equivalent level of runoff treatment as "wet" pond BMPs. However, it may be a viable option for retrofitting detention ponds which serve existing development. It could also be used in conjunction with a "partial" infiltration BMP for controlling streambank erosion (in which case detention of the water quality storm would not be necessary). Table III-4.1 presents a summary of detention BMP applications.

Table III-4.1  
Classification of Detention BMPs

Pre-treatment (No SBEC)	Pre-treatment with SBEC	Treatment of Conventional Pollutants (SBEC option)	Treatment of Nutrients (SBEC option)	SBEC Only
Presetting Basin (BMP RD.10)	Extended Detention Dry Pond (BMP RD.11)	Wet Pond (BMP RD.05)	Constructed Wetland (BMP RD.09)	Extended Detention Dry Vault-Tank (BMP RD.20)
		Wet Vault/Tank (BMP RD.15)	Wet Pond (BMP RD.06)	

SBEC = Streambank Erosion Control

### III-4.3 GENERAL DESIGN CRITERIA

This section provides the design engineer with general standards and criteria for the design of detention facilities to control surface water flow to reduce erosion and sedimentation, and to provide water quality protection in general.

Detention BMPs are to be designed to provide runoff treatment and/or streambank erosion control. Runoff treatment is required in all cases. Streambank erosion control is required if the development site discharges directly or indirectly to a stream system.

#### III-4.3.1 Hydrologic Analysis

All detention facilities shall be analyzed using the hydrograph methods and routing procedures described in Chapter III-1.

#### III-4.3.2 Sizing Detention BMPs for Runoff Treatment

Detention BMPs will vary in size, even though the runoff treatment volume will be the 6-month, 24-hour design storm in all cases. Wet pond-type BMPs will each have a different surface area-pool depth relationship. Wet pond-type BMPs designed for nutrient control will have the largest areas because of the need to establish shallow marsh areas. Pretreatment BMPs, which do not maintain a permanent pool, will have the smallest surface areas. The following is a list of detention BMPs, in order of decreasing surface area, that can be used for runoff treatment:

1. Constructed Wetland
2. Wet Pond (Nutrient Control)
3. Wet Pond (Conventional Pollutants) and Wet Vault/Tank
4. Presettling Basin

#### Sizing Constructed Wetlands, Wet Ponds and Wet Vaults/Tanks

The permanent pool volume is the same for constructed wetlands, wet ponds, and wet vaults/tanks, i.e., the permanent pool volume equals the runoff volume from the 6-month, 24-hour design storm. However, surface areas will vary with the type of BMP as each has a specific surface area-depth relationship. A constructed wetland, for example, has a large surface area because of the need to establish shallow pool areas (e.g., 50 percent of the surface area should be in pools whose depth is 6 inches or less). The maximum permanent pool depth should not exceed six feet in order to maximize effectiveness and to prevent anaerobic conditions from developing.

Table III-4.2 presents the minimum recommended surface area/pool depth configurations for these BMPs, along with the *maximum* average depth for each.

**Table III-4.2**  
**Surface Area - Pool Depth Relationships**  
**for Wet Pond-type BMPs**

Detention BMP	Pool Depth (feet)	Surface Area (as percent of total BMP surface area)	Maximum Average BMP Depth (feet)*
Constructed Wetland	0 - 0.5	50%	2.05
	0.5 - 1	15%	
	2 - 3	15%	
	3 - 6	20%	
Wet Pond (Nutrient Control)	0 - 2	30%	4.8
	2 - 6	70%	
Wet Pond (Conventional) or Wet Vault/Tank	0 - 6	100%	6.0

\* The average BMP depth is found by summing the products of the pool depths and surface areas (as fraction of total surface area), e.g., for the Wet Pond (Nutrient Control),  $d = (2 \text{ ft} * 0.30) + (6 \text{ ft.} * 0.70) = 4.8 \text{ feet.}$

Using Table III-4.2, the size of each BMP can be found since the volume of the BMP is simply the product of the average surface area and the average pool depth. A sizing example is given below which illustrates this.

*Sizing Example for Constructed Wetland (BMP RD.09)*

A proposed development site will be 10 acres in size with 35 percent impervious cover. The runoff volume for the 6-month, 24-hour design storm ( $P = 2"$ ) is calculated to be 0.7-inch, or 0.292 acre-feet (12,705 square feet). Determine the minimum size of a constructed wetland used to treat the 6-month storm for this site.

The permanent pool volume of each of the BMPs is given by the equation:

$$V_{pp} = A_s * d \text{ where}$$

$A_s$  is the average surface area for the BMP and  
 $d$  is the average permanent pool depth of the BMP

Solving for  $A_s$  gives:

$$A_s = \frac{V_{pp}}{d}$$

$V_{pp}$  is equal to the volume of the 6-month, 24-hour design storm (= 0.7-inch or 12,705 sq.ft.) and the maximum average depth,  $d$ , is 2.05 feet, as shown in Table III-4.2. Therefore the minimum surface area of the constructed wetland will be:

$$A_s = \frac{12,705 \text{ sq.ft.}}{2.05 \text{ ft.}} = \underline{6,198 \text{ sq.ft.}}$$

The surface area and volume of each of the pool depths is then found, using Table III-4.2 for guidance:

Size of Constructed Wetland for Example Problem

Pool Depth (feet)	Surface Area as a percent of Total Surface Area	Surface Area (sq.ft.)	Pool Volume (cu.ft.)
0.5	50%	3099	1550
1.0	15%	930	9303
3.0	15%	930	2788
6.0	20%	1239	7437
	100%	6198	12705

Sizing of Presettling Basins

Presettling basins are designed to settle out particulate pollutants for a range of runoff volumes, up to the 6-month, 24-hour storm. Sizing is based on application of a settling equation; in this manual the Camp-Hazen equation is recommended:

- E =  $1 - \exp(-wA_s/Q_0)$  where
- E = fraction of particulates to remove; set equal to 0.8 (= 80% removal efficiency is recommended);
- w = settling velocity of target particle; silt is recommended using a settling velocity of 0.0004 ft/sec.
- $A_s$  = surface area of presettling basin
- $Q_0$  = average release rate from the presettling basin.

Rearranging the Camp-Hazen equation and solving for  $A_s$  gives:

$$A_s = -(Q_0/w) * \ln(1-E) \text{ where } \ln \text{ is the natural logarithm}$$

The average release rate,  $Q_0$ , is found by dividing the runoff treatment volume (maximum = runoff from 6-month, 24-hour storm) by the design detention time (maximum of 24 hours recommended).

A more complete discussion is provided under "Design Criteria" in Section III-4.4.4 (BMP RD.10, Presettling Basin). However, protection of beneficial uses in receiving waters will always be required. There may be instances, depending on the nature of pollutants to be controlled and the receiving waters, when a higher removal rate, and hence larger surface area, will be required by the local government and/or Ecology or other State agencies.

Ratio of Surface Area-to-Total Drainage Area for Detention BMP

The ratio of the BMP surface area to the total drainage area can be an important planning consideration for development projects. While the exact ratio will be site specific, a general range of values can be estimated for each of the detention BMPs used for runoff treatment. Four case studies were analyzed to compare the surface areas for each BMP, using the SBUH hydrologic analysis method presented in Chapter III-1. For wet pond-type BMPs the information in Table III-4.2 was used; for the Presettling Basin the Camp-Hazen equation was solved for the 6-month, 24-hour design storm. The results are shown in Table III-4.3. Note that the constructed wetland has a much larger surface area requirement than the other BMPs. Constructed wetlands should be considered as facilities which provide additional benefits beyond those needed for stormwater management (e.g., aesthetic amenity, recreational facility, wildlife habitat).

Table III-4.3  
 Minimum Surface Area-to-Drainage Area Ratios  
 for Runoff Treatment Detention BMPs  
 (Example Case Studies)

-----  $A_s/A_d$  -----

Case No.	Site IC (%)	Treatment Volume (ac-ft)	Constructed Wetland	Wet Pond (Nutrient Control)	Wet Pond (Conventional) or Wet Vault/Tank	Presettling Basin
1	25	0.59	2.9%	1.2%	1.0%	0.27%
2	50	0.89	4.3%	1.8%	1.5%	0.41%
3	75	1.18	5.8%	2.5%	2.0%	0.55%
4	100	1.48	7.2%	3.1%	2.5%	0.69%

Notes:  $A_s$  = Surface Area of BMP  
 $A_d$  = Drainage Area  
 IC = "Impervious Cover"  
 Treatment Volume = volume of runoff from the 6-month, 24-hour storm; for wet pond BMPs this is the "permanent pool" volume

Rainfall volume for the 6-month, 24-hour storm = 2.0 inches  
 Drainage area = 10 acres  
 Pervious Area CN = 74; Impervious Area CN = 98  
 Presettling Basin designed for 80% removal efficiency and 24 hour detention time.

III-4.3.3 Sizing Detention BMPs for Streambank Erosion Control

Detention BMPs can be designed to provide streambank erosion control by temporarily detaining runoff and releasing it such that the peak flows released from the *developed* site will be limited to 50 percent of the *existing* condition 2-year, 24-hour event while maintaining the *existing* condition peak flow rates for the 10-year and 100-year, 24-hour design storms, with appropriate correction factors (see Section III-4.2.1 for discussion of the correction factor). Detention BMPs which have permanent pools (i.e., "wet ponds") can provide streambank erosion control by including a "live storage" volume above the permanent pool ("dead storage") volume.

The "live storage" volume can be added to "wet pond" detention BMPs by simply increasing the depth of the BMP since there are no surface area-depth requirements for streambank erosion control. Thus, "wet pond" BMPs which provide streambank erosion control can have depths greater than six feet as long as the "permanent pool" volume used for *runoff treatment* does not exceed six feet.

### III-4.4 STANDARDS AND SPECIFICATIONS FOR DETENTION PONDS

#### III-4.4.1 BMP RD.05 Wet Pond (Conventional Pollutants)

##### Purpose and Definition

This BMP is designed to provide runoff treatment for conventional pollutants but not nutrients. It may also be designed to provide streambank erosion control. A wet pond is an open pond which treats runoff using a permanent pool of water ("dead storage"). As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment (see BMP RD.06, Wet Pond for Nutrient Control). Streambank erosion control is provided in the "live storage" area above the permanent pool. Figure III-4.1 illustrates a typical wet pond BMP.

##### Planning Considerations

Wet ponds require careful planning in order to function correctly. Throughout the design process the designer should be committed to considering the potential impacts of the completed facility. Such impacts can be positive or negative and can be as broadly classified as social, economic, political, and environmental. Designers can often influence the positive or negative aspects of these impacts by their careful evaluation of decisions made in the design process. Generally speaking, the completed facility must provide for safety to people as well as protection of real property, water quality, and wildlife habitats.

##### Multiple Uses

Multi-purpose use of the facility and aesthetic enhancement of the general area should also be major considerations. Above all, the facility should function in such a manner as to be compatible with overall stormwater systems both upstream and downstream to promote a watershed approach to providing stormwater management as well as local flood control and erosion protection.

If the facility is planned as an artificial lake to enhance property values and promote the aesthetic value of the land, pretreatment in the form of landscape retention areas or perimeter swales should be incorporated into the stormwater management facility. If possible, catchbasins should be located in grassed areas. By incorporating this "treatment train" concept into the overall collection and conveyance system, the engineer can prolong the utility of these permanently wet installations and improve their appearance. Any amount of runoff waters, regardless how small, that is filtered or percolated along its way to the final detention area can remove oil and grease, metals, and sediment. In addition, this will reduce the annual nutrient load to prevent the wet detention lake from eutrophying.

Detention system site selection should consider both the natural topography of the area and property boundaries. Aesthetic and water quality considerations may also dictate locations. For example, ponds with wetland vegetation are more aesthetically pleasing than ponds without vegetation. Ponds containing wetland vegetation also provide better conditions for pollutant capture and treatment.

A storage facility is an integral part of the environment and therefore should serve as an aesthetic improvement to the area if possible. Use of good landscaping principles is encouraged. The planting and preservation of desirable trees and other vegetation should be an integral part of the storage facility design.

##### Water Quality Considerations

In planning new detention facilities, it should be kept in mind that the goal of improved water quality downstream may conflict with certain desired uses of the facility. It is only logical that if the basin is used to remove pollutants, the

water quality within the basin itself will be lowered, thus reducing the applicability for uses such as water supply, recreation, and aesthetics. In planning the facility the engineer or planner should have a good knowledge of site-specific runoff constituents and an understanding of the possible effects on the quality of the stored water.

#### Basin Planning

The design of urban detention facilities should be coordinated with a basin plan for managing stormwater runoff. In a localized situation, an individual property owner can, of course, by his or her actions alone, provide effective assistance to the next owner downstream if no other areas contribute to that owner's problems. However, uncontrolled proliferation of impoundments within a watershed can severely alter natural flow conditions, causing compounded flow peaks or increased flow duration which can contribute to downstream degradation. In addition, upstream impacts due to future land use changes should be considered when designing the structure. Land use planning and regulation may be necessary to preserve the intended function of the impoundment. See Minimum Requirement #9 (Basin Planning) and the appendix in Volume I for a further discussion of basin planning.

#### Sediment and Debris

More often than not, detention ponds serve primarily as sedimentation basins during construction when erosion rates are particularly high. In and of itself, this situation does not present a problem. Unfortunately, these facilities are often installed without the benefit of the designer having evaluated the capacity of either the initial or the final (post-construction) design configuration to perform this type of function.

If a facility is to be used as the principal means to avoid having excessive levels of turbidity discharged from the site during construction, the engineer should evaluate the pond geometry in conjunction with the rate of outflow and grain size distribution of the soils and design the temporary sediment basin according to BMPs E3.35 or E3.40 in Volume II.

#### Heavy Metal Contamination

Studies have shown high accumulation rates of lead, zinc, and copper on and near heavily traveled highways and streets. Runoff from highways and streets can be expected to carry significant concentrations of these heavy metals. If a significant portion of the drainage area into a pond consists of highways, streets, or parking areas or other known sources of heavy metal contamination, there is a potential environmental health hazard. In such cases the multiple use functions of the pond should be limited and accessibility should be restricted. Additionally, liners may be required in order to prevent these types of pollutants from migrating into the underlying soil and ground water system.

This may require that sediment dredged out of the basins during maintenance cleaning be treated as a Dangerous Waste. Investigations of sediments removed from detention ponds to date have found that many pollutants are tightly bound with only a slight possibility of leaching. To be safe, sediments to be removed should be analyzed and elutriate tests performed to verify that the sediment can be safely disposed of by conventional methods (see Volume IV, Catchbasin Sediment Disposal Policy (to be written) which deals with disposal procedures).

#### Overflows

Detention facility design must take into consideration overflows and secondary overflow. Overflows include all facilities designed to bypass flows over or around the restrictor system. Overflow may result from higher intensity or longer duration storms than the design storm or result from plugged orifices or inadequate storage



due to sediment buildup in the facility.

Secondary overflow occurs when the capacities of all conveyance facilities, and all overflow facilities are exceeded or are not functioning. In such instances, stormwater will often exit the conveyance system through catchbasin grates and flow down the corridor of least resistance. Careful consideration must be given to the impact of secondary overflows on public health, safety and welfare, property, and wildlife habitat. When secondary overflow occurs, design of secondary drainage facilities following careful analysis and planning can significantly reduce impacts. Street alignments and grades are the key components in developing secondary drainage design, and consideration should be given early in the planning stages to their use as secondary overflow facilities.

#### Site Constraints and Setbacks

Site constraints are any manmade restrictions such as property lines, easements, structures, etc. that impose constraints on development. Constraints may also be imposed from natural features such as requirements of the local government's Sensitive Areas Ordinance and Rules (if adopted). These should also be reviewed for specific application to the proposed development.

All facilities shall be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government, and 100 feet from any septic tank/drainfield (except wet vaults shall be a minimum of 20 feet).

All facilities shall be a minimum of 50 feet from any steep (greater than 15%) slope. A geotechnical report must address the potential impact of a wet pond on a steep slope.

#### Dam Safety

In urban or urbanizing areas, failure of an impoundment structure can cause significant property damage and even loss of life. Such structures should be designed only by professional engineers registered in the State of Washington who are qualified and experienced in impoundment design. Wherever they exist, local safety standards for impoundment design shall be followed. Where no such criteria exist, widely recognized design criteria such as those used by the USDA Soil Conservation Service, Ecology Dam Safety Standards, or U.S. Army Corps of Engineers are recommended.

#### Safety, Signage and Fencing

Ponds which are readily accessible to populated areas should incorporate all possible safety precautions. Steep side slopes (steeper than 3H:1V) at the perimeter shall be avoided and dangerous outlet facilities shall be protected by enclosure. Warning signs for deep water and potential health risks shall be used wherever appropriate. Signs should be placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks or paths. A notice should be posted warning residents of potential waterborne disease that may be associated with body contact recreation such as swimming in these facilities.

If the pond surface exceeds 20,000 sq. feet, include a safety bench around the basin with a width of 5 feet, and with a depth not exceeding 1 foot during non-storm periods. Emergent vegetation such as cattails should be placed on the bench to inhibit entry by unauthorized people.

A fence is required at the maximum water surface elevation, or higher, when a pond slope is a wall. Local governments and Homeowners Associations may also require appropriate fencing as an additional safety requirement in any event.

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## Design Criteria

### Sizing Wet Ponds

Wet ponds designed for treatment of conventional pollutants utilize a permanent pool of water to provide treatment and are to be designed using the hydrologic analysis methods presented in Chapter III-1.

#### Permanent Pool Volume

The permanent pool volume shall be equal to the runoff volume of the 6-month, 24-hour design storm. It is not necessary to vegetate the permanent pool, but establishment of a shallow marsh system can provide additional pollutant removal capabilities.

#### Surface Area-Pool Depth Relationships

The pond surface area is found by dividing the permanent pool volume by the depth, with a maximum depth of six (6) feet recommended. A minimum depth of three (3) feet is recommended so that resuspension of trapped pollutants is inhibited. Permanent ponds deeper than six (6) feet could potentially contaminate ground water (should they intersect the existing ground water level). Also, deeper ponds can stratify and create anaerobic condition that can cause pollutants which are normally bound in the sediment (e.g., metals and phosphorus) to resolubilize; their release back to the water column can seriously affect the effectiveness of the BMP and also create nuisance conditions.

See Table III-4.2 for the surface area-pool depth relationship. Table III-4.3 illustrates typical surface area-to-drainage area ratios for this and other detention BMPs.

If the wet pond is also designed to provide streambank erosion control, then additional surface area and depth will be required for the "live storage" volume located above the permanent pool. There is no specific surface area-pool depth relationship for the "live storage" volume.

Ponds designed to provide streambank erosion control may be deeper than six feet as long as the permanent pool volume provided for runoff treatment does not exceed six feet.

#### Outlet Structure

The outlet structure must be designed to accomplish an extended detention time so that runoff can be released at the flow rates established by Minimum Requirement #5, Streambank Erosion Control (see Chapter I-2). Figure III-4.3 illustrates methods for extending detention time in wet ponds.

#### Pond Configuration and Geometry

Wet ponds shall be multi-celled with a least two cells, and preferably three. The cells should be approximately equal in size. The first cell should be three feet deep in order to effectively trap coarser sediments and reduce turbulence which can resuspend sediments. It should be easily accessible for maintenance purposes.

Long, narrow, and irregularly shaped ponds are preferred, as these configurations are less prone to short-circuiting and tend to maximize available treatment area. The length-to-width ratio should be at least 3:1 and preferably 5:1. Irregularly shaped ponds may perform more effectively and will have a more natural appearance.

The inlet and outlet should be at opposite ends of the pond where feasible. If this is not possible, then baffles can be installed to increase the flow path and water residence time (see BMP RD.10, Presettling Basin, for details).

Interior side slopes up to the maximum water surface shall be no steeper than 3H:1V. Exterior side slopes shall be no steeper than 2H:1V.

The pond bottom shall be level to facilitate sedimentation.

Pond walls may be retaining walls, provided that the design is prepared and stamped by a structural engineer registered in the State of Washington, that they are constructed of reinforced concrete per Section III-4.6.1, that a fence is provided along the top of the wall, and that at least 25 percent of the pond perimeter will be a vegetated soil slope of not greater than 3H:1V.

#### Other Design Considerations

##### Liner to Prevent Infiltration

Detention BMPs should have negligible infiltration rates through the bottom of the pond. Infiltration will impair the proper functioning of detention BMPs and can contaminate ground water. If infiltration is anticipated, then a detention facility must either **not** be used and an infiltration BMP used instead (see Chapter III-3) or a liner should be installed to prevent infiltration. If a liner is used, the specifications provided in Section III-3.7 (Filtration BMPs) can be used. When using a liner the following are recommended:

- A layer of (track) compacted top soil (minimum 18" thick shall be placed over the liner prior to seeding with an appropriate seed mixture (see BMP E1.35 in Chapter II-5).
- Other liners may be used provided the design engineer can supply support documentation that the material will provide the required performance.

##### Overflow and Emergency Spillway

If streambank erosion control is not required, a pond overflow system must provide controlled discharge of the 100-year, 24-hour design storm event for developed site conditions without overtopping any part of the pond embankment or exceeding the capacity of the emergency spillway. The design must provide controlled discharge directly into the downstream conveyance system. This assumes the pond will be full due to plugged control structure inflow pipe and/or plugged restrictor/orifices conditions.

Open Type 2 catchbasins can function as weirs when used as pond overflow structures to control overtopping. The overflow structure, as shown in Figure III-4.5, may be required in some circumstances to protect embankments from overtopping.

In addition to the above overflow requirements, an emergency overflow spillway (secondary overflow) must be provided to safely pass the 100-year, 24-hour design storm event (for developed site conditions and assuming the pond is full to the crest of the spillway) over the pond embankment in the event of control structure failure or for storm/runoff events exceeding design. The spillway must be located to direct overflows safely towards the downstream conveyance system and shall be located in existing soil wherever feasible. The emergency overflow spill shall be armored with riprap in conformance with Table III-2.4 and shall extend to the toe of each face of the berm embankment.

- Design of emergency overflow spillways requires the analysis of a broad-crested trapezoidal weir. The following weir section is required for the emergency overflow spillway, as per Figure III-4.4.

Figure III-4.2 Methods for Extending Detention Time in Wet Ponds

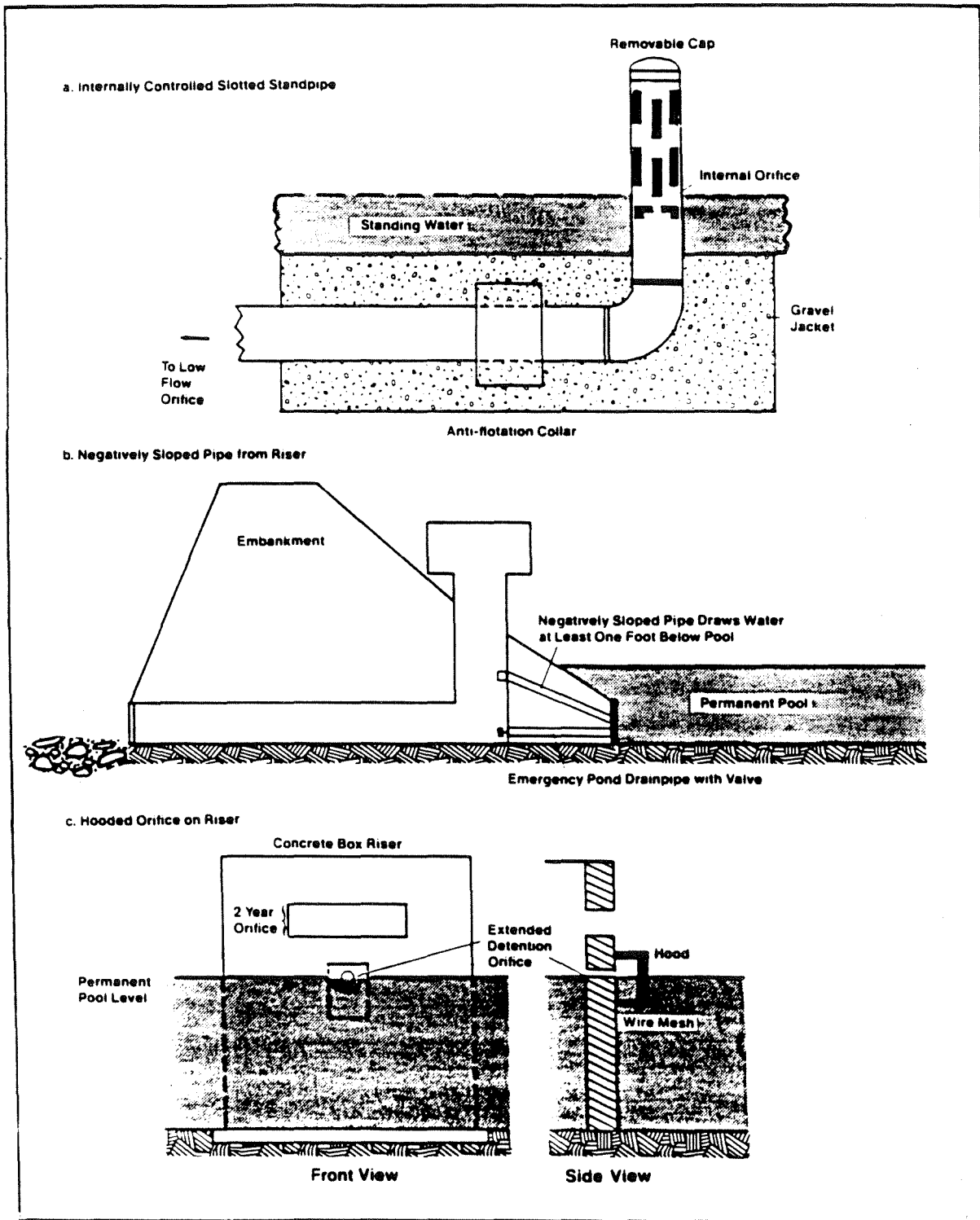
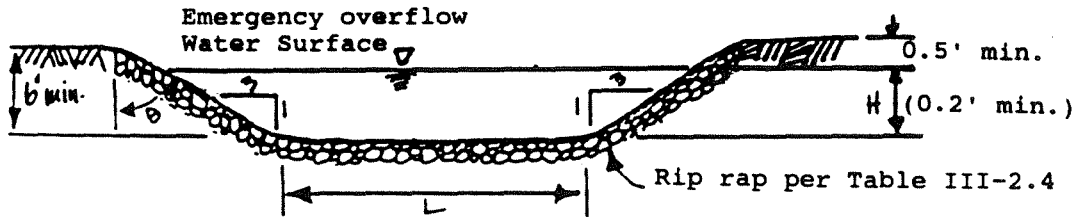


Figure III-4.3 Weir Section for Emergency Overflow Spillway



- The emergency overflow spillway weir section can be designed to pass the 100-year, 24-hour design storm event for developed conditions as follows:

For this weir,  $Q_{100} = C (2g)^{1/2} [(2/3)LH^{3/2} + 8/15 \tan \theta H^{5/2}]$

using:  $C = 0.6$  (discharge coefficient);  
 $\tan \theta = 3$  (for 3:1 slopes);  
 $\theta = 72^\circ$ ;

The equation becomes:  $Q_{100} = 3.21 (LH^{3/2} + 2.4H^{5/2})$

To find width L, the equation is rearranged to use the computed  $Q_{100}$  (peak flow for the 100-year, 24-hour design storm) and trial values of H (0.2 feet minimum).

$L = (Q_{100}/(3.21H^{3/2})) - (2.4H^{5/2})$ ;  
 $= 6$  feet minimum

**Berm Embankment/Slope Stabilization**

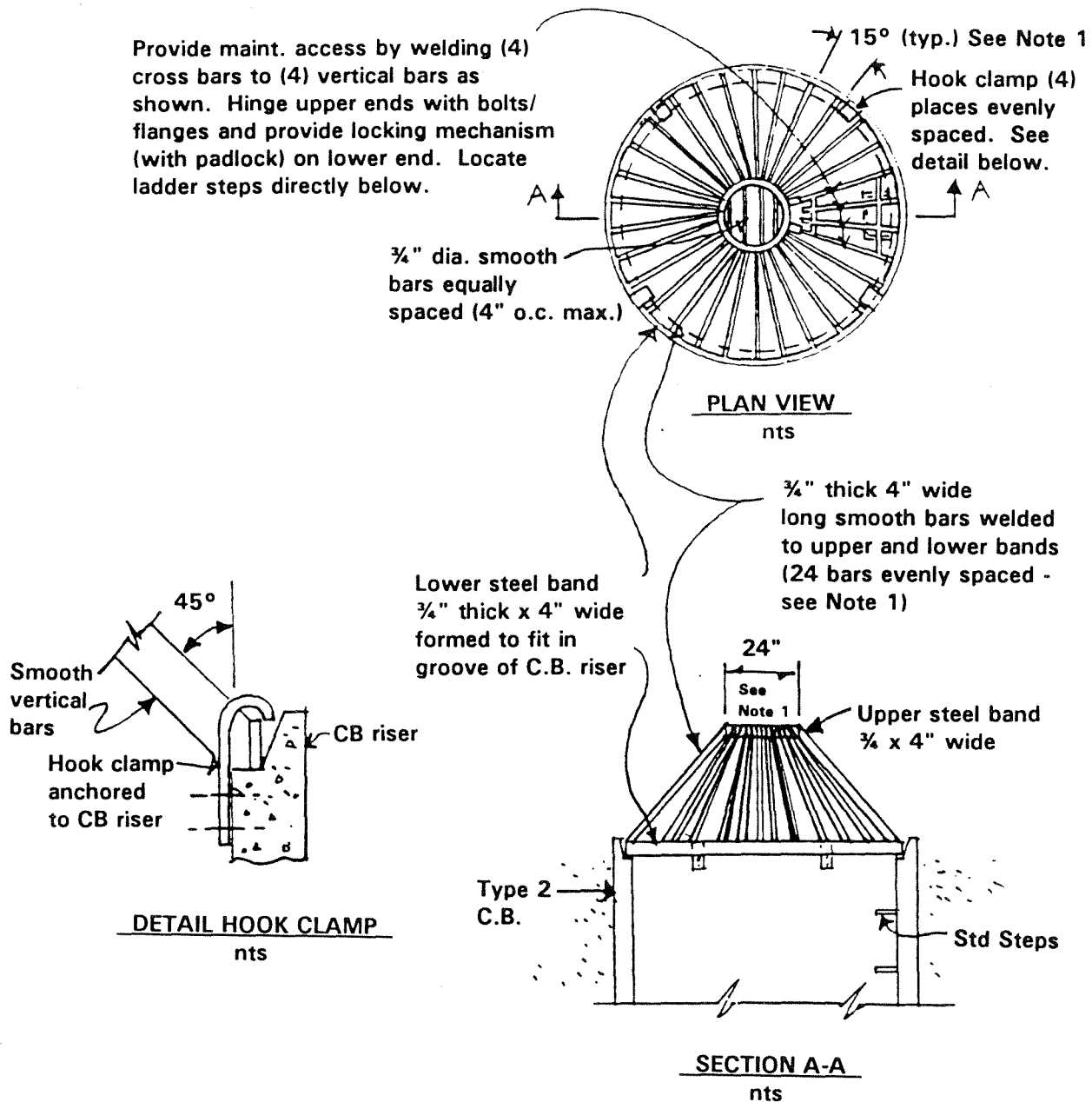
Pond embankments higher than 6 feet shall require design by a geotechnical-civil engineer licensed in the State of Washington. The embankment shall have a minimum 15 foot top width where necessary for maintenance access; otherwise, top width may vary as recommended by the geotechnical-civil engineer.

The berm dividing the pond into cells shall have a 5 foot minimum top width, a top elevation set one foot lower than the design water surface, maximum 3:1 side slopes, and a quarry spall and gravel filter "window" between the cells (see Figure III-4.5).

For berm embankments of 6 feet or less than (including 1 foot freeboard), the minimum top width shall be 6 feet or as recommended by the geotechnical-civil engineer.

The toe of the exterior slope of pond berm embankment must be no closer than 5 feet from the tract or easement property line.

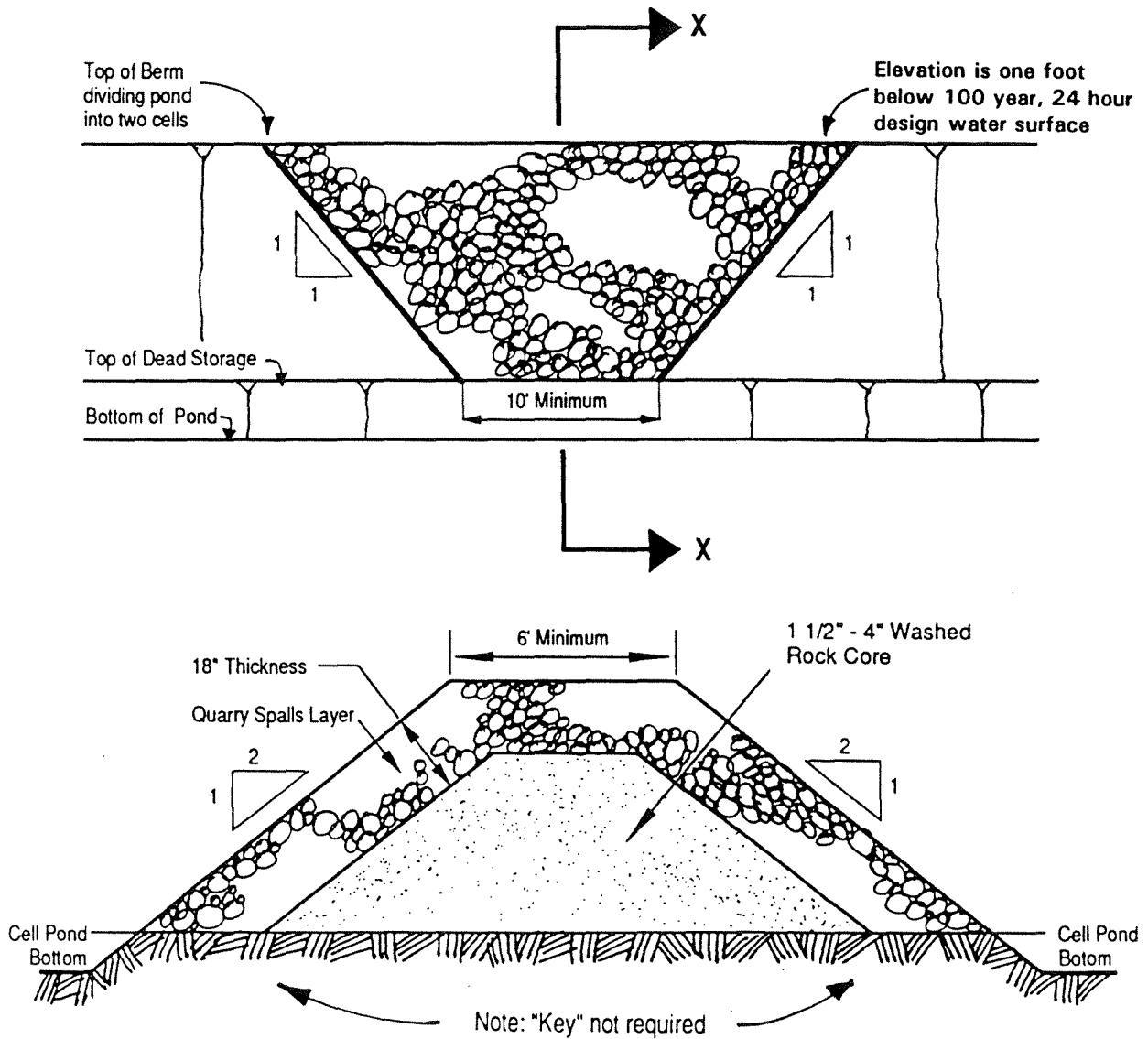
Figure III-4.4 Detention Pond Overflow Structure



Notes:

1. Dimensions are for installation on 54" dia. C.B. For different dia. C.B.'s adjust dimensions to maintain 45° angle on "vertical" bars and 7" O.C. max. spacing of bars around lower steel band.
2. Metal parts: corrosion resistant.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection (except on Class 2 streams).

Figure III-4.5 Quarry Spall and Gravel Filter "Window"



Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) free of loose surface soil materials, roots and other organic debris.

Pond berm embankments must be constructed by excavating a "key" equal to 50 percent of the berm embankment cross-sectional height and width (except on highly compacted till soils where the "key" minimum depth can be reduced to 1 foot of excavation into the till).

The berm embankment shall be constructed on compacted soil (95 percent minimum dry density, standard proctor method per ASTM D1557), placed in 6-inch lifts, with the following soil characteristics per the United States Department of Agriculture's Textural Triangle: a minimum of 30 percent clay, a maximum of 60 percent sand, a maximum of 60 percent silt, with nominal gravel and cable content (Note, in general, excavated glacial till will be well-suited for berm embankment material).

Anti-seepage collars must be placed on outflow pipes in berm embankments impounding water greater than 8 feet in depth at the design water surface.

Exposed earth on the pond bottom and side slopes shall be sodded or seeded with the appropriate seed mixture as soon as is practicable (see Erosion and Sediment Control BMP E1.35 in Volume II). Establishment of protective vegetative cover shall be ensured with jute mesh or other protection and reseeded as necessary (see Erosion and Sediment Control BMPs E1.15 and E1.35 in Volume II).

#### Gravity Drain

A gravity drain for maintenance shall provide an outlet invert of one foot above the bottom of the facility and shall be sized to drain the facility in four hours or less.

#### Erosion and Sediment

Bank erosion is often a significant problem during the initial stages of development. Stabilization with sod down to the permanent pool and preventing undue sediment deposition is required for the planting to survive.

Erosion and sediment control BMPs must be used to retain sediment on-site during construction (see Erosion and Sediment Control in Volume II). BMPs must be shown on the design plans and the engineer must provide instructions for proper O&M. Permanently stabilize all areas above the normal water level of ponds to prevent erosion and sedimentation of plantings (see Chapter II-5).

#### Littoral Zone Planting

For treating conventional pollutants a wet pond does not require the establishment of vegetation in its shallow areas, or "littoral zones." However, a shallow marsh system can provide additional treatment of runoff and be aesthetically pleasing (see BMP RD.06, Wet Pond for Nutrient Control, for details). If littoral zone vegetation is planned it shall be planted according to the advice of a wetlands specialist. Nursery sources are recommended wherever possible. Small (2-4 inch) containers are encouraged to avoid transporting large amounts of potting soil to the pond. White roots and active basal budding indicate a healthy stock.

Most wetlands specialists prefer to have someone on-site during the construction phase to ensure that the littoral shelf is located and graded properly. Knowing exactly where the normal water level of the facility will reside after construction is absolutely essential to the success of this element of the system.



## Construction and Maintenance Criteria

### Construction

Widely acceptable construction standards and specifications such as those developed by the USDA - Soil Conservation Service or the U.S. Army Corps of Engineers for embankment ponds and reservoirs should be followed to build the impoundment.

Chapter 17 of the SCS Engineering Field Manual provides guidance on construction methods for the various elements of a pond or reservoir. Specifications for the work should conform to methods and procedures for installing earthwork, concrete, reinforcing steel, pipe, water gates, metal work, woodwork, and masonry, that are applicable to the site and the purpose of the structure, and satisfy all requirements of the local government.

### Maintenance

#### General

Maintenance is of primary importance if detention ponds are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or some individual shall accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan shall be formulated outlining the schedule and scope of maintenance operations. Debris removal in detention basins can be achieved through the use of trash racks or other screening devices.

Design with maintenance in mind. Good maintenance will be crucial to successful use of the impoundment. Hence, provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Table III-4.4 for specific maintenance requirements.

Any standing water removed during the maintenance operation must be disposed of to a sanitary sewer at an approved discharge location. Residuals must be disposed in accordance with current health department requirements of the local government.

#### Vegetation

If a shallow marsh is established, then periodic removal of dead vegetation will be necessary. The frequency of removal has not been established and Ecology requests comments on this issue. Since decomposing vegetation can release pollutants captured in the wet pond, especially nutrients, it may be necessary to harvest dead vegetation annually prior to the winter wet season. Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur. If harvesting is to be done in the wetland, a written harvesting procedure shall be prepared by a wetland scientist and will be submitted with the drainage design to the local government.

#### Sediment

Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be continually monitored in the basin. Owners, operators, and maintenance authorities should be aware that significant concentrations of heavy metals (e.g., lead, zinc, and cadmium) as well as some organics such as pesticides, may be expected to accumulate at the bottom of these treatment facilities. Testing of sediment, especially near points of inflow, should be conducted regularly to determine the leaching potential and level of accumulation of hazardous material before disposal. For disposal procedures, refer to Volume IV - disposal requirements for catchbasin and pond sediments (to be written).

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### Access

Pond access tracts and roads are required when ponds do not abut public right-of-way. Road(s) shall provide access to the control structure and along side(s) of the pond as necessary for vehicular maintenance. For ponds with bottom widths of 15 feet or more, the access road shall extend to the pond bottom and an access pad provided to facilitate cleaning. For ponds less than 15 feet in width, an access road must extend along one side.

Roads and pads shall meet the following criteria:

- Maximum Grade: 15 percent to control structure, 20 percent into pond.
- Provide 40 foot minimum outside radius on the access road to the control structure and the turn around to the pond bottom.
- Fence gates shall be provided for access roads at "straight" sections of road.
- Access roads shall be 15 feet in width.
- Access pads shall be 15 feet in width and 25 feet in length.
- Manhole and catchbasin lids must be at either edge of an access road or pad and be at least 3 feet from a property line.

Access shall be limited by a double-posted gate if a fence is required or by bollards. Bollards shall consist of two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.

Access roads and pads shall be constructed by utilizing one of the following techniques:

- Construct an asphalt surface meeting the same standard as residential minor access streets, as required by the local government.
- Construct a gravel surface road by removing all unsuitable material, laying a geotextile fabric over the native soil, placing quarry spalls (2"-4") six inches thick then providing a two-inch thick crushed gravel surface.
- Construct a landscape block (24"x24"x 6") surface by removing all unsuitable material, laying a geotextile fabric over the native soil, placing landscape blocks, filling the honeycombs with soil particles, and planting grass.

### Nuisance Conditions

The presence of wet ponds and marshes in established urban areas is perceived by many people to be undesirable. They are often thought of as mud holes where mosquitoes and other insects breed. If the wet pond has a shallow marsh established (more likely in the cases of BMP RD.06 and BMP RD.09), the pond can become a welcomed addition to an urban community. Constructed fresh water marshes can provide miniature wildlife refuges, and while insect populations are increased, insect predators also increase, often reducing the problem to a tolerable level. Advice from the University of Washington (Rick Sugg, personal communication) suggests that in the Puget Sound lowlands, the extra breeding habitat provided by any wetponds would not be significant. Nevertheless, local governments and homeowners associations may wish to temporarily drain wet ponds during late spring (May) and summer if there is sufficient concern. However, it is imperative that vegetation in shallow marsh areas not die off during draindown periods. Otherwise, the pollutant removal effectiveness of the wet pond can be severely impacted. In addition, the decaying vegetation can create nuisance conditions.

Table III-4.4 Specific Maintenance Requirements for Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
I. Ponds - General	Trash and debris	Any trash or debris which exceeds 1 ft <sup>3</sup> /1000 ft <sup>2</sup> (equal to the volume of a standard size office garbage can). In general, there should be no evidence of dumping.	Trash and debris cleared from site.
	Poisonous vegetation	Any poisonous vegetation which may constitute a hazard to maintenance personnel or the public, e.g. tansy, poison oak, stinging nettles, devils club.	No danger of poisonous vegetation where maintenance personnel or the public might normally be. Coordinate with the local county health dept.
	Pollution	1 gallon or more of oil, gas or other contaminants <u>or</u> any amount found that could: 1) cause damage to plant, animal or marine life, 2) constitute a fire hazard, 3) be flushed downstream during storms or 4) contaminate ground water.	No contaminants present other than a surface film. Coordinate with the local county health dept.
	Unmowed grass/ground cover	In residential areas, mowing is needed when the cover exceeds 18 inches in height. Otherwise, match facility cover with adjacent ground cover and terrain as long as there is no decrease in facility function.	When mowing is needed, grass or ground cover should be mowed down to 2 inches. A dense grass cover must be maintained on slopes, and in dry ponds on the bottom as well.
	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. Coordinate with the local county health dept.
	Insects	When insects such as wasps or hornets interfere with maintenance activities.	Insects destroyed or removed from site. Coordinate with people who remove wasps for anti-venom production.
	Tree growth	Tree growth does not allow maintenance access or interferes with maintenance activity. If trees are not interfering with access, leave trees alone.	Trees do not hinder maintenance activities. Selectively cultivate trees such as alders for firewood.
Side Slopes of Pond	Erosion	Eroded damage > 2 inches deep where cause of damage is still present or where there is potential for continued erosion.	Slopes should be stabilized with appropriate erosion control BMPs e.g. seeding, plastic covers, riprap.
Storage Area, Forebay	Sediment	Accumulated sediment that exceeds 10% of the designed forebay depth, or every three years.	Sediment cleaned out to designed pond shape and depth; reseeded if necessary to control erosion.
Pond Dikes	Settling	Any part of dike which has settled 4 inches lower than the design elevation.	Dike should be built back to the design elevation.
Emergency Overflow, Spillway	Rock missing	Only 1 layer of rock above native soil in an area $\geq 5 \text{ ft}^2$ or any exposure of native soil.	Replace rock to design standards.
II. Debris Barriers - General	Trash and debris	Trash or debris that is plugging $\geq 20\%$ of the openings in the barrier.	Barrier clear to receive capacity flow.

STORMWATER MANAGEMENT MANUAL FOR THE PUGET SOUND BASIN

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed	
III. Fencing - General	Metal Damaged/missing bars	Bars are bent out of shape $\geq 3$ inches. Bars or entire barrier is missing. Bars are loose and rust is causing 50% deterioration to any part of the barrier.	Bars in place with no bend $\geq 3/4$ ". Bars in place according to design. Repair or replace barrier to standards.	
	Missing or broken parts	Any defect in the fence that permits easy entrance to the facility. Parts broken or missing.	Parts in place to provide adequate security. Broken or missing parts replaced.	
	Erosion	Erosion $\geq 4$ inches deep and 12 - 18 inches wide permitting an opening under the fence.	No opening under the fence $\geq 4$ inches in depth.	
Wire Fences	Damaged parts	Posts out of plumb more than 6 inches.	Posts plumb within $1\frac{1}{2}$ inches.	
		Top rails bent more than 6 inches.	Top rail free of bends $\geq 1$ inch.	
		Any part of fence (including posts, top rails and fabric) $\geq 1$ foot out of design alignment.	Fence is aligned and meets design standards.	
		Missing or loose tension wire.	Tension wire in place & holding fabric.	
		Missing or loose barbed wire sagging more than $2\frac{1}{2}$ inches between posts.	Barbed wire in place with $< 3/4$ inch sag between posts.	
IV. Gates - General	Deteriorated paint or protective coating	Extension arm missing, broken or bent out of shape more than $1\frac{1}{2}$ inches.	Extension arm in place with no bends larger than $3/4$ inch.	
		Part(s) that have a rusting or scaling condition which has affected structural adequacy.	Structurally adequate posts or parts with a uniform protective coating.	
		Openings in fabric	Openings in fabric are such that an 8 inch diameter ball could fit through.	No openings in fence.
		Damaged or missing members	Missing gate or locking device.	Gates and locking devices in place.
			Broken or missing hinges such that gate cannot be easily opened and closed by maintenance personnel.	Hinges intact & lubed, gate working freely.
V. Access Roads, Easements - General	Blocked roadway	Gate is out of plumb $\geq 6$ inches and $\geq 1$ foot out of design alignment.	Gate is aligned & vertical.	
		Missing stretcher bar, stretcher bands and ties.	Stretcher bar, bands & ties in place.	
		See "Fencing" standard, above.	See "Fencing" standard, above.	
		Trash and debris	Exceeds $1 \text{ ft}^3/1000 \text{ ft}^2$ or the amount that would fill a standard size garbage can.	Trash & debris cleared from site.
		Debris which could damage vehicle tires.	Roadway free of such debris.	
		Obstructions which reduce clearance above road surface to $< 14$ feet.	Roadway overhead clear to 14 feet high.	

STORMWATER MANAGEMENT MANUAL FOR THE PUGET SOUND BASIN

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
V. Access Roads, Easements, continued	Blocked roadway, continued	Any obstructions restricting access to a 10 - 12 foot width for a distance of $\geq$ 12 feet or any point restricting access to a < 10 foot width.	Obstruction moved to allow at least a 12 foot access route.
	Settlement, potholes, mushy spots, ruts	When any surface exceeds 6 inches in depth and 6 ft <sup>2</sup> in area. In general, any surface defect which prevents or hinders maintenance access.	Road surface uniformly smooth with no evidence of potholes, settlement, mushy spots or ruts.
	Vegetation in surface	Weeds growing in the road surface that are $\geq$ 6 inches tall and < 6 inches apart within a 400 ft <sup>2</sup> area.	Road surface free of weeds taller than 2 inches.
	Erosion damage	Erosion within 1 foot of the roadway $\geq$ 8 inches wide & 6 inches deep.	Shoulder free of erosion & matching the surrounding road.
	Weeds and brush	Weeds and brush exceed 18 inches in height or hinder maintenance access.	Weeds and brush cut to 2 inches in height or cleared in such a way as to allow maintenance access.

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III-4.4.2 BMP RD.06 Wet Pond (Nutrient Control)**Purpose and Definition**

This BMP is similar to BMP RD.05 (Wet Pond for treatment of conventional pollutants) but has a shallow marsh area which provides additional treatment of pollutants, especially nutrients. The shallow marsh area is contained within the "permanent pool" volume. Streambank erosion control can be provided by detaining runoff in the "live storage" area above the permanent pool. Figure III-4.6 illustrates a wet pond for nutrient control.

**Planning Considerations**

See BMP RD.05, Wet Pond (Conventional Pollutants). The primary difference is that this BMP requires the establishment of a shallow marsh in order to provide additional treatment of runoff, particularly nutrients.

**Marsh Establishment**

Establishment of fresh water marshes in ponds can aid in water quality improvement. Marsh areas create a sink for many pollutants with a high degree of water treatment or purification, depending upon the runoff detention time and the availability of wetland plants and aquatic life to assimilate pollutants.

Wetland-associated plants will establish themselves naturally in shallow, wet ponds. It may be beneficial, however, to accelerate marsh establishment by planting appropriate native vegetation in shallow areas. Certain wetland plant species have a greater capacity for pollutant assimilation and are less maintenance intensive than others.

Marsh establishment for stormwater treatment is still in the investigational stages in Washington. One particular limitation is the fact that the major plant growing season (April - October) is largely out of phase with the times of greatest stormwater runoff. However, preliminary indications show that such measures can be appropriate for the following applications:

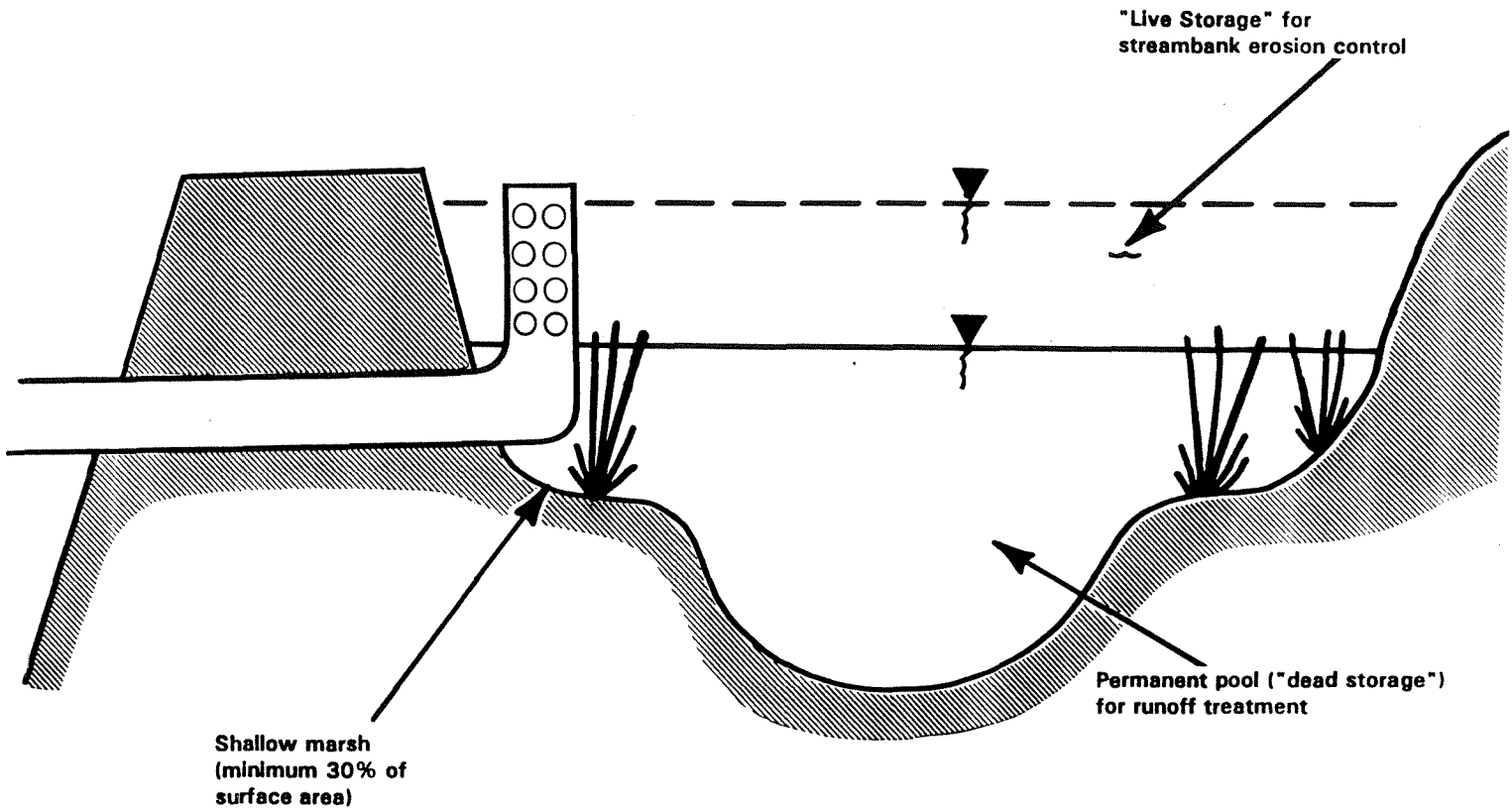
1. At the perimeter of deep detention facilities to filter direct sheet flow runoff from the adjacent drainage area.
2. On shallow sills or shelves separating in-line tandem ponds or forebays to filter runoff before it enters the major impoundment from tributaries or storm drain inlets.
3. Surrounding the outflow of detention facilities to promote assimilation of dissolved pollutants before water exits the primary impoundment.

Note: In any event, the value of the plant communities will depend upon how much untreated stormwater flows through them.

Marsh establishment in facilities that also serve as temporary sediment basins may be difficult during construction due to the need for frequent clean-out of accumulated sediment. Wet ponds should be designed with the need for periodic sediment removal in mind. To continue functioning, marshes also require periodic sediment removal. Sediment should be removed from the deepest parts of the basin where vegetation is sparse. Heavily vegetated areas should be disturbed as little as possible. Overhead scooping equipment works well for dredging selected portions of marsh areas.

The presence of marshes in established urban areas is perceived by many people to be undesirable. They are often thought of as mud holes where mosquitoes and other insects breed. Actually, once a marsh becomes fully established, it can become a

Figure III-4.6  
BMP RD.06 Wet Pond for Nutrient Control



welcomed addition to an urban community. Constructed fresh water marshes can provide miniature wildlife refuges, and while insect populations are increased, insect predators also increase, often reducing the problem to a tolerable level. However, allowance should be made to periodically drain the pond to help control mosquitoes (see Maintenance details). Also, ponds that are stocked with fish should also aid in control (2).

#### Design Criteria

See BMP RD.05, Wet Pond (Conventional Pollutants). The primary difference between this BMP and BMP RD.05 is that a larger surface area is required in order to establish a shallow marsh system in the littoral zone. Important design criteria, including the pond configuration and geometry, and other considerations are discussed above in BMP RD.05.

#### Sizing Wet Ponds for Nutrient Control

Wet ponds designed for treatment of nutrients utilize a permanent pool of water which has a shallow marsh established. Hydrologic analysis methods presented in Chapter III-1 are to be used for design purposes.

#### Permanent Pool Volume

The permanent pool volume shall be equal to the runoff volume of the 6-month, 24-hour design storm.

#### Surface Area-Pool Depth Relationships

The pond should be designed using the following surface area-depth relationship (for the permanent pool volume):

- 70% of the area @ 2 - 6 feet
- 30% of the area @ 0 - 2 feet

The maximum depth of the permanent pool should be six feet. Permanent pools deeper than six feet may contaminate ground water (should they intersect the existing ground water level). Also, deeper ponds can stratify and create anaerobic conditions that can cause pollutants which are normally bound in the sediment (e.g., metals and phosphorus) to resolubilize; their release back to the water column can seriously affect the effectiveness of the BMP and also create nuisance conditions.

The maximum average depth of this BMP is 4.8 feet. See Table III-4.2 for surface area-pool depth relationships for this and other detention BMPs and Table III-4.3 for typical surface area-to-drainage area ratios.

If the wet pond is also designed to provide streambank erosion control, then additional surface area and depth will be required for the "live storage" volume located above the permanent pool. There is no specific surface area-pool depth relationship for the "live storage" volume. Ponds designed to provide streambank erosion control may be deeper than six feet as long as the permanent pool volume provided for runoff treatment does not exceed six feet.

#### Pond Configuration and Geometry

See BMP RD.05, Wet Pond (Conventional Pollutants).

#### Littoral Zone Planting

Littoral zones shall be planted according to the advice of a wetlands specialist.



Nursery sources are recommended wherever possible. Small (2-4 inch) containers are encouraged to avoid transporting large amounts of potting soil to the pond. White roots and active basal budding indicate a healthy stock.

Most wetlands specialists prefer to have someone on-site during the construction phase to ensure that the littoral shelf is located and graded properly. Knowing exactly where the normal water level of the facility will reside after construction is absolutely essential to the success of this element of the system.

Bank erosion is often a significant problem during the initial stages of development. Stabilization with sod down to the permanent pool and preventing undue sediment deposition is required for the planting to survive.

#### Other Design Considerations

See BMP RD.05, Wet Pond (Conventional Pollutants).

#### Construction and Maintenance Criteria

See BMP RD.05, Wet Pond (Conventional Pollutants).

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III-4.4.3 BMP RD.09 Constructed Wetland**Purpose and Definition**

A Constructed Wetland is an artificial wetland intentionally constructed on a nonwetland site for the purpose of managing stormwater runoff. The primary function of a Constructed Wetland is to provide runoff treatment of both conventional pollutants and nutrients, using a permanent pool of water which has extensive shallow marsh areas. A secondary function will be to provide streambank erosion control by adding a "live storage" volume above the permanent pool volume; however, this feature must be more carefully planned than for other wet pond-type BMPs. A Constructed Wetland can provide other benefits as well and, due to its larger surface area compared to other BMPs, should be designed to provide recreational opportunities, wildlife habitat, and to be an aesthetic amenity.

Figures III-4.7 and III-4.8 illustrate a constructed wetland BMP.

**Planning Considerations**

See BMP RD.05 and BMP RD.06, wet ponds for treatment of conventional pollutants and nutrients, respectively, for the following considerations:

- Multiple Uses
- Basin Planning
- Sediment and Debris
- Heavy Metal Contamination
- Overflows
- Site Constraints and Setbacks
- Dam Safety
- Safety, Signage, and Fencing
- Marsh Establishment

Because of the larger surface area of constructed wetlands, and the greater potential for multiple uses, additional planning considerations are provided below.

**General**

Constructed wetlands are essentially a version of a wet pond (see BMPs RD.05 and RD.06). The difference is in the emphasis placed on vegetation, and depth-area considerations. The aim is to replicate the functions and values of natural wetlands as much as possible. They are therefore more complex to build than ordinary wet ponds, the most simple of which need very little if any planted vegetation. Compared to wet ponds, constructed wetlands are shallower and have greater surface area (see Table III-4.3 above for a comparison). Chapter III-5, "Natural Wetlands and Stormwater Management," should be read carefully if a primary objective is to replicate the functions of a natural wetland system.

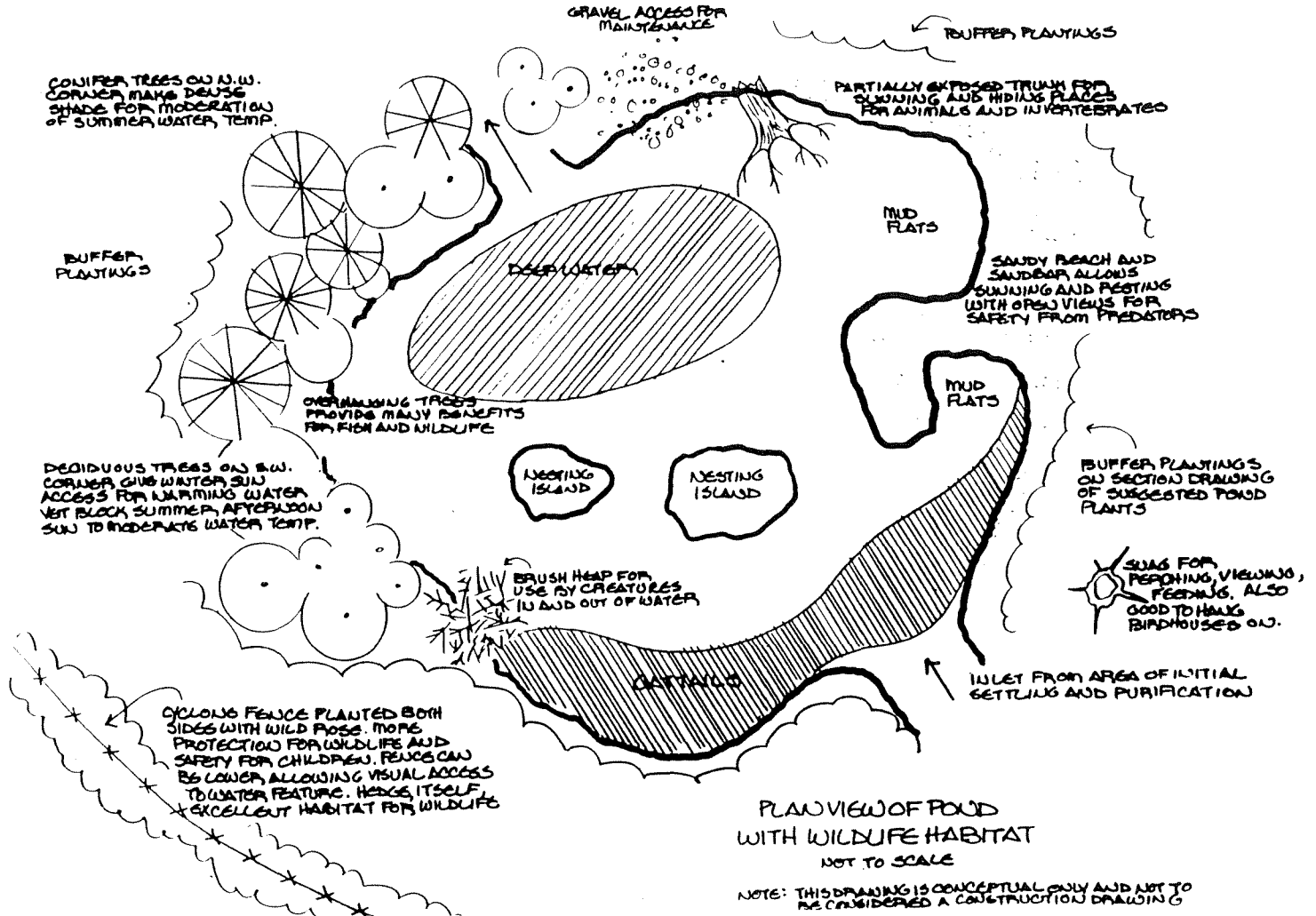
The two most important considerations when planning for a constructed wetland are the hydrologic factors and selection of vegetation.

**Hydrologic Factors**

The following hydrologic factors need to be considered to ascertain whether the site being considered is suitable for a constructed wetland.

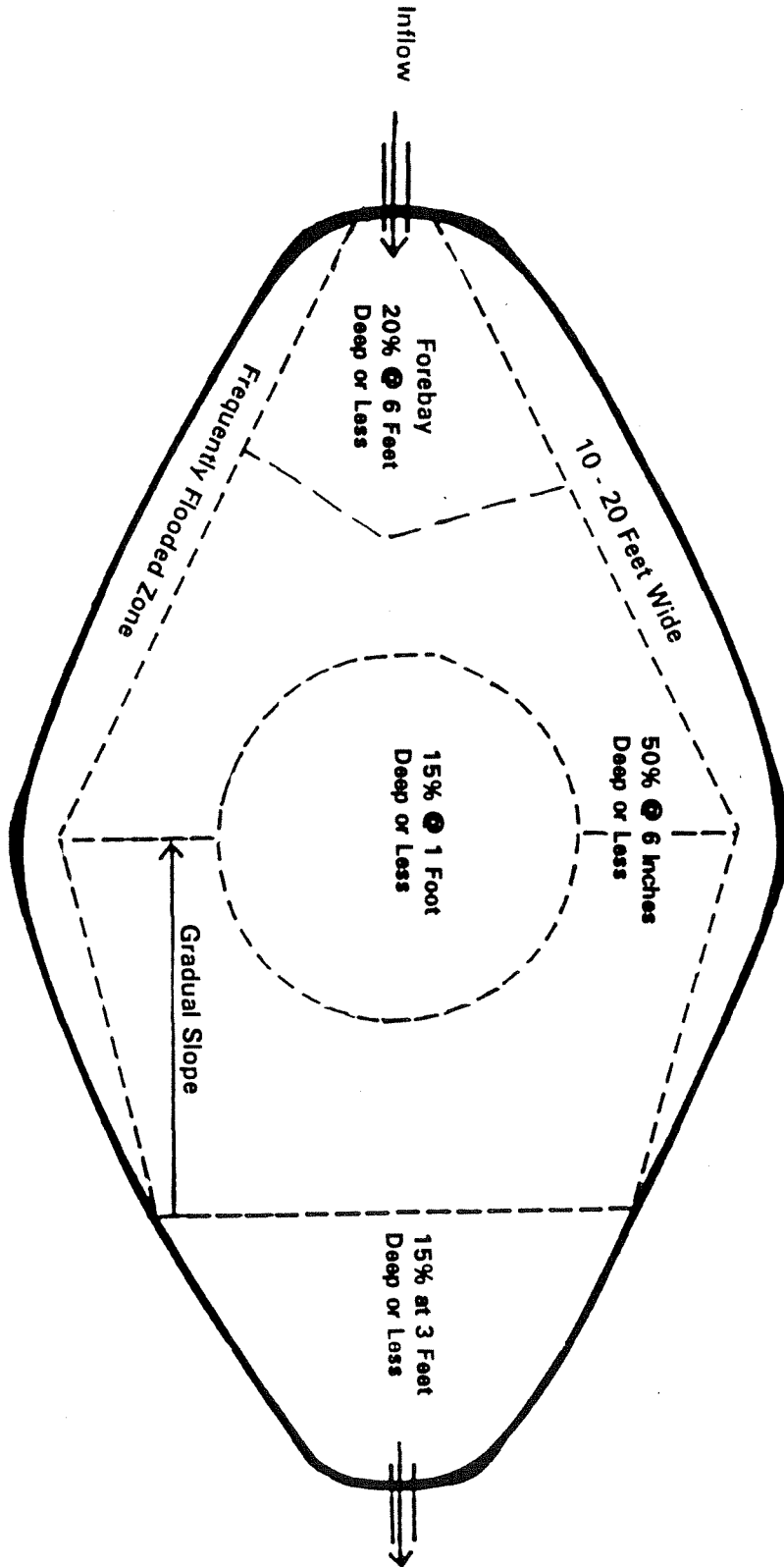
- a) **Flow.** An analysis of flow is needed to determine depth-area relationships. See Chapter III-1 for hydrologic analysis methods. Section III-4.3.2 above for a discussion of depth-area relationships.

Figure III-4.7 BMP RD.09 Constructed Wetland



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Figure III-4.8 Diagram of a Constructed Wetland



Adapted from "Guidelines for Constructing Wetland Stormwater Basins", 1987

- b) *Climatic Conditions.* Overall climatic conditions determine the types of plants that may be used and the seasonality of flow rates.
- c) *Ground Water Conditions and Soil Permeability.* These factors need to be considered to avoid pollution of ground water and to determine whether the wetland may need to be lined.

#### Vegetation Selection

Selection of vegetation needs to be done by a wetlands specialist. The selection will be based on climate, hydroperiod of the wetland, sensitivity to pollution, and aesthetic appeal. Grazing pressures and detrimental effects of wind, waves, and water currents will also need to be taken into account. A well planned wetland will also need a diverse mixture of floating, emergent, and submergent plants. Above all, the plants will need to be able to withstand the pollutant concentration of the incoming water and tolerate some fluctuation in the water level of the wetland.

Artificial establishment of vegetation is done to influence future plant species composition and to establish a vegetated marsh as quickly as possible. Complete coverage and optimum treatment potential can often take five years or more. Constructed wetlands with a smaller vegetative cover can still significantly reduce pollution.

Soils testing should be conducted to determine soil type. Plant species should be chosen based on their ability to thrive in particular soil types. Plant types should be discussed with plant specialists and nurseries during the selection process.

#### Wildlife

The species of vegetation chosen should maximize heterogeneity and value to all types of wildlife. Although not required, measures to further enhance habitat for wildlife are encouraged. Maximizing vegetation density around the wetland will discourage the entry of domestic animals that would prey on wildlife. Provision of an island for nesting birds is encouraged (see Figures III-4.7 and III-4.9). Unless the constructed wetland is adequately maintained, with potentially contaminated sediment removed regularly, the possibility of pollutant contamination of the wildlife using the wetland does exist.

#### Impacts of Fluctuating Water Levels

Large sudden fluctuations in water levels of the wetland environment often destroy wetland/upland edge vegetation. Most edge vegetation cannot survive drought-saturation extremes, leaving stream, lake, and wetland banks exposed to potential erosion.

Water level extremes may result from urbanization through the clearing of vegetation and increased amounts of impervious surfaces. This causes large surges when it rains and low flows in the summer due to lack of ground water. It is therefore important to prevent surges whenever possible and design for gradual increases and decreases in water level. This can be done through the use of upstream detention and a controlled release of stormwater runoff from that facility. Constructed wetlands are better for polishing the quality of runoff and less useful for hydraulic detention purposes.

See Chapter III-5 for a further discussion of the impacts of fluctuating water levels.

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## Design Criteria

Important design criteria applicable to all wet ponds is provided with BMP RD.05 and BMP RD.06, including:

- Liner to Prevent Infiltration
- Overflow and Emergency Spillway
- Berm Embankment/Slope Stabilization
- Gravity Drain
- Erosion and Sediment
- Littoral Zone Planting

### Sizing of Constructed Wetlands

See BMP RD.06, Wet Pond (Nutrient Control). The primary difference is that a constructed wetland has different surface area-pool depth relationships for the permanent pool, as follows:

- 50% of the area = 0.5 feet (approximately)
- 15% of the area @ 0.5 to 1 foot
- 15% of the area @ 2 to 3 feet
- 20% of the area 3+ feet deep with a maximum depth of 6 feet

This relationship results in a *maximum average* permanent pool depth of 2.05 feet. See Table III-4.2 for surface area-pool depth relationships for this and other detention BMPs and Table III-4.3 for typical surface area-to-drainage area ratios.

### Permanent Pool

To maintain a permanent pool of water in a wetland, inflow from stormwater, baseflow, and ground water must be greater than the outflow via infiltration, evapotranspiration, and discharge. If the rate of infiltration is high and a permanent pool cannot be maintained, a clay liner (or equivalent) will be necessary. The discharge rate may also be reduced to increase residence time.

### "Live Storage" Volume

The "live storage" volume must be sufficient to meet the release requirements for streambank erosion control, i.e., 50% of the existing condition 2-year, 24-hour peak flow; maintain existing condition peak flow rates for 10-year and 100-year, 24-hour events. A correction factor must be applied to the calculated detention volume in order to account for weaknesses with current hydrologic analysis methods. See Chapter III-1 for a discussion.

### Pond Configuration and Geometry

See BMP RD.05, Wet Pond (Conventional Pollutants).

A forebay, a deeper area where sediments can settle out, should be established along the wetland inflow points to capture sediment. The forebay should have a water depth of about 3 feet and may occupy up to 25 percent of the normal pool area.

### Side Slopes

Side slopes shall not be steeper than 3:1. There should be an area of low slope surrounding the permanent pool which is temporarily flooded during most runoff events but drains as the runoff leaves the basin. It is recommended that this area be 10 to 20 feet in width.

### Length-to-Width Ratio

The length-to-width ratio should be at least 3:1 and preferably 5:1. If area constraints make this ratio unworkable, baffles, islands, or peninsulas may be installed to increase the flow path and prevent short-circuiting.

### Other Criteria

Constructed wetlands can be constructed along a series of different elevations. Water passage from one level to the other can be over an aeration cascade to oxygenate the water. The increased oxygen will promote bacterial digestion of organic matter.

### Soil and Vegetation Plan

#### Soil

The soil in which the vegetation is planted should be appropriate for the wetland plants selected. Either soil tests indicating the adequacy of the soil or a soil enhancement plan shall be submitted with the overall wetland design.

The soil substrate must be soft enough to permit easy insertion of the plants. If the basin soil is compacted or vegetation has formed a dense root mat, the upper 6 inches of soil should be disked prior to planting. If soil is brought in, it needs to be laid at least 4 inches deep in order to provide sufficient depth for plant rooting. Soil may be taken from another wetland or from ditch cleaning operations if available. However, if this type of soil is used, the plant species composition may be influenced by volunteer vegetation. Studies have shown up to 32,430 seeds per square meter in marsh soils. Enriching non-wetland soils with organic matter seems to increase vegetative yields.

#### Vegetation

A wetland scientist shall prepare that portion of a vegetation plan for the design that relates to vegetation selection and installation. Suggestions for wetland vegetation may be found in "Water Pollution Control Aspects of Aquatic Plants: Implications for Stormwater Quality Management" by Louise Kulzer of Metro in Seattle, and in Figures III-4.10 and III-4.11.

1. All plant materials shall conform to Ch. 16-432 WAC, "Rules Relating to Standards for Nursery Stock".
2. Prior to planting, plants located temporarily on-site must be kept moist, fresh, and protected from wind and sun.

### Construction and Maintenance Criteria

#### Construction

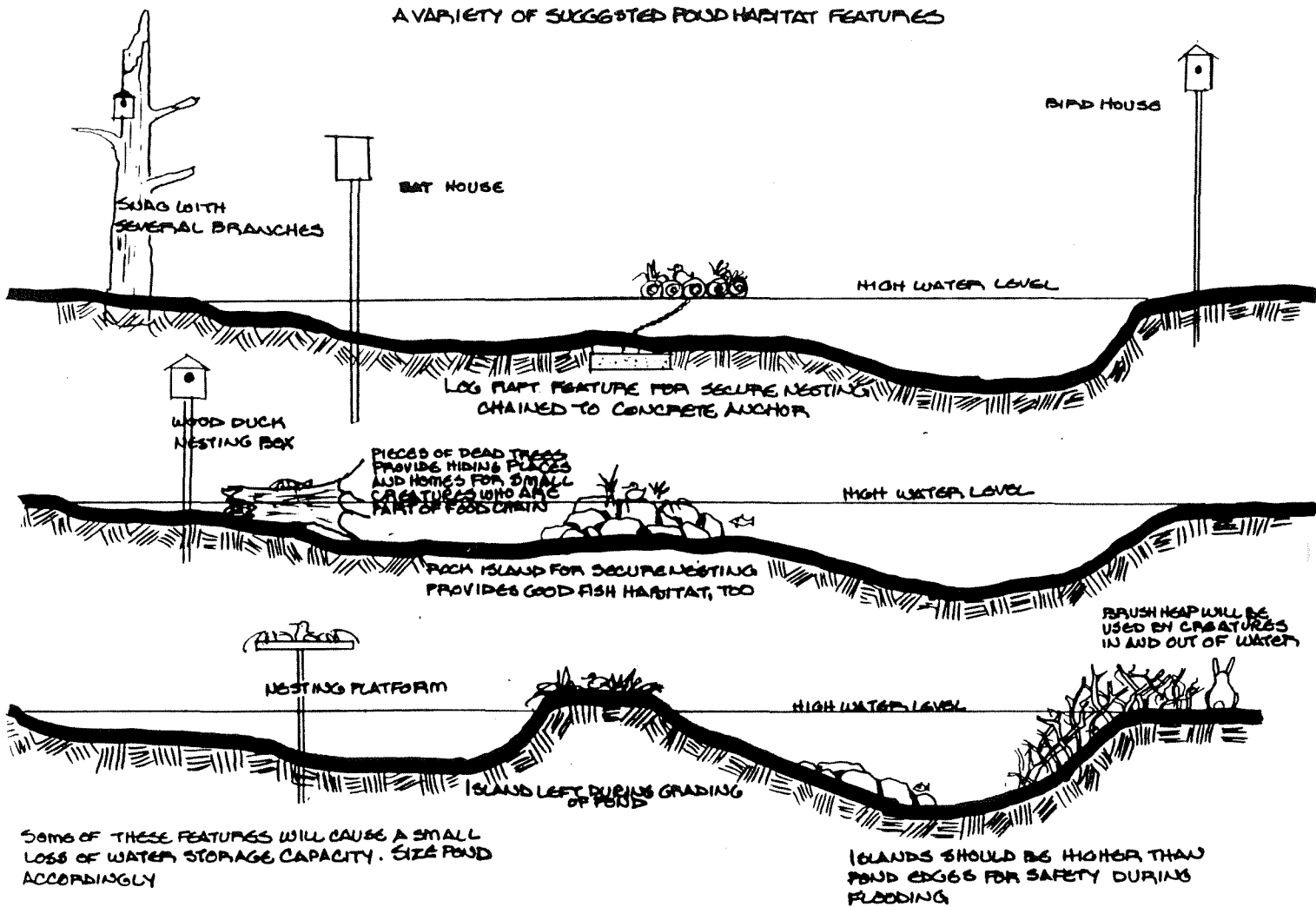
See BMP RD.05, Wet Pond (Conventional Pollutants).

#### Maintenance

See BMP RD.05, Wet Pond (Conventional Pollutants).

If oil/water separators precede the wetland they must be cleaned regularly. Floatables must be removed annually from the forebay; surface sheen must also be removed. The forebay bottom should be cleaned once every five years, or when 6 inches of the permanent pool in the forebay is lost to accumulated material, whichever comes first. If solubilization of pollutants from accumulated bottom sediments is found to occur, annual cleaning may be necessary. Grass along the

Figure III-4.9 Suggested Habitat Features for a Constructed Wetland



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basin slopes above the permanent pool must be well maintained to prevent erosion.

Any standing water removed during maintenance operations must be disposed of to a sanitary sewer at an approved discharge location. Residuals must be disposed in accordance with current health department requirements of the local government.

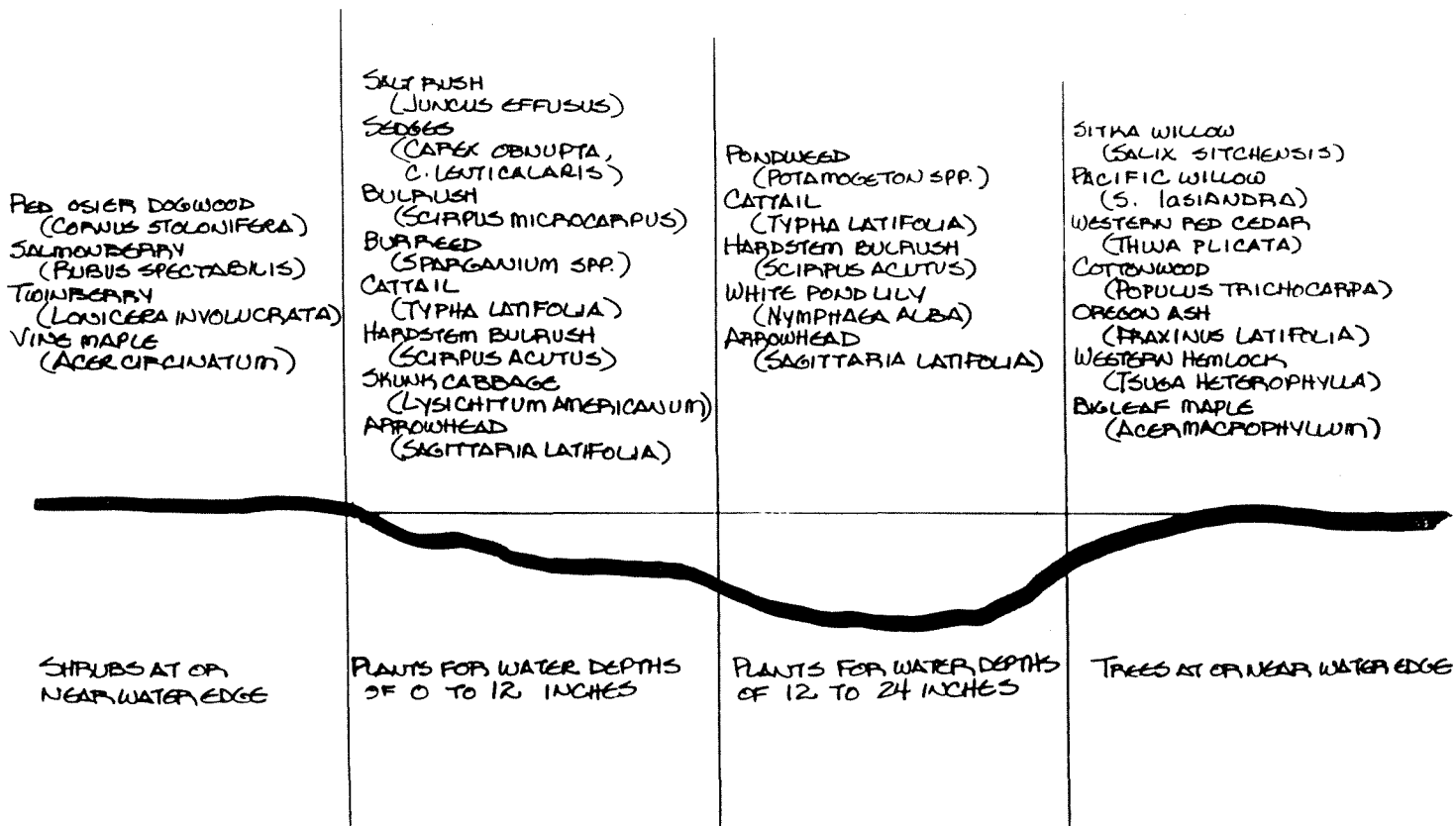
If harvesting is to be done in the wetland, a written harvesting procedure shall be prepared by a wetland scientist and will be submitted with the drainage design to the local government.

#### References

- (1) Stockdale, Erik C., Freshwater Wetlands, Urban Stormwater, and Nonpoint Pollution Control: A Literature Review and Annotated Bibliography, Second Edition, King County Department of Parks, Planning and Resources, Seattle, Washington, February, 1991.
- (2) Sediment and Stormwater Division, Water Resources Administration, Maryland Department of Natural Resources, Guidelines for Constructing Wetland Stormwater Basins, March, 1987.
- (3) Sediment and Stormwater Division, Water Resources Administration, Maryland Department of Natural Resources, Wetland Basins for Stormwater Treatment: Discussion and Background, (undated)
- (4) Kulzer, L., Water Pollution Control Aspects of Aquatic Plants: Implications for Stormwater Quality Management, METRO Office of Water Quality, Seattle, Washington, 1990.
- (5) Stephenson, Marian, et.al., The Use and Potential of Aquatic Species for Wastewater Treatment - Appendix A The Environmental Requirements of Aquatic Plants, Publication No. 65, University of California, Davis, California, October, 1980.
- (6) Canning, Douglas J., Urban Runoff Water Quality: Effects and Management Options, Second Edition, Shorelands Technical Advisory Paper No. 4, Washington State Department of Ecology, 1988.
- (7) Hammer, David E., and Robert H. Kadlec, Design Procedures for Wetland Treatment Systems, EPA 600/2-83-026, April, 1983.

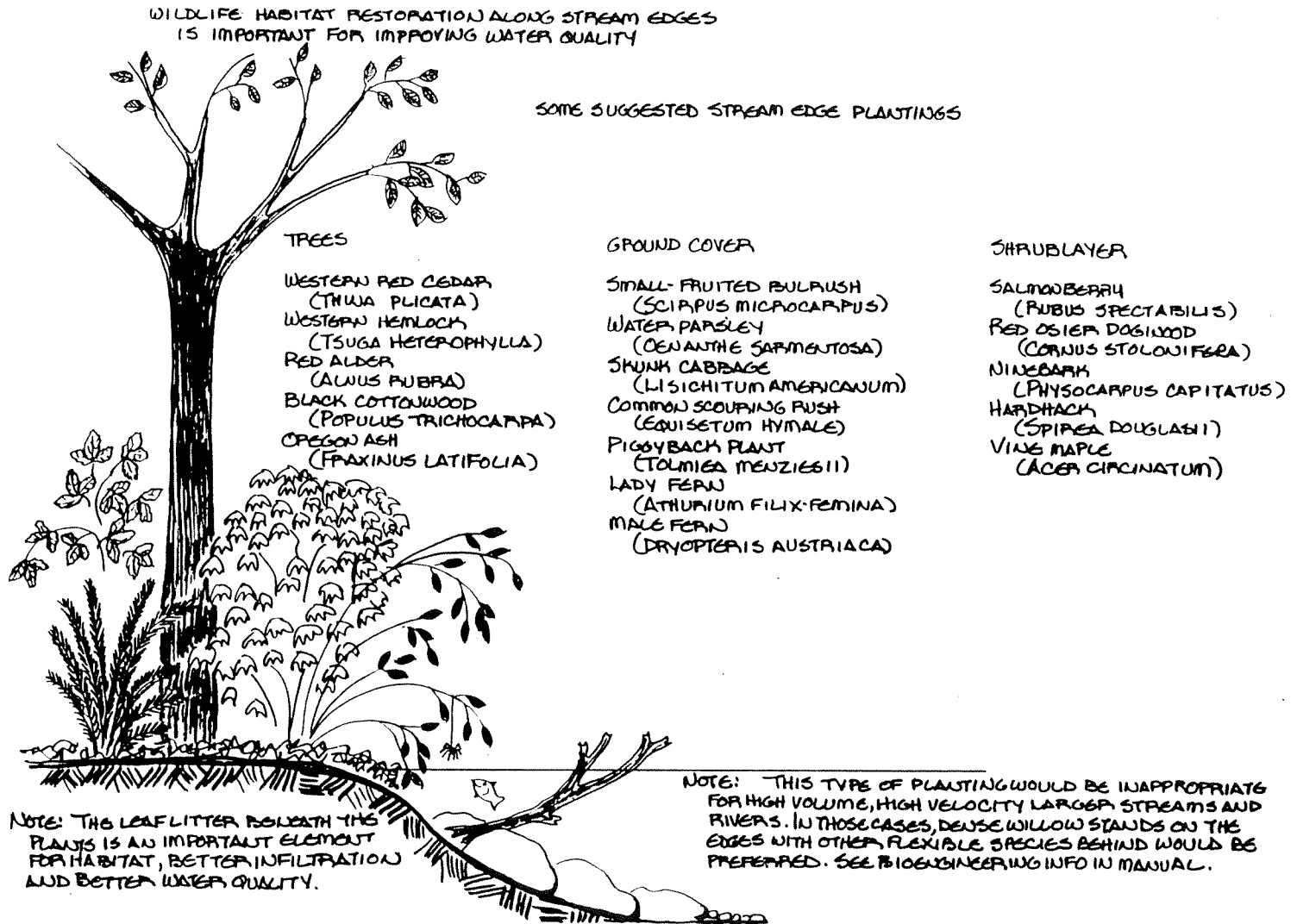
Figure III-4.10 Suggested Plantings for Specific Depths of a Constructed Wetland

SUGGESTED PLANTINGS FOR SPECIFIC AREAS OF A POND



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Figure III-4.11 Suggested Stream Edge Plantings for a Constructed Wetland



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### III-4.4.4 BMP RD.10 Presettling Basin

#### Purpose and Definition

A Presettling Basin provides pretreatment of runoff in order to remove suspended solids which can impact other primary treatment BMPs. A presettling basin has no "permanent pool" volume; runoff is detained so that particulates can settle out before being discharged to a another BMP. Runoff treated by a Presettling Basin must be further treated by a water quality infiltration or filtration BMP, a wet pond-type BMP, or a biofilter. Presettling basins may need to be located "off-line" from the primary conveyance/detention system if used to protect infiltration or filtration BMPs from siltation.

Presettling Basins are not to be used to provide streambank erosion control. If pretreatment and streambank erosion control are to be combined into one structure, see BMP RD.11, Extended Detention Dry Pond (note, however, that such a facility may have limited application in the Puget Sound Basin).

Figure III-4.12 illustrates a presettling basin.

#### Planning Considerations

*One of the major concerns with infiltration and filtration facilities is their tendency to clog with sediment. To minimize this, all runoff entering infiltration or filtration facilities is required to be pretreated to remove the majority of particulate material. Presettling basins can be used when there is no requirement to provide streambank erosion control.*

*In some cases there may be greater concern than usual about sediments entering an infiltration or filtration facility (e.g. highly erodible soils). In these instances a combination of a presettling basin with a biofilter or vegetative filter strip is recommended (see BMP RB.05 and BMP RB.06).*

#### Sediment and Debris

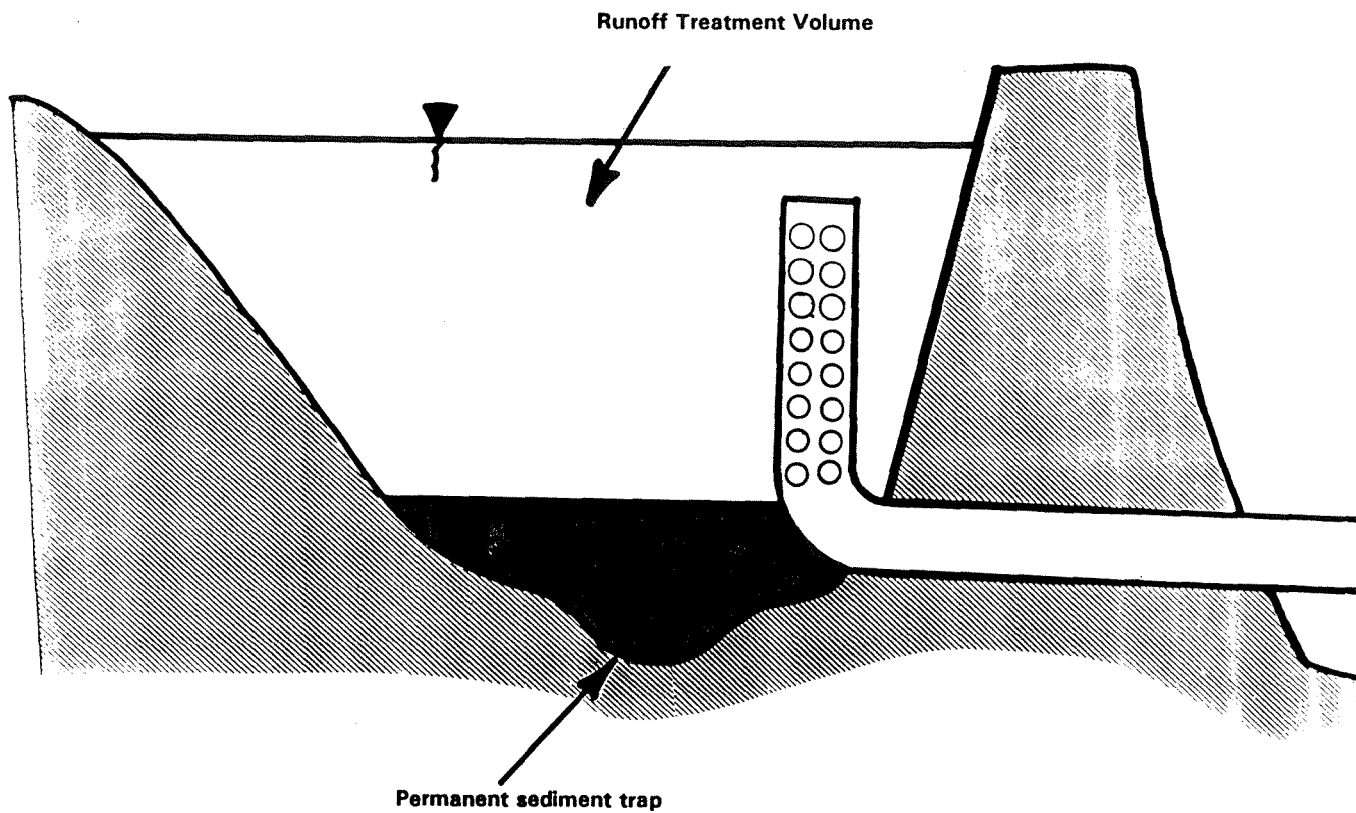
*More often than not, ponds serve primarily as sedimentation basins during construction when erosion rates are particularly high. In and of itself, this situation does not present a problem. Unfortunately, these facilities are often installed without the benefit of the designer having evaluated the capacity of either the initial or the final (post-construction) design configuration to perform this type of function.*

*If a facility is to be used as the principal means to avoid having excessive levels of turbidity discharged from the site during construction, the engineer should evaluate the pond geometry in conjunction with the rate of outflow and grain size distribution of the soils and design the temporary sediment basin according to BMPs E3.35 or E3.40 in Volume II.*

#### Heavy Metal Contamination

*Studies have shown high accumulation rates of lead, zinc, and copper on and near heavily traveled highways and streets. Runoff from highways and streets can be expected to carry significant concentrations of these heavy metals. If a significant portion of the drainage area into a pond consists of highways, streets, or parking areas or other known sources of heavy metal contamination, there is a potential environmental health hazard. In such cases the multiple use functions of the pond should be limited and accessibility should be restricted. Additionally, liners should be provided for ponds expected to accept these types of pollutants, for certain soil types, according to Section III-4.3.2.*

Figure III-4.12  
BMP RD.10 Presettling Basin



Note: No streambank erosion control is provided by this BMP.

This may require that sediment dredged out of the basins during maintenance cleaning be treated as a Dangerous Waste. Investigations of sediments removed from detention ponds to date have found that many pollutants are tightly bound with only a slight possibility of leaching. To be safe, sediments to be removed should be analyzed and elutriate tests performed to verify that the sediment can be safely disposed of by conventional methods (see Volume IV, Catchbasin Sediment Disposal Policy (to be written) which deals with disposal procedures).

#### Site Constraints and Setbacks

Site constraints are any manmade restrictions such as property lines, easements, structures, etc. that impose constraints on development. Constraints may also be imposed from natural features such as requirements of the local government's Sensitive Areas Ordinance and Rules (if adopted). These should also be reviewed for specific application to the proposed development.

All facilities shall be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government, and 100 feet from any septic tank/drainfield (except wet vaults shall be a minimum of 20 feet).

All facilities shall be a minimum of 50 feet from any steep (greater than 15%) slope. A geotechnical report must address the potential impact of a wet pond on a steep slope.

#### Dam Safety

In urban or urbanizing areas, failure of an impoundment structure can cause significant property damage and even loss of life. Such structures should be designed only by professional engineers registered in the State of Washington who are qualified and experienced in impoundment design. Wherever they exist, local safety standards for impoundment design shall be followed. Where no such criteria exist, widely recognized design criteria such as those used by the USDA Soil Conservation Service, Ecology Dam Safety Standards, or U.S. Army Corps of Engineers are recommended.

#### Safety, Signage and Fencing

Ponds which are readily accessible to populated areas should incorporate all possible safety precautions. Steep side slopes (steeper than 3H:1V) at the perimeter shall be avoided and dangerous outlet facilities shall be protected by enclosure. Warning signs for deep water and potential health risks shall be used wherever appropriate. Signs should be placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks or paths. A notice should be posted warning residents of potential waterborne disease that may be associated with body contact recreation such as swimming in these facilities.

If the pond surface exceeds 20,000 sq. feet, include a safety bench around the basin with a width of 5 feet, and with a depth not exceeding 1 foot during non-storm periods. Emergent vegetation such as cattails should be placed on the bench to inhibit entry by unauthorized people.

A fence is required at the maximum water surface elevation, or higher, when a pond slope is a wall. Local governments and Homeowners Associations may also require appropriate fencing as an additional safety requirement in any event.

#### Design Criteria

The hydrologic analysis methods in Chapter III-1 shall be used for design purposes.

## Sizing Presettling Basins

Presettling basins are to be designed to settle out particulate pollutants for a range of runoff events, up to the 6-month, 24-hour design storm. The smaller storms (i.e., less than the 6-month, 24-hour storm) also need to be controlled because these frequently occurring events carry the majority of the annual pollution. Schueler (13) recommends that a maximum detention time for the maximum detention volume be 40 hours. Ecology recommends that 24 hours be used due to the Pacific Northwest rainfall pattern, with the exception of the case when presettling basins are used in tandem with water quality infiltration BMPs. For that case, the total detention time for both the presettling basin and the infiltration BMP should be 24 hours in order to maintain aerobic conditions in the infiltration BMP. Schueler also recommends that smaller events (0.1-0.2 inches) be detained no less than six hours. These are general recommendations but can be deviated from if the designer uses an appropriate equation to size the presettling basin. The Camp-Hazen equation (8) is recommended as it takes into account effects of turbulent flow, which is a typical condition during runoff events:

$$E = 1 - \exp(-wA_s/Q_0) \quad \text{where}$$

E = trap efficiency = fraction of suspended solids to remove; set equal to 0.8 (= 80% removal efficiency);

w = settling velocity of target particle; silt is recommended using a settling velocity of 0.0004 ft/sec.

A<sub>s</sub> = surface area of presettling basin

Q<sub>0</sub> = average release rate from the presettling basin.

The choice of a minimum 80 percent removal for suspended solids as the criterion for selecting the surface area is considered reasonable and cost-effective. However, protection of beneficial uses in receiving waters will always be required. There may be instances, depending on the nature of pollutants to be controlled and the receiving waters, when a higher removal rate, and hence larger surface area, will be required by the local government and/or Ecology or other State agencies.

Rearranging the Camp-Hazen equation and solving for A<sub>s</sub> gives:

$$A_s = -(Q_0/w) * \ln(1-E) \quad \text{where } \ln \text{ is the natural logarithm}$$

The average release rate, Q<sub>0</sub>, can be calculated by dividing the runoff treatment volume (maximum = runoff from 6-month, 24-hour storm) by the detention time, t<sub>d</sub>:

$$Q_0 = \frac{V}{t_d}$$

The detention time will vary depending on the amount of runoff but should not exceed 24 hours for the 6-month, 24-hour storm. Longer detention times are not recommended because of the frequency of rainfall in the Northwest during the winter wet season (on the average it rains every two days from October to late March). The Camp-Hazen equation can be solved to determine the ratio of the presettling basin surface area to the total drainage area. Table III-4.5 presents the results of such an analysis and can be used for planning purposes. See Table III-4.3 for typical surface area-to-drainage area ratios for this and other detention BMPs for the maximum treatment storm (i.e., 6-month, 24-hour event).

Note that while Table III-4.5 gives recommended surface area-to-drainage area ratios it will still be necessary for the designer to size the outlet(s) for the presettling basin such that the drawdown times in Table III-4.5 are achieved for the runoff volumes shown. In some cases the minimum orifice size (0.5 inch diameter) may make it impossible to achieve the drawdown times presented. In such cases, the drawdown time can be decreased, which will increase the outflow rate and the size of

the orifice, along with the surface area of the basin.

Table III-4.5  
Presettling Basin Design Criteria to Treat a Range of Runoff Events\*

Runoff Volume (inches)	Design Detention Time $t_d$ (hours)	Ratio of Basin Surface Area to Drainage Area ( $A_b/A_d$ )
0.20	6	0.31%
0.50	12	0.39%
1.00	18	0.52%

\* If the 6-month, 24-hour design storm runoff volume is less than the values in the first column of the table, a design detention time of 24 hours should be used.

#### Pond Configuration and Geometry

The shape of the presettling basin and the flow regime within this basin will influence how effectively the basin volume is utilized in the sedimentation process. The length to width ratio of the basin should be 3:1 or greater. Inlet and outlet structures should be located at extreme ends of the basin in order to maximize particle settling opportunities.

Short-circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are by-passed by the flow regime and are, therefore, ineffective in the settling process) should be minimized. Baffles may be used to mitigate short-circuiting and/or dead storage problems. Figure III-4.13 illustrates basin geometry considerations, including the use of baffles to improve basin performance.

Interior side slopes up to the maximum water surface shall be no steeper than 3H:1V. Exterior side slopes shall be no steeper than 2H:1V.

The basin bottom shall be level to facilitate sedimentation.

Basin walls may be retaining walls, provided that the design is prepared and stamped by a structural engineer registered in the State of Washington, that they are constructed of reinforced concrete per Section III-4.6.1, that a fence is provided along the top of the wall, and that at least 25 percent of the pond perimeter will be a vegetated soil slope of not greater than 3H:1V.

#### Permanent Sediment Trap (Optional)

A sediment trap is a storage area which captures sediment and removes it from the basin flow regime. In so doing the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to ten (10) percent of the sedimentation basin volume. Water collected in the sediment trap shall be conveyed from the basin in order to prevent standing water conditions from occurring. Water collected in the sediment trap shall drain out within 60 hours. Access for cleaning the sediment trap drain system is necessary. Figure III-4.14 illustrates a permanent sediment trap.



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### Inlet Structure and Isolation/Diversion Structure

The inlet structure design must be adequate for isolating the water quality volume (i.e., runoff volume from the 6-month, 24-hour storm) from the larger design storms and to convey the peak flows for the larger design storms past the basin. The water quality volume should be discharged uniformly and at low velocity into the presettling basin in order to maintain near quiescent conditions which are necessary for effective treatment. It is desirable for the heavier suspended material to drop out near the front of the basin; thus a drop inlet structure is recommended in order to facilitate sediment removal and maintenance. Energy dissipation devices may be necessary in order to reduce inlet velocities which exceed three (3) feet per second.

Note: On very small lots (approximately 1 acre) this design may result in an outlet orifice smaller than the minimum allowed (one-half inch). In this case, some of the design variables in the Camp-Hazen equation can be revised in order to increase orifice size (e.g., reduce detention time, increase treatment volume, increase trap efficiency (E)).

### Off-line Isolation/Diversion Structure

Presettling basins may need to be located off-line when used to protect infiltration and filtration BMPs from siltation. Off-line systems are designed to capture and treat the 6-month, 24-hour design storm; this is typically achieved by using isolation/diversion baffles and weirs. A typical approach for achieving isolation of the water quality volume is to construct an isolation/diversion weir in the stormwater channel such that the height of the weir equals the maximum height of water in the infiltration/filtration basin during the 6-month, 24-hour design storm. When additional runoff greater than the water quality storm enters the stormwater channel it will spill over the isolation/diversion weir and mixing with the already-isolated water quality volume will be minimal. Figures III-3.24 and III-3.25 in Section III-3.4 (Filtration BMPs) illustrate two types of isolation/diversion structures which have been successfully used.

### Outlet Structure

The outlet structure conveys the water quality volume from the presettling basin to the primary treatment BMP (e.g., infiltration basin, sand filtration basin). The outlet structure shall be designed to provide a range of detention times for different runoff volumes, as shown in Table III-4.5 with a maximum detention time of 24 hours for the 6-month, 24-hour design storm. A perforated pipe or equivalent is the recommended outlet structure. The 24 hour drawdown time should be achieved by installing a throttle plate or other flow control device at the end of the riser pipe (the discharges through the perforations should not be used for draw-down time design purposes). The perforated riser pipe can be selected from Table III-4.6.

A trash rack shall be provided for the outlet. Openings in the rack should not exceed 1/3 the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations it is recommended that geotextile fabric be wrapped over the pipe's bottom rows and that a cone of one (1) to three (3) inch diameter gravel be placed around the pipe (see Reference 75). If a geotextile fabric wrap is not used then the gravel cone must not include any gravel small enough to enter the riser pipe perforations. Figure III-4.15 illustrates these considerations.

Table III-4.6  
Perforated Riser Pipe Specifications

Riser Pipe Nominal Dia. (inches)	Vertical Spacing Between Rows (center to center - inches)	Number of Perforations per Row	Diameter of Perforations (inches)
6	2.5	9	1
8	2.5	12	1
10	2.5	16	1

Source: City of Austin. This information is based on commercially available pipe. Equivalent designs are acceptable.

Other Design Considerations

Liner to Prevent Infiltration

Detention BMPs should have negligible infiltration rates through the bottom of the pond. If infiltration is anticipated then a detention facility must either **not** be used and an infiltration BMP used instead (see Chapter III-3) or a liner installed to prevent infiltration. If a liner is used, the specifications provided in Section III-3.7 (Filtration BMPs) can be used. When using a liner the following are recommended:

- A layer of (track) compacted top soil (minimum 18" thick shall be placed over the liner prior to seeding with an appropriate seed mixture (see BMP E1.35 in Chapter II-5).
- Other liners may be used provided the design engineer can supply support documentation that the material will provide the required performance.

Berm Embankment/Slope Stabilization

Pond embankments higher than 6 feet shall require design by a geotechnical-civil engineer licensed in the State of Washington. The embankment shall have a minimum 15 foot top width where necessary for maintenance access; otherwise, top width may vary as recommended by the geotechnical-civil engineer.

The berm dividing the pond into cells shall have a 5 foot minimum top width, a top elevation set one foot lower than the design water surface, maximum 3:1 side slopes, and a quarry spall and gravel filter "window" between the cells.

For berm embankments of 6 feet or less than (including 1-foot freeboard), the minimum top width shall be 6 feet or as recommended by the geotechnical-civil engineer.

The toe of the exterior slope of pond berm embankment must be no closer than 5 feet from the tract or easement property line.

Pond berm embankment must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical report) free of loose surface soil materials, roots and other organic debris.

Pond berm embankments must be constructed by excavating a "key" equal to 50 percent of the berm embankment cross-sectional height and width (except on highly compacted till soils where the "key" minimum depth can be reduced to 1 foot of excavation into the till).

Figure III-4.13 Use of Baffles to Improve Performance of Presettling Basins

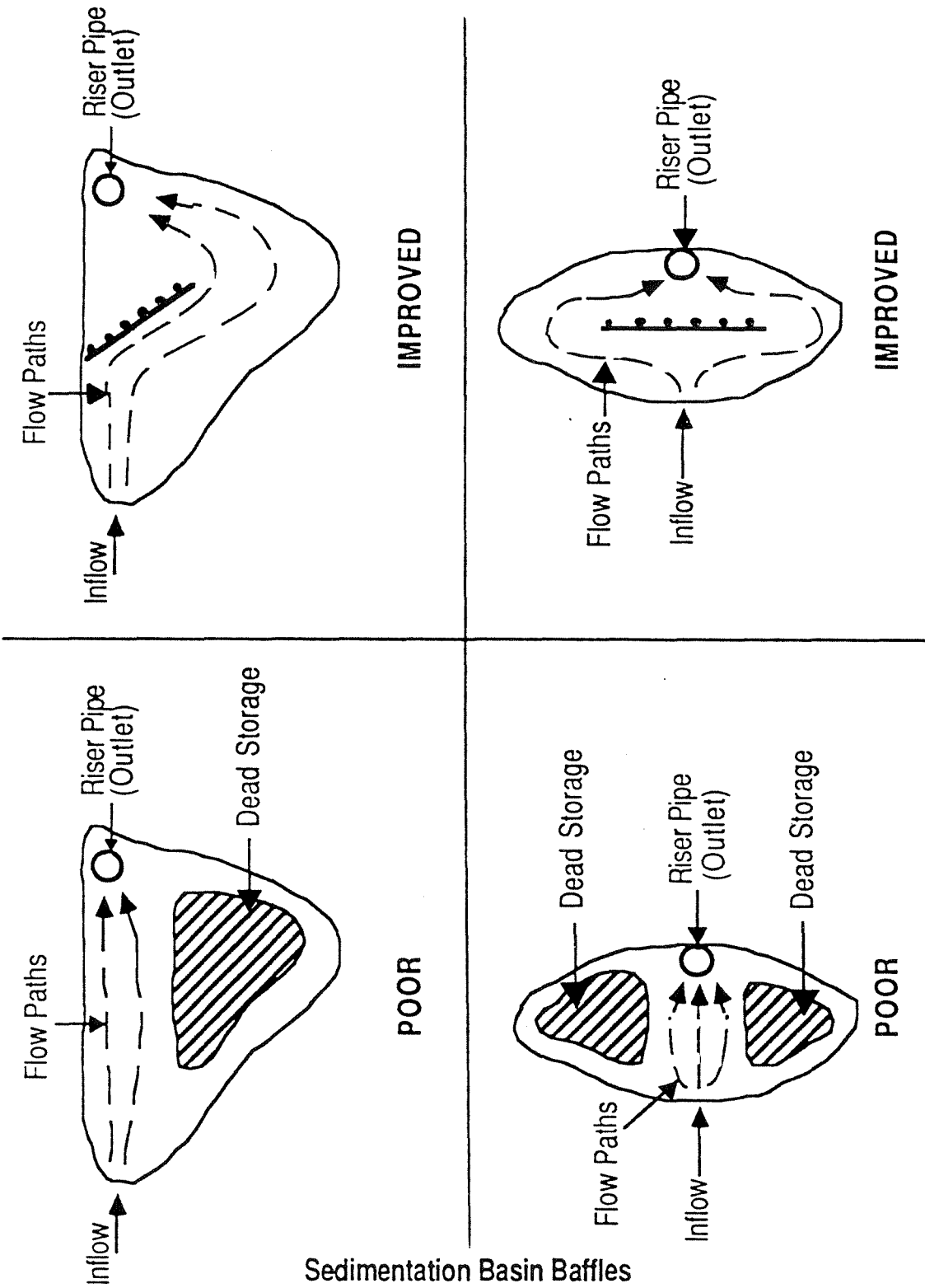


Figure III-4.14 Permanent Sediment Trap for Presettling Basin

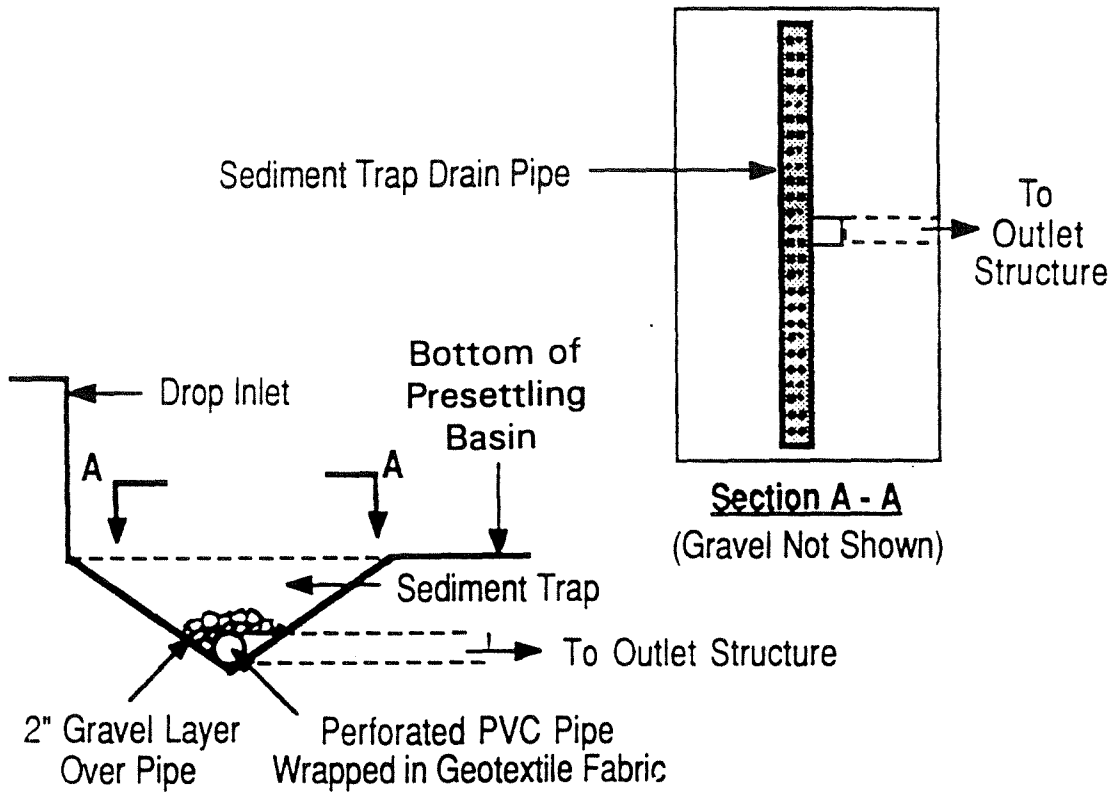
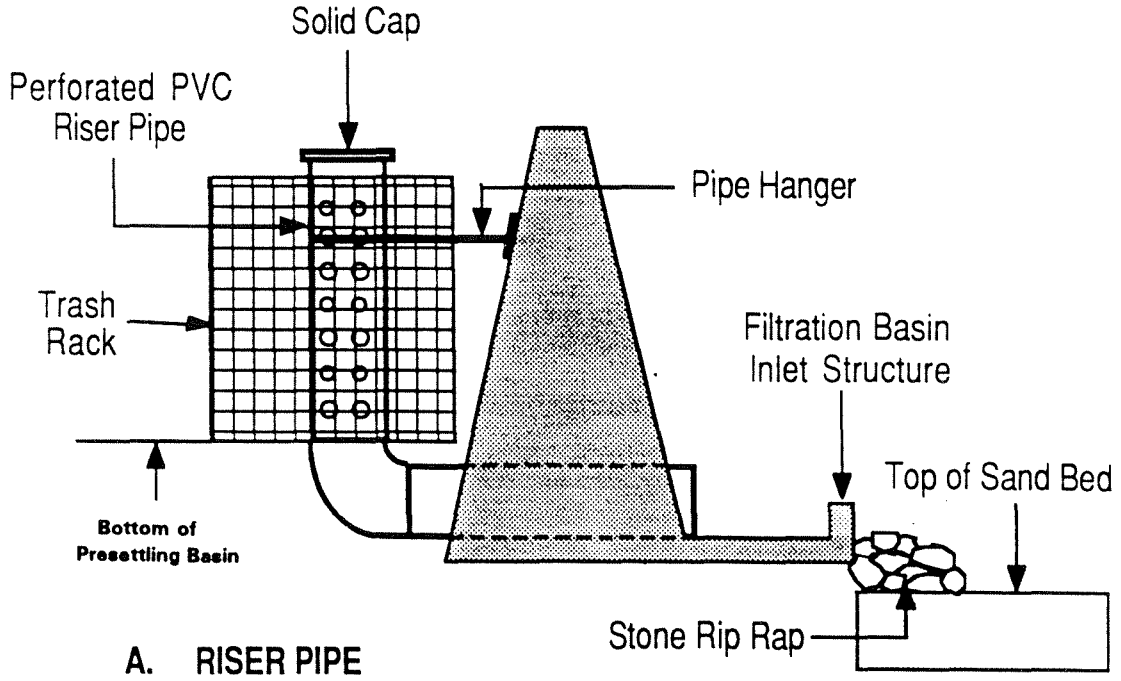


Figure III-4.15  
Perforated Riser Pipe Outlet Structure with Trash Rack



The berm embankment shall be constructed on compacted soil (95 percent minimum dry density, standard proctor method per ASTM D1557), placed in 6-inch lifts, with the following soil characteristics per the United States Department of Agriculture's Textural Triangle: a minimum of 30 percent clay, a maximum of 60 percent sand, a maximum of 60 percent silt, with nominal gravel and cable content (Note, in general, excavated glacial till will be well-suited for berm embankment material).

Anti-seepage collars must be placed on outflow pipes in berm embankments impounding water greater than 8 feet in depth at the design water surface.

Exposed earth on the pond bottom and side slopes shall be sodded or seeded with the appropriate seed mixture as soon as is practicable (see Erosion and Sediment Control BMP E1.35 in Volume II). Establishment of protective vegetative cover shall be ensured with jute mesh or other protection and reseeded as necessary (see Erosion and Sediment Control BMPs E1.15 and E1.35 in Volume II).

#### Erosion and Sediment

Erosion and sediment control BMPs must be used to retain sediment on-site during construction (see Erosion and Sediment Control in Volume II). BMPs must be shown on the design plans and the engineer must provide instructions for proper O&M. Permanently stabilize all areas of ponds to prevent erosion and sedimentation of plantings (see Chapter II-5).

#### Construction and Maintenance Criteria

See BMP RD.05, Wet Pond (Conventional Pollutants).

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III-4.4.5 BMP RD.11 Extended Detention Dry Pond*Purpose and Definition*

An Extended Detention Dry Pond is designed to provide both pretreatment and streambank erosion control. It is similar to BMP RD.10 (Presettling Basin) except that it has an additional storage volume which provides an extended period of detention to control streambank erosion. Unlike the presettling basin, an extended detention dry pond will always be located "on-line" with the primary conveyance/detention system.

*Planning Considerations*

See *BMP RD.10, Presettling Basin*, for the following planning considerations:

- *Sediment and Debris*
- *Heavy Metal Contamination*
- *Site Constraints and Setbacks*
- *Dam Safety*
- *Safety, Signage and Fencing*

Other planning considerations are:

*Multiple Uses*

Multi-purpose use of the facility and aesthetic enhancement of the general area should also be major considerations. Above all, the facility should function in such a manner as to be compatible with overall stormwater systems both upstream and downstream to promote a watershed approach to providing stormwater management as well as local flood control and erosion protection.

If the facility is planned as an artificial lake to enhance property values and promote the aesthetic value of the land, pretreatment in the form of landscape retention areas or perimeter swales should be incorporated into the stormwater management facility. If possible, catchbasins should be located in grassed areas. By incorporating this "treatment train" concept into the overall collection and conveyance system, the engineer can prolong the utility of these permanently wet installations and improve their appearance. Any amount of runoff waters, regardless how small, that is filtered or percolated along its way to the final detention area can remove oil and grease, metals, and sediment. In addition, this will reduce the annual nutrient load to prevent the wet detention lake from eutrophying.

Detention system site selection should consider both the natural topography of the area and property boundaries. Aesthetic and water quality considerations may also dictate locations. For example, ponds with wetland vegetation are more aesthetically pleasing than ponds without vegetation. Ponds containing wetland vegetation also provide better conditions for pollutant capture and treatment.

A storage facility is an integral part of the environment and therefore should serve as an aesthetic improvement to the area if possible. Use of good landscaping principles is encouraged. The planting and preservation of desirable trees and other vegetation should be an integral part of the storage facility design.

*Basin Planning*

The design of urban detention facilities should be coordinated with a basin plan for managing stormwater runoff. In a localized situation, an individual property owner can, of course, by his or her actions alone, provide effective assistance to the next owner downstream if no other areas contribute to that owner's problems. However, uncontrolled proliferation of impoundments within a watershed can severely

alter natural flow conditions, causing compounded flow peaks or increased flow duration which can contribute to downstream degradation. In addition, upstream impacts due to future land use changes should be considered when designing the structure. Land use planning and regulation may be necessary to preserve the intended function of the impoundment. See Minimum Requirement #9 (Basin Planning) and the appendix in Volume I for a further discussion of basin planning.

#### Overflows

Detention facility design must take into consideration overflows and secondary overflow. Overflows include all facilities designed to bypass flows over or around the restrictor system. Overflow may result from higher intensity or longer duration storms than the design storm or result from plugged orifices or inadequate storage due to sediment buildup in the facility.

Secondary overflow occurs when the capacities of all conveyance facilities, and all overflow facilities are exceeded or are not functioning. In such instances, stormwater will often exit the conveyance system through catchbasin grates and flow down the corridor of least resistance. Careful consideration must be given to the impact of secondary overflows on public health, safety and welfare, property, and wildlife habitat. When secondary overflow occurs, design of secondary drainage facilities following careful analysis and planning can significantly reduce impacts. Street alignments and grades are the key components in developing secondary drainage design, and consideration should be given early in the planning stages to their use as secondary overflow facilities.

#### Design Criteria

See BMP RD.10, Presettling Basin, for the following design criteria:

- Pond Configuration and Geometry
- Outlet Structure
- Liner
- Berm Embankment/Slope Stabilization
- Erosion and Sediment

#### Sizing Extended Detention Dry Basins

For pretreating runoff, see BMP RD.10, Presettling Basin. Pretreatment should be provided for a range of runoff volumes, up to the 6-month, 24-hour design storm.

For streambank erosion control, use the design methods and procedures provided in Chapter III-1. A multiple orifice design will be necessary in order to meet the three release requirements, i.e., 50% of the existing condition 2-year, 24-hour peak flow; maintain existing condition peak flow rates for the 10-year and 100-year, 24-hour events. A correction factor must be applied to the calculated detention volume, as discussed in Section III-1.2, in order to account for weaknesses in current hydrologic analysis methods.

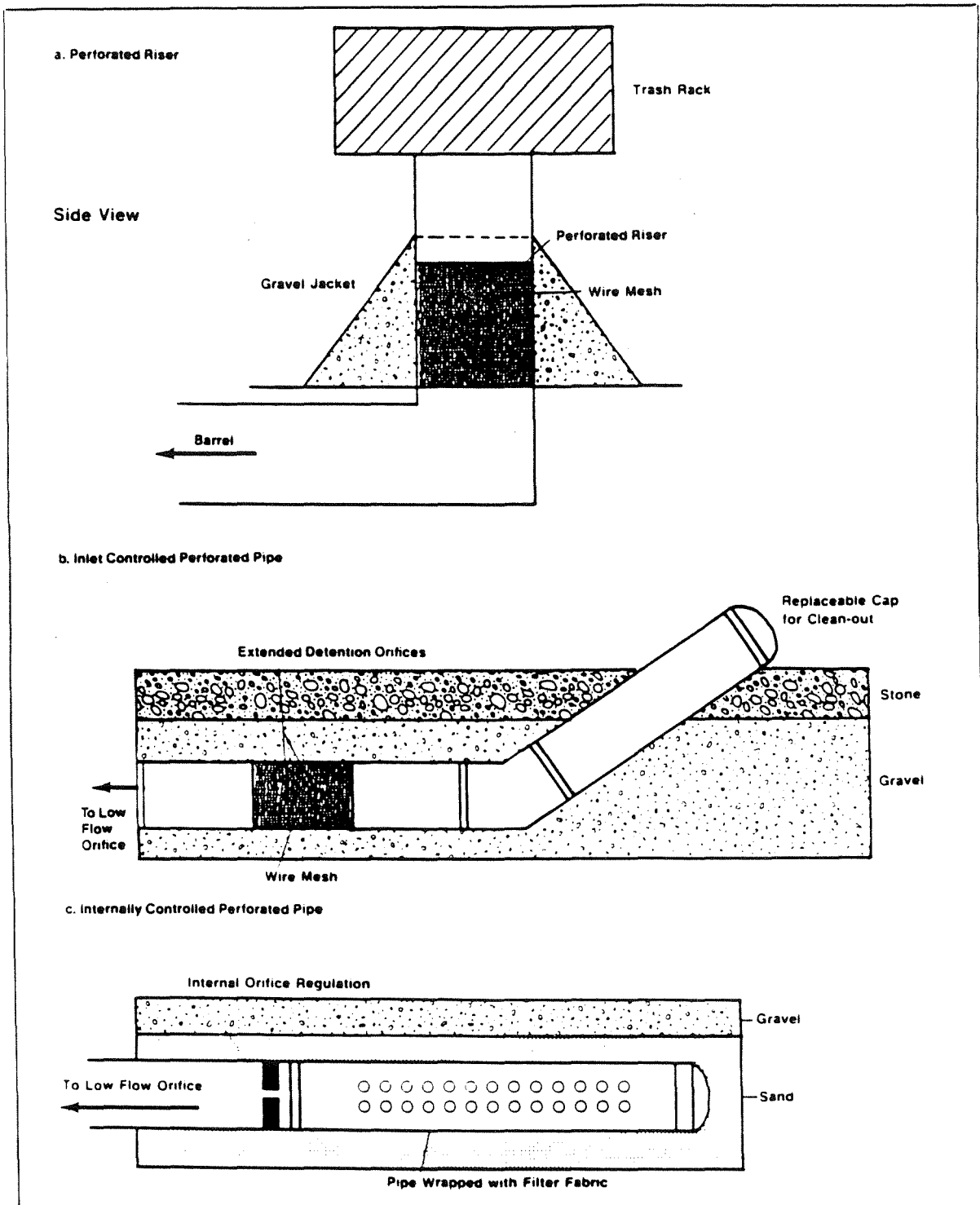
Figure III-4.16 illustrates methods to provide extended detention for this BMP.

#### Construction and Maintenance Criteria

See BMP RD.05, Wet Pond (Conventional Pollutants).



Figure III-4.16 Methods for Extending Detention Times for Dry Detention Ponds



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### III-4.5 STANDARDS AND SPECIFICATIONS FOR VAULTS AND TANKS

#### III-4.5.1 BMP RD.15 Wet Vault/Tank

##### Purpose and Definition

Wet vaults and tanks are underground facilities used for the storage of surface water, and are typically constructed from reinforced concrete (vaults) or corrugated pipe (tanks). Wet vaults and tanks are typically concrete or structural facilities designed to provide runoff treatment through the use of a permanent pool of water. Streambank erosion control can also be provided by adding a "live storage" volume above the permanent pool. Figures III-4.17 and III-4.18 illustrate tank/vault systems.

##### Planning Considerations

See BMP RD.05, Wet Pond (Conventional Pollutants). Additional planning considerations are provided below.

If a wet vault/tank is designed to provide runoff treatment but not streambank erosion control it must be located "off-line" from the primary conveyance/detention system. Flows above the peak flow for the water quality design storm (i.e., 6-month, 24-hour event) must bypass the facility in a separate conveyance to the point of discharge. A mechanism must be provided at the bypass point to take the facility "off-line" for maintenance purposes (see Section III-3.7 for isolation/diversion structures).

##### Limitations

Wet vaults/tanks cannot provide the equivalent level of treatment accomplished by wet ponds and constructed wetlands because neither biological uptake nor vegetative filtration are available as pollutant removal mechanisms. Gravity-settling of suspended solids is the primary removal mechanism but vaults/tanks are unlikely to be as effective as open ponds in removing particulates because little or no soil layer exists in which to permanently stabilize trapped sediments. Also, being underground, vaults and tanks are more difficult to inspect and maintain. Therefore, they shall only be permitted for use on small sites, and then only after it has been demonstrated to the satisfaction of the local government that more desirable BMPs are not practicable, according to the BMP selection process outlined in Chapter I-4.

##### Other

Wet vaults/tanks shall be a minimum of 20 feet from any structure, property line, NGPE, and from any septic tank/drainfield. All facilities shall be a minimum of 50 feet from any steep slope. A geotechnical report must address the potential impact on a steep slope.

##### Design Criteria

The design criteria for a wet vault/tank shall be the same as for BMP RD.05, Wet Pond (Conventional Pollutants).

##### Sizing Wet Vaults/Tanks

Volume/outflow analysis shall be in accordance with the hydrologic methods outlined in Chapter III-1, with appropriate correction factors. Restrictor/orifice structure design shall be per Section III-2.4.

- Permanent Pool for Water Quality Treatment - same as for wet ponds (BMP RD.05).
- Streambank Erosion Control ("Live Storage") - same as for wet ponds (BMP RD.05)

The length-to-width ratio at the design surface area shall be no less than 3:1.

#### Forebay

The vault shall be divided into 2 cells using a baffle, with the first cell, the forebay, occupying about 25 percent of the area. The top of the baffle wall must be coincident with the depth of the permanent pool.

#### Construction and Maintenance Criteria

See BMP RD.05, Wet Pond (Conventional Pollutants). Additional construction and maintenance criteria is provided below.

#### Construction

Standard vault details are shown in Figure III-4.17; standard tank details in Figures III-4.18 and III-4.19.

#### Materials

##### (a) Vaults

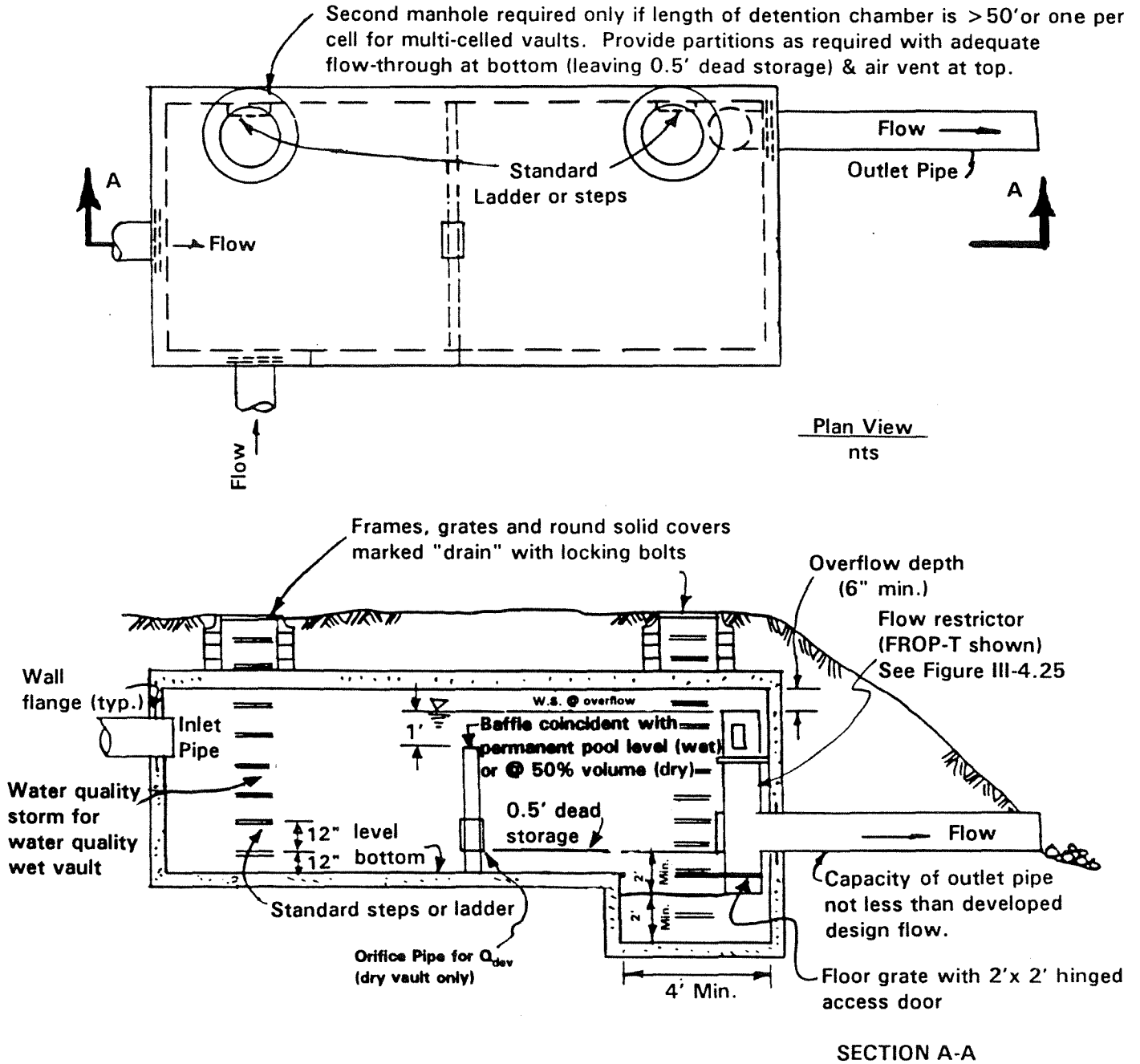
Minimum 3000 psi structural reinforced concrete. All construction joints must be provided with water stops. Pre-cast vaults shall be designed by a structural engineer.

##### (b) Tank

Pipe material, joints, and protective treatment for tanks shall be in accordance with WSDOT/APWA Standard Specifications Section 9.05, and AASHTO designations as noted below:

- Corrugated iron or steel pipe and pipe arch, Treatment 1 through 6.
- Aluminized Type 2 corrugated steel pipe and pipe arch (meets AASHTO designations M274 and M36).
- Steel spiral rib pipe, Treatment 1 through 6.
- Aluminum spiral rib pipe.
- Corrugated aluminum pipe and pipe arch.
- Reinforced concrete pipe.
- Corrugated high density polyethylene pipe (CPEP) - Smooth Interior

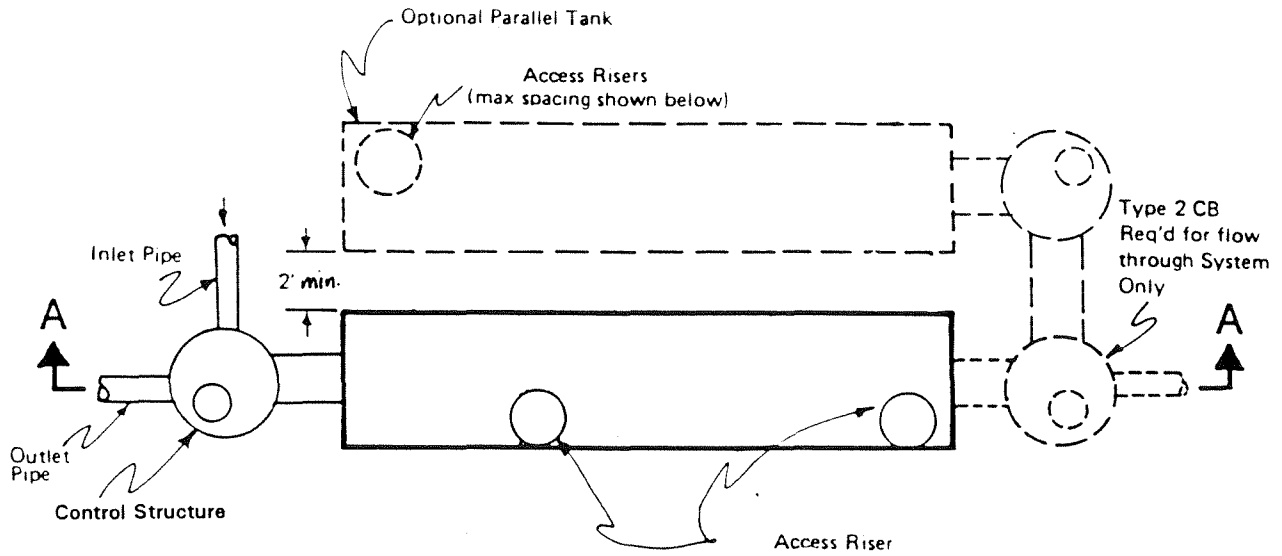
Figure III-4.17 Typical Detention Vault (Dry/Wet)



Notes:

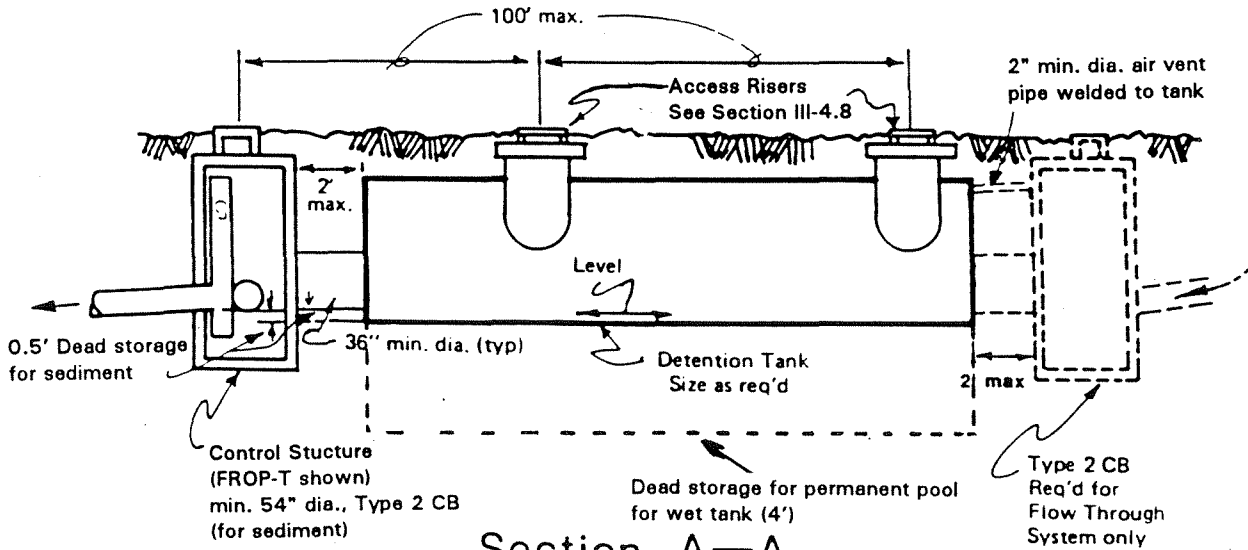
1. Plans must be designed & stamped by a registered professional structural engineer.
2. All metal parts shall be corrosion resistant.
3. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.

Figure III-4.18 Typical Detention Tank (Dry/Wet)



Plan View

NO SCALE  
 "Flow Back Up" System Shown  
 Optional Designs for "Flow Through" System and  
 Parallel Tanks Shown Dashed



Section A-A

NO SCALE

NOTE: All metal parts corrosion resistant. Steel parts galvanized and asphalt coated (Treatment I or better)

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### Structural Stability

#### (a) Vaults

All vaults shall meet structural requirements for overburden support and HS-20 traffic loading. Cast-in-place wall sections shall be designed as retaining walls. All structural designs shall be stamped by a structural engineer licensed in the State of Washington. Structural designs for cast-in-place vaults may require a separate commercial building permit from the local government. Vaults shall be placed on native material with suitable bedding. Vaults shall not be allowed in fill slopes unless analyzed in a geotechnical report for stability and construction practices.

#### (b) Tanks

All tanks shall meet structural requirements for overburden support and traffic loading, if appropriate. HS-20 live loads must be accommodated for tanks lying under roadways or parking areas. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gauge material than the pipe and/or require reinforcing ribs. Tanks shall be placed on native material with a suitable bedding. Tanks shall not be allowed in fill slopes.

#### (c) Buoyancy (Tanks)

In moderately pervious soils where seasonal ground water may induce flotation, buoyancy tendencies must be balanced by ballasting with either backfill or concrete backfill, providing concrete anchors, increasing the total weight, or by providing subsurface drains to permanently lower the ground water table. Calculations must be submitted which demonstrate stability.

### Minimum Access Requirements

#### (a) Vaults

Provide 1 access cover per 50 feet of length or width and at least 1 access cover with ladder to the bottom of the vault per cell. The minimum internal height shall be 7 feet and the minimum width shall be 4 feet. The maximum depth to the vault invert shall be 20 feet. (Note, concrete vaults may be a minimum of 3 feet in height and width if used as tanks with access manholes at each end).

#### (b) Tanks

The maximum depth to a tank invert shall be 20 feet. Spacing between access openings for tanks shall not exceed 100 feet. 36-inch minimum diameter CMP riser-type manholes of the same gauge as the tank material per Figures III-4.17 and III-4.18 may be used for access along the length of the tank and at the upstream terminus of the tank if the tank is designed with a common inlet/outlet so that it is a backup system rather than a flow-through system. Note, Figure III-4.17 is not allowed for use in roadways, driveways, parking stalls, or anywhere it would be subjected to vehicular loads. All tank access openings must be readily accessible by maintenance vehicles. See Figure III-4.19 for tank access details.

### Locking Lids

All vault access openings shall have round, solid, locking lids using 1/2 inch diameter allen head screw locks.

### Maintenance

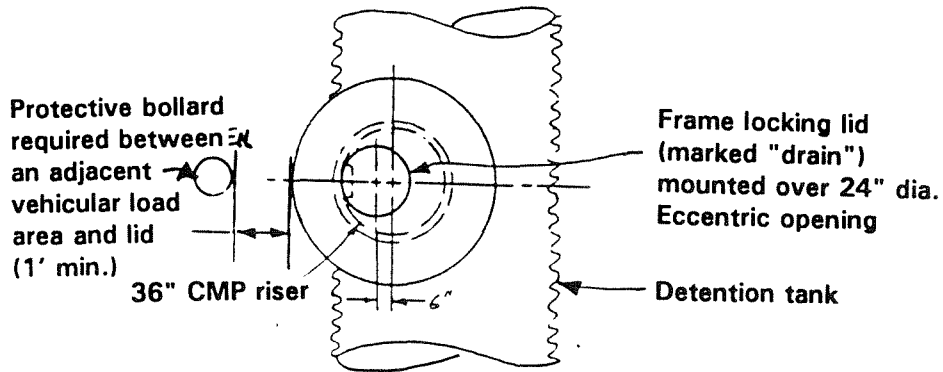
See Wet Pond (BMP RD.05) and Table III-4.7.

Access Roads

Access roads are required to at least one access cover for each cell. The access roads shall meet the requirements for access roads described in the maintenance details for wet ponds.

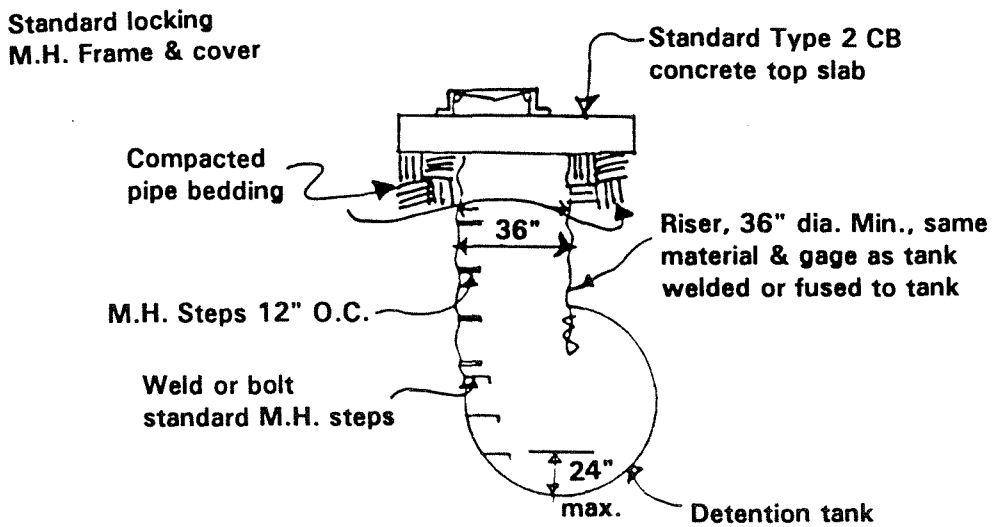
Figure III-4.19 Detention Tank Access Details

Restrictions for application: use only for access to detention tanks. Not allowed for use in roadways, driveways, parking stalls or where vehicular loads would occur.



**PLAN VIEW**

nts



**SECTION**

nts

**Notes:**

1. Use adjusting blocks as required to bring frame to grade.
2. All materials must be corrosion resistant.
3. Must be conveniently located for maintenance vehicle access.



III-4.5.2 BMP RD.20 Extended Detention Dry Vault/Tank

**Purpose and Definition**

An Extended Detention Dry Vault/Tank is physically similar to BMP RD.15 (Wet Vault/Tank) but provides **only** streambank erosion control. Dry vaults/tanks are not to be used for runoff treatment purposes because of their limited pollution removal capabilities. Dry Vaults/Tanks must always be preceded by a BMP which has treated runoff up to the 6-month, 24-hour design storm.

This BMP accomplishes streambank erosion control by detaining runoff and then releasing it a reduced flows in order to meet the standards established by Minimum Requirement #5 (see Chapter I-2).

Figures III-4.17 and III-4.18 illustrate detention vault/tank systems.

*Planning Considerations*

*Limitations*

*Dry vaults and tanks provide little water quality benefits compared to open ponds and wet vaults/tanks. Also, being underground, are more difficult to inspect and maintain. Therefore, they shall always be preceded by treatment BMPs. Vaults/tanks shall be permitted for use only on small sites, and then only after it has been demonstrated, to the satisfaction of the local government, that more desirable BMPs are not practicable, according to the BMP selection process outlined in Chapter I-4.*

**Design Criteria**

An extended detention dry vault is designed only to provide streambank erosion control. The design methods and procedures provided in Chapter III-1 shall be used. A multiple orifice design will be necessary in order to meet the three release requirements, i.e., 50% of the existing condition 2-year, 24-hour peak flow; maintain existing condition peak flow rates for the 10-year and 100-year, 24-hour events. A correction factor must be applied to the calculated detention volume, as discussed in Section III-1.2, in order to account for weaknesses in current hydrologic analysis methods.

**Construction and Maintenance Criteria**

See BMP RD.15, Wet Vault/Tank and Table III-4.7.

Table III-4.7 Specific Maintenance Requirements for Detention Vaults/Tanks

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
I. Storage Area	Plugged air vents	One-half of the end area of a vent is blocked at any point with debris and sediment.	Vents free of debris and sediment.
	Debris and sediment	Accumulated sediment depth is $\geq 10\%$ of the diameter of the storage area for $\frac{1}{2}$ the length of the storage vault or any point exceeds $15\%$ of the diameter. Example: 72-inch storage tank would require cleaning when sediment reaches a depth of 7 in. or more than $\frac{1}{2}$ the length of the tank.	All sediment and debris removed from storage area.
	Joints between tank/pipe section	Any crack allowing material to be transported into the facility.	All joints between tank/pipe sections are sealed.
II. Manhole	Cover not in place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking mechanism not working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have $< \frac{1}{2}$ inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
	Cover difficult to remove	One maintenance person cannot remove lid after applying 800 pounds of lift. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder rungs unsafe	Local Government Safety Officer and/or maintenance person judge that ladder is unsafe due to missing rungs, misalignment, rust or cracks.	Ladder meets design standards and allows maintenance persons safe access.
III. Catchbasins	See "catchbasins" standard, Section III-4.8	See "catchbasins" standard, Section III-4.8.	See "catchbasins" standard, Section III-4.8.

III-4.6 REFERENCES

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- (5) Horner, R.R., Highway Construction Site Erosion and Pollution Control: Recent Research Results, Proceedings from the 39th Annual Road Builders' Clinic, Washington State University, 1988.
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- (8) Chen, C., Design of Sediment Retention Basins, National Symposium on Urban Hydrology and Sediment Control, Mini Course No. 2, University of Kentucky, Lexington, Kentucky, July, 1975.

CHAPTER III-5 NATURAL WETLANDS AND STORMWATER MANAGEMENT

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## CHAPTER III-5

## WETLANDS AND STORMWATER MANAGEMENT

## III-5.1 INTRODUCTION

The purpose of this chapter is to present preliminary guidelines for the discharge of pre-treated stormwater to natural wetlands.

The preliminary guidelines, prepared by Dr. Richard R. Horner, provide information on how the functions and values of natural wetlands may be preserved, and their possible use for hydraulic control of treated stormwater. Monitoring guidelines, definitions, references, and appendices are also included (see Section III-5.2).

Wetland ecosystems can be highly effective managers of stormwater runoff. They can remove pollutants and also attenuate flows and recharge ground water. However, natural wetlands may not be used as pollution control facilities, in lieu of treatment BMPs, such as constructed wetlands, infiltration facilities etc.

On the other hand, constructed wetlands that are built in upland areas for the specific purpose of treating stormwater can be viewed as analogous to wet ponds, and therefore are not subject to the same restrictions that are placed on natural wetlands. In addition, constructed wetlands by their very nature offer control over the design features which can maximize their water treating ability (see below). They may be lined to prevent pollution of ground water, where necessary, and can be configured to maximize ease of maintenance and general accessibility. Also, harvesting can be done, if necessary, to maintain the capability of the wetland to remove soluble pollutants. Harvesting natural wetlands is neither acceptable nor practical. Constructed wetlands as a BMP can be found in Chapter III-4.

III-5.1.1 Pollutant Removal Mechanisms

The major pollutant removal mechanisms operating in wetlands may be divided into physical, chemical, and biological. Physical mechanisms include sedimentation, filtration, and adsorption; chemical mechanisms include precipitation and adsorption; biological mechanisms include plant and bacterial uptake and metabolism, and plant absorption. The combination of these removal mechanisms can result in high removal efficiencies of pollutants - up to 90 percent or higher. However, high removal efficiencies are dependent on the exact nature of the wetland and how it has been designed and constructed.

Many studies have shown that wetlands, whether natural or artificial, remove pollutants both from stormwater runoff and wastewater effluent. While the results of those studies may vary, they generally achieved significant removal levels for nitrogen (N), total suspended solids (TSS), BOD, and heavy metals. The pollutant showing the most variability in removal rate was phosphorus (P), which was removed at high levels for the most part but in some studies showed net increases of concentration when measured at the outlet of the system.

Nutrient and pollutant uptake in wetlands varies considerably during the year but even seasonal removal has its benefits. If a wetland takes up nutrients during the summer growing season, positive recreational and wildlife benefits result even though those nutrients may be released during the winter months.

The details given below have been selected to maximize the operation of these pollutant removal mechanisms.

**III-5.2 NATURAL WETLANDS AND STORMWATER MANAGEMENT**

The use of natural wetlands to manage stormwater runoff is not considered a BMP. Preliminary guidance on the management of natural wetlands is presented below. The guidelines were prepared by Rich Horner on behalf of the Puget Sound Wetlands and Stormwater Management Research Program. You will note that many of the guidelines and prerequisites are common to two or more of the guide sheets.

(PRELIMINARY GUIDELINES)      DRAFT, 3/22/91

**WETLANDS AND STORMWATER MANAGEMENT**

**INTRODUCTION**

The Puget Sound Wetlands and Stormwater Management Research Program is performing comprehensive research with the goal of deriving strategies that protect wetland resources in urban and urbanizing areas, while also benefiting the management of urban stormwater runoff that can affect those resources. The research primarily involves long-term comparisons of wetland ecosystem characteristics before and after their watersheds urbanize, and between a set of wetlands that become affected by urbanization (treatment sites) and a set that remain unaffected (control sites). This work is being supplemented by shorter term and more intensive studies of pollutant transport and fate in wetlands, several laboratory experiments, and ongoing review of relevant work being performed elsewhere. These research efforts are aimed at defining the types of impacts that urbanization can cause and the degree to which they develop under different conditions, in order to identify means of avoiding or minimizing impacts that impair wetland structure and functioning. The program's scope embraces both situations where urban drainage incidentally affects wetlands in its path, as well as those in which direct stormwater management actions change wetlands' hydrology, water quality or both.

This document presents preliminary management guidelines for urban wetlands and their stormwater discharges based on the initial research results. The guidelines are being incorporated in a computer-based management model. The guidelines and the model will be the principal vehicles to implement the research findings in environmental planning and management practice. They will be refined as additional results become available and finalized at the program's conclusion.

## III-5.2.1 GUIDE SHEET 1

## GENERAL APPROACH AND PROBLEM DEFINITION

- 1.1 If you are unfamiliar with these guidelines, read the description of the approach that follows. If you are familiar, proceed to Step 1.2.
- (a) These provisions currently have the status of guidelines rather than requirements. Application of these guidelines does not fulfill assessment and permitting requirements that may be associated with a project. It is, in general, necessary to follow the stipulations of the State Environmental Policy Act and to contact such agencies as the local planning agency; the Washington Departments of Ecology, Fisheries, and Wildlife; the U.S. Environmental Protection Agency; and the U.S. Army Corps of Engineers.
  - (b) These guidelines are intended to be part of the Department of Ecology's Stormwater Management Manual for the Puget Sound Drainage Basin. Volume and chapter citations within the guidelines refer to other parts of the manual.
  - (c) The guidelines are organized in a branching decision-tree format. After using Guide Sheet 1 to define the management problems(s) to be resolved, you will be directed to Guide Sheet 2 for an initial consideration of wetland protection guidelines and then to additional sheets that guide the analysis of the selected problem(s). Refer to Figure III-5.1 for a diagram of the guideline application process.
  - (d) This system can be applied with whatever information concerning the problem(s) is available. Of course, the comprehensiveness and certainty of the outcome will vary with the amount and quality of information employed. The guidelines can be applied in an iterative fashion to improve management understanding as the information improves. Appendix AIII-5.1 lists the information needed to perform basic analyses by guide sheet, followed by other information that can improve understanding and analysis.
  - (e) The guidelines use certain terms that require definition to ensure that the intended meaning is conveyed to all users. Such terms are printed in boldface the first time that they appear, and are defined in Appendix AIII-5.2.
  - (f) These guidelines emphasize avoiding structural, hydrologic, and water quality modifications of existing wetlands to the extent possible in the process of urbanization and the management of urban stormwater runoff.
  - (g) In pursuit of this goal, the guidelines take a systematic approach to management problems that potentially involve both urban stormwater (quantity, quality, or both) and wetlands. The consideration of wetlands involves their areal extent, values, and functions. This approach emphasizes a comprehensive analysis of alternatives to solve the identified problem. The guidelines encourage conducting the analysis on a drainage catchment scale and considering all of the possible stormwater management alternatives, which may or may not involve a wetland. They favor on-site best management practices (located outside of a wetland or its buffer) and pretreatment of stormwater runoff prior to release to wetlands.
  - (h) Furthermore, the guidelines take a holistic view of managing wetland resources in an urban setting. Thus, they recognize that urban wetlands

have the potential to be affected structurally and functionally whether or not they are formally designated for stormwater management purposes. Even if an urban wetland is not structurally or hydrologically engineered for such purposes, it may experience altered hydrology (more or less water), reduced water quality, and a host of other impacts related to urban conditions. It is the objective of the guidelines to avoid or reduce to the maximum extent possible the negative effects on wetland resources from both specific stormwater management actions and incidental urban impacts.

- (i) The guideline provisions were drawn principally from the available results of the Puget Sound Wetlands and Stormwater Management Research Program. Where those results are the basis for a numerical criterion, no separate reference is given. Numerical provisions based on other work are referenced. See Appendix AIII-5.3 for references.

1.2 Refer to Guide Sheet 2 for wetland protection guidelines. Apply this guidance in developing the solution of your management problem(s) in order to protect the overall structure and functioning of any existing wetland(s).

1.3 If you have one or more of the management problems in the list below, proceed as directed. If you have a management problem that is not listed, guidelines are not currently available for its analysis. However, please communicate your needs for guidelines for consideration by the Puget Sound Wetlands and Stormwater Management Research Program (Richard Horner; telephone 206-543-7923).

- (a) One or both of the following runoff quantity problems is associated with existing development, or expected with new development:

- (i) Flooding

Flood control tends to target relatively infrequent (e.g., 5-year or less frequent recurrence), larger storms.

- (ii) Stream channel erosion

Stream channel erosion prevention generally requires the control of relatively frequent (e.g., < 2-year recurrence interval), smaller storms. Often, management is intended to mitigate both stream channel erosion and flooding. The guidelines are the same for both of these problem areas, except where the hydrologic differences affect the provisions.

If you have one or both of these management problems, proceed to Guide Sheet 3; otherwise, continue.

- (b) Improving storm runoff water quality is an objective.

Use of Waters of the State and Waters of the United States, including wetlands, for the treatment or conveyance of wastewater (including stormwater) is prohibited under state and federal law. While the subject remains under policy review, it appears that regulations under development may allow the use of wetlands to improve stormwater quality under specific conditions on a case-by-case basis, *provided that the stormwater runoff has been pretreated by an infiltration facility, wet pond, or presettling basin with biofilter, sized to treat at least the 6-month 24-hour storm for the developed condition, and according to General Minimum Requirements #4 and #6 (see Chapters III-3 and III-4 for design details)*. If you have this management problem, proceed to Guide Sheet 4 to evaluate the circumstances of your case; otherwise, continue.



- (c) A comprehensive management plan is needed for wetlands in a newly developing area.

Wetlands in newly developing areas will be impacted by development even if not specifically "used" in stormwater management. Therefore, the task is to ensure proper overall management of the resources and protection of their general functioning, including their role in storm drainage systems. Stormwater management in newly developing areas is distinguished from management in already developed locations by the existence of many more feasible stormwater treatment options prior to development. The guidelines emphasize appropriate selection among the options to achieve optimum overall resource protection benefits, extending to downstream receiving waters and ground water aquifers, as well as to wetlands.

If you have this management problem, proceed to Guide Sheet 5.

III-5.2.2 GUIDE SHEET 2

GENERAL WETLAND PROTECTION GUIDELINES

- 2.1 Consult regulations issued under federal and state laws that govern the discharge of pollutants, specifically Ch. 173-200 WAC and Ch. 173-201 WAC. Wetlands are classified as "Waters of the United States" and "Waters of the State" in Washington.
- 2.2 Apply the following guidelines to protect the ecological structure and functioning of wetlands that are modified to supply runoff water quantity or quality control benefits or are incidentally subject to the effects of an urbanizing watershed.
- (a) Require effective erosion control at any construction sites in the wetland's drainage catchment (refer to Volume II).
  - (b) Institute a program of source control BMPs to minimize the generation of pollutants that will enter storm runoff that drains to the wetland (refer to Volume IV).
  - (c) Maintain the wetland buffer required by local regulations or recommended by the Puget Sound Water Quality Authority's draft wetland guidelines.
  - (d) Provide oil/water separation according to the requirements of Chapter III-7.
  - (e) Provide a pretreatment system for all urban runoff entering the wetland. This system should consist of, at minimum, a presettling basin (forebay), followed by, a biofilter (vegetated swale or filter strip). Design the forebay and biofilter according to Chapters III-4 and III-6). Locate these facilities outside and upstream of the wetland and its buffer.
  - (f) Determine the existing and projected land uses of the contributing catchment by consulting land use and zoning maps and/or the applicable comprehensive plan, or by performing field reconnaissance. If the contributing catchment exhibits any of the following characteristics, then install a level of treatment in addition to the facilities specified above:
    - (i) More than 20 percent of the catchment area is committed to commercial, industrial, and/or multiple family residential land uses; or
    - (ii) The combination of all urban land uses (including single family residential) exceeds 50 percent of the catchment area; or
    - (iii) The concentration of total cadmium, copper, lead, or zinc in the open water of the wetland, as measured according to Guide Sheet 7, exceeds the U.S. Environmental Protection Agency (1986a) criteria (either four-day or one-hour average) more than once annually.

For the additional treatment consider infiltration (refer to Chapter III-3) and biofiltration (refer to Chapter III-6). In the analysis of the infiltration alternatives, pay particular attention to the selection criteria in Chapter III-3 to avoid ground water contamination.

- (g) If the wetland inlet will be modified for the stormwater management project, use a diffuse flow method, such as a spreader swale, to discharge water into the wetland in order to prevent flow channelization.
- (h) Research has shown that wetlands that have experienced an increased mean annual water level fluctuation also lose species in their plant communities, especially when the mean annual fluctuation increases to more than 21 cm (8.4 inches). When a wetland in a relatively undisturbed condition normally has a mean annual fluctuation less than 21 cm, avoid increasing it beyond that level. When a wetland's hydrology has been disturbed so that it has apparently experienced a mean annual fluctuation greater than 21 cm, consider actions that restore the pre-disturbance hydrology. Such actions include the alternatives listed in Guide Sheet 3, Step 3.3, and reversal of steps taken to increase the depth, frequency, and duration of inundation.

Note: These provisions may not necessarily protect sensitive animal life stages; see Guidelines 2.2 (j) and (k) below.

- (i) Protect priority peat systems, forested communities, and sensitive scrub-shrub and emergent wetland plant communities by:
- (i) Limiting the frequency of water level rise above the maximum depth for the existing conditions on the site to no more than--
- One occurrence in 5 years for priority peat systems and forested communities;
- One occurrence per year for sensitive scrub-shrub and emergent communities;
- Maximum depth can be measured by a continuous recording level gage or a series of crest stage gage (Reinelt and Horner 1990) readings over time or estimated by a locally calibrated, continuous simulation, hydrologic model, such as the HSPF model.
- (ii) And, limiting the duration of flooding above the maximum depth for the existing conditions on the site to 48 hours.
- (iii) And, avoiding water level rise above the maximum depth for the existing conditions on the site during the early plant growing season months March-May.

Note: These guidelines are based on general literature reports and best professional judgment, and are being evaluated in the research program. These provisions may not necessarily protect sensitive animal life stages; see Guidelines 2.2 (j) and (k) below.

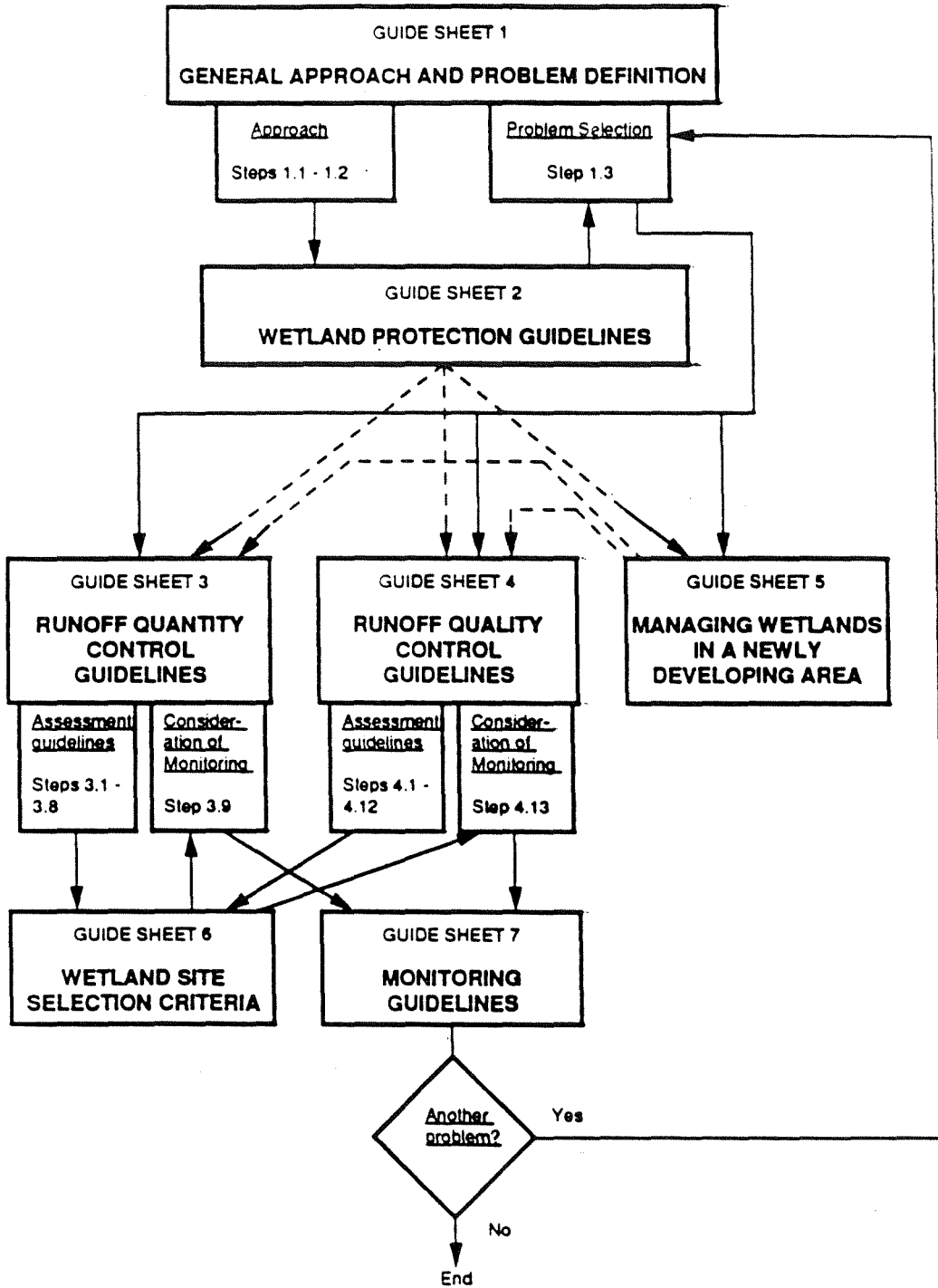
- (j) Protect animal inhabitants by avoiding water level rise above the pre-project maximum depth experienced by sensitive life stages, especially during breeding, egg-laying, and rearing periods. (Note: Guidelines for birds, mammals, and amphibians are being formulated as part of the ongoing comprehensive management model development under the Puget Sound Wetlands and Stormwater Management Research Program; these specific guidelines will be incorporated when they are ready.)
- (k) Protect fish habitats by avoiding water velocities above tolerated levels (selected to protect fish in each life stage when they are present), siltation of spawning beds, etc. Habitat requirements vary substantially among fish species. If the wetland is associated with a larger water body, contact the Departments of Fisheries and Wildlife to determine the

species of concern and the acceptable ranges of habitat variables.

- (l) If it is expected that the runoff quantity or quality control objectives will require a greater frequency, a longer duration, or a different pattern of inundation than the limits stated above for the protection of sensitive plant communities and/or animal life stages allow, use an alternative such as selectively bypassing flow or providing supplementary storage.
- (m) If stranding of protected commercial or sport fish is an issue, develop a strategy to avoid stranding that minimizes disturbance in the wetland (e.g., by making provisions for fish return to the stream as the wetland drains or avoiding use of the facility during fish presence).
- (n) The research has shown that wetlands that have experienced a lengthened period in the summer without water standing above the soil surface also lose species in their plant communities, especially when the loss of standing water extends beyond two months. When a wetland in a relatively undisturbed condition normally has standing water for most of the summer, avoid increasing the period of drying, especially beyond two months. When a wetland's hydrology has been disturbed so that it has apparently experienced a lengthened period without standing water, consider actions that restore the pre-disturbance hydrology. Such actions include stormwater infiltration (refer to Chapter III- 3), restoration of surface inflow that has been bypassed around the wetland, and reversal of steps taken to drain the wetland.
- (o) Avoid compaction of soil and introduction of exotic plant species during any work in a wetland.
- (p) If a relatively high quality, diverse, or unique natural plant community was present before construction, restore and replant areas of construction disturbance with native vegetation that best replicates the pre-construction community. In cases where the plant community has been degraded, consists primarily of invasive weedy non-native or aggressive native species, and has low structural diversity, enhancing it with a greater variety of native species would, in general, be consistent with expanding wetland values and functions.
- (q) Avoid the removal or damage of nurse logs and snags, which form important wildlife habitats, to the maximum extent possible. Replace any such materials that are removed or damaged under the guidance of a qualified wildlife biologist.
- (r) Take specific site design and maintenance measures to avoid general urban impacts (e.g., littering and vegetation destruction). Examples are protecting existing buffer zones; discouraging access, especially by vehicles, by plantings outside the wetland; and encouragement of stewardship by a homeowners' association. Fences should not be used, because they interfere with wildlife movements.

### 2.3 Return to Guide Sheet 1, Step 1.3.

Figure III-5.1 Guideline Application Process



APPENDIX A  
DEFINITIONS

APPENDIX B  
REFERENCES

APPENDIX C  
PLANT SPECIES NATIVE TO WETLANDS IN THE PUGET SOUND REGION

III-5.2.3 GUIDE SHEET 3

RUNOFF QUANTITY CONTROL GUIDELINES

- 3.1 If the problem is attributable to existing development, assess possible alternative solutions that are applicable at the site of the problem occurrence, including:
- (a) Protect health, safety, and property from flooding by removing habitation from the floodplain or installing a protective barrier at the point of flooding danger. Solutions must comply with existing ordinances and should be consistent with the protection of all beneficial stream uses to the extent possible.
  - (b) Prevent stream channel erosion by stabilizing the eroding bed and/or bank area with bioengineering techniques, preferably, or by structurally reinforcing it, if this solution would be consistent with the protection of aquatic habitats and beneficial uses of the stream (refer to BMPs E2.80, E2.85, and E2.90 in Chapter II-4).
- 3.2 If the potential problem is attributable to new development, assess possible regulatory and land use control alternatives, such as density controls, clearing limits, etc.
- 3.3 If the alternatives considered in Step 3.1 or 3.2 cannot solve an existing or potential problem, perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied on-site or on a regional scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment. As an aid to selecting the appropriate BMP, refer to Chapter I-4.
- (a) For new development, on-site facilities that should be assessed include, in order of preference:
    - (i) Infiltration basins or trenches (refer to Chapter III-3 and see Guide Sheet 2, Step 2.2(f), for cautions on the application of infiltration systems);
    - (ii) Retention/detention ponds (refer to Chapter III-4) stormwater detention volume shall not exceed 1 foot.
    - (iii) Below-ground vault or tank storage (refer to Chapter III-4);Opportunities for the construction of on-site facilities for existing development are usually limited. In this situation the feasibility of below-ground and parking lot storage should be explored.
  - (b) Regional facilities that should be assessed for solving problems associated with either new development or existing development include:
    - (i) Infiltration basins or trenches (refer to Chapter III-3 and pay particular attention to the selection criteria for avoiding ground water contamination);
    - (ii) Detention ponds (refer to Chapter III-4);
    - (iii) Constructed wetlands (refer to Chapter III-4).

- 3.4 Consider existing wetlands only if upland alternatives are inadequate to solve the existing or potential problem. First consider among existing wetlands those in Category IV in the Puget Sound Water Quality Authority's draft wetland guidelines. In general, Category IV wetlands have monotypic vegetation of similar age and class, lack special habitat features, and are isolated from other aquatic systems. A preferred selection is a wetland that has been drained, has experienced a lengthened summer dry period, or has been otherwise degraded, and that can be restored or enhanced to perform runoff quantity control and other functions. If an existing wetland alternative is being considered, evaluate it further according to the subsequent guidelines.
- 3.5 An existing wetland should not be modified for runoff quantity control and should be given maximum protection from overall urban impacts (see Guide Sheets 2 and 5) under any of the following circumstances:
- (a) It is primarily an estuarine or forested wetland or a priority peat system.
  - (b) It is a rare or irreplaceable wetland type, as identified by the Washington Natural Heritage Program (telephone (206) 753-2449), the Puget Sound Water Quality Preservation Program (telephone (206) 438-7429), or local government.
  - (c) It provides rare, threatened, or endangered species habitat that could be impaired by the proposed action. Determining whether or not the conserved species will be affected by the proposed project requires a careful analysis of its requirements in relation to the anticipated habitat changes.
- In general, the wetlands in these groups are classified in Categories I and II in the Puget Sound Water Quality Authority's draft wetland guidelines.
- 3.6 An existing wetland should not be modified for a stream channel erosion control project if an altered hydroperiod would affect priority peat system or forested zones. These zones are especially sensitive to frequent water level rises such as are expected with this type of project. An existing wetland may be modified for a flood control project that affects priority peat system or forested zones only if these zones are protected by application of the guidelines in Guide Sheet 2 and if all local, state, and federal permitting and regulatory requirements are met.
- 3.7 If more than one wetland in the drainage could be selected for the project, refer to Guide Sheet 6 for site selection criteria.
- 3.8 Review the wetland protection guidelines in Guide Sheet 2 and apply them to the project design.
- 3.9 Proceed to Guide Sheet 7 to develop a project monitoring plan.

## III-5.2.4 GUIDE SHEET 4

## RUNOFF QUALITY CONTROL GUIDELINES

*Editor's Note: Whenever considering the possible role of wetlands in stormwater quality control, the underlying principle is that, no matter what practices are adopted, water quality standards for wetlands (see Ch. 173-201 WAC) must be achieved, and the standards set in General Minimum Requirements #4 and #6 must be met (see Chapter I-2). As a general rule it can be said that in all instances where urban stormwater is discharging into wetlands, implementation of some combination of source control and treatment BMPs will be needed (see Chapter I-4 for guidance on BMP selection).*

- 4.1 Perform an analysis of the contributing and receiving drainage catchments to define the type and extent of runoff water quality problems associated with existing or new development that require control to protect the beneficial uses of receiving waters, including wetlands (refer to Chapter 173-201 WAC for the definition of beneficial uses). This analysis should include a hydrologic assessment (refer to Chapter III-1); identification of key water pollutants, such as solids, oxygen-demanding substances, nutrients, metals, oils, trace organics, and bacteria; and evaluation of the potential effects of hydrologic conditions and water pollutants throughout the drainage system.
- 4.2 Perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied on-site or on a regional scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment. As an aid to selecting the appropriate BMP, refer to Chapter I-4. Consider both source control BMPs (Step 4.2(a)) and treatment BMPs (Step 4.2(b)).
  - (a) Implementation of source control BMPs that prevent the generation or release of water pollutants at potential sources. This alternative usually offers the more feasible opportunity to control runoff water quality in existing developments (refer to Volume IV);
  - (b) Installation of facilities that capture water pollutants after their release (treatment BMPs). This alternative often has limited application in existing developments because of space limitations, although it can be employed when redevelopment occurs in already developed areas. Facilities that should be considered include:
    - (i) Infiltration basins or trenches (refer to Chapter III-3 and pay particular attention to the selection criteria for avoiding ground water contamination);
    - (ii) Wet or extended-detention ponds (refer to Chapter III-4);
    - (iii) Oil/water separators or their equivalent (refer to Chapter III-7);
    - (iv) Constructed wetlands (refer to Chapter III-4);
    - (v) Biofiltration facilities (vegetated swales or filter strips) (refer to Chapter III-6).
- 4.3 Consider existing wetlands only if upland alternatives are inadequate to solve the existing or potential problem. Use of Waters of the State and Waters of the United States, including wetlands, for the treatment or conveyance of wastewater (including stormwater) is prohibited under state and federal law. It appears that federal and state regulations now under development may allow



the use of existing wetlands for improving stormwater quality, subject to analysis on a case-by-case basis and only if the following conditions are met:

- (a) If restoration or enhancement of a previously degraded wetland is required, and if the upgrading of other wetland functions can be accomplished along with benefiting runoff quality control,  
  
and
- (b) If appropriate source control and treatment BMPs are applied in the contributing catchment on the basis of the analysis in Step 4.2 and water quality standards for wetlands are observed.

If these circumstances apply, first consider among existing wetlands those in Category IV in the Puget Sound Water Quality Authority's draft wetland guidelines. In general, Category IV wetlands have monotypic vegetation of similar age and class, lack special habitat features, and are isolated from other aquatic systems. If an existing wetland alternative is being considered, evaluate it further according to the subsequent guidelines.

- 4.4 An existing wetland should not be modified for runoff quality control and should be given maximum protection from overall urban impacts (see Guide Sheets 2 and 5) under any of the following circumstances:
- (a) It is primarily an estuarine or forested wetland or a priority peat system.
  - (b) It is a rare or irreplaceable wetland type, as identified by the Washington Natural Heritage Program, the Puget Sound Water Quality Preservation Program, or local government.
  - (c) It provides rare, threatened, or endangered species habitat that could be impaired by the proposed action. Determining whether or not the conserved species will be affected by the proposed project requires a careful analysis of its requirements in relation to the anticipated habitat changes.

In general, the wetlands in these groups are classified in Categories I and II in the Puget Sound Water Quality Authority's draft wetland guidelines.

- 4.5 If more than one wetland in the drainage could be selected for the project, refer to Guide Sheet 6 for site selection criteria.
- 4.6 Water quality benefits to downstream receiving waters (lakes, streams, Puget Sound) can be gained in a wetland through one or a combination of three strategies. Assess these strategies in the order given below. Application of these strategies must be consistent with the wetland protection guidelines in Guide Sheet 2. The strategies are:
- (a) Select the wetland according to criteria that promote water quality improvement (refer to Step 4.7).
  - (b) Engineer the drainage system at the entrance to the wetland to promote stormwater quality improvement (refer to Step 4.8).
  - (c) Modify the wetland to incorporate features that promote stormwater quality improvement (refer to Step 4.9).

Proceed to Step 4.7, 4.8, or 4.9, depending on your selection of strategy.

- 4.7 Select a wetland to promote stormwater quality improvement according to the following criteria:
- (a) The most important consideration in achieving water quality benefits is maximizing the actual water residence time. Therefore, select a site that provides the maximum possible actual water retention time. The following characteristics represent goals to which the site selection should come as close as possible:
    - (i) A retention time of approximately one week for good control of particulate pollutants and two weeks or more for control of nutrients and other relatively soluble pollutants (U.S. Environmental Protection Agency 1986b). The retention time is approximately the ratio of wetland water volume/average outflow rate, unless the soil infiltration rate is relatively high.
    - (ii) A relatively high wet pool area/watershed area ratio (the wet pool area is the surface area encompassed by the live and dead storage volumes). This ratio should be at least 0.01 and, preferably, 0.025 or higher (U.S. Environmental Protection Agency 1986).
    - (iii) A configuration that avoids short-circuiting of flow from the inlet to the outlet, featuring--
      - [a] An outlet remote from the inlet;
      - [b] A flow pattern that minimizes velocity at the water entrance point and between the inlet and outlet;
      - [c] A small outlet for the release of small storms and a large outlet or spillway for the discharge of large storms.
  - (b) The wetland should have a standing water pool during the seasons in which water quality benefits are desired, with a range of depths from < 15 cm to approximately 1 m (Schueler 1987).
  - (c) Water quality benefits are best promoted by a minimum of channelized flow. Therefore, flow should be in a sheet or in multiple channels.
  - (d) Water quality benefits are best promoted if pH is circumneutral (6-7) or alkaline.
  - (e) Select a wetland with surface soils of moderate-to-fine textured (e.g., soils in the loam classes) and with relatively high muck (highly decomposed organic matter) content to promote the functioning of water pollutant removal mechanisms.
  - (f) Select a wetland that offers substantial contact between water and dense, fine herbaceous plants with good winter viability to promote filtration and other pollutant removal mechanisms.
  - (g) If a project site can be selected according to these criteria to provide the required water quality benefits, proceed to Step 4.10; otherwise, proceed to Step 4.8 to assess another strategy.
- 4.8 Consider engineering the drainage system that routes runoff to a wetland to promote stormwater quality improvement. Possible drainage system modifications include:

- (a) Reduce the entrance velocity of the flow by enlarging the inlet conveyance, decreasing its slope, and/or installing baffling to reduce momentum.
- (b) Spread the inlet flow rather than introduce it at a single point in order to get more widespread flow distribution and promote a long actual water residence time.
- (c) Redirect the inlet flow to a different point if necessary to avoid short circuiting from inlet to outlet.
- (d) If a project site can be selected according to these criteria to provide the required water quality benefits, proceed to Step 4.10; otherwise, proceed to Step 4.9 to assess another strategy.

4.9 Modification of the wetland to promote stormwater quality improvement should be considered only if the wetland is already highly disturbed and serves minimal ecological functions, and if opportunities exist for concurrently improving the ecological functioning of such wetlands and increasing their resource values. If modification is appropriate according to these guidelines, stormwater quality improvement can be promoted in the following ways:

- (a) Enlarge the wet pool area (surface area encompassed by the live and dead storage volumes) to increase the wetland volume and wetland area/watershed area ratio. This ratio should be at least 0.01 and, preferably, 0.025 or higher (U.S. Environmental Protection Agency 1986). (Note: Wetland enlargement should not be at the expense of ecologically valuable uplands, especially forested systems.)
- (b) Deepen to increase volume, or alter depth contours to achieve a range of depths such as advised for constructed wetlands in Chapter III-4.
- (c) Raise the outlet to increase volume. Outlet works construction may require a Clean Water Act Section 404 permit; consult the U.S. Army Corps of Engineers.
- (d) Control the outlet rate to increase water residence time. The water volume/average overflow rate ratio (under design flow conditions) should be approximately one week for good control of particulate pollutants and as much as two weeks for nutrient control (U.S. Environmental Protection Agency 1986).
- (e) Revise the flow pattern to maximize sheet flow.
- (f) Install baffling to reduce inlet velocities and aid in distributing flow.
- (g) Plant dense, fine, native herbaceous plants (do not introduce invasive weedy species).

Proceed to Step 4.10.

4.10 Review the wetland protection guidelines in Guide Sheet 2 and apply them to the project design.

4.11 Certain maintenance operations may have to be performed to receive water quality benefits over the long term. Guidelines pertaining to maintenance are:

- (a) Prevent sediment discharge to the wetland to the maximum extent possible through the use of effective erosion control in the drainage catchment (refer to Volume II).

- (b) Remove sediments when water residence time declines by about 25 percent and/or plant growth and the performance of other wetland functions are negatively affected. If other guidelines have been followed, the need for sediment removal should only be in the pretreatment facility and, occasionally, the inlet zone of the wetland. Time sediment removal so that sensitive life stages of wetland inhabitants are not affected. Enclose the area of work with silt fencing if necessary to prevent particle escape from that area (refer to BMP E3.10 in Chapter II-4).
- (c) Plant harvesting should be evaluated under the following circumstances--
  - (i) Nutrient control is an important objective (plant uptake is more important for control of nutrients than other pollutants);
  - (ii) The wetland is already highly disturbed and has no other functions that would be impaired by the harvest;
  - (iii) Much of the vegetation is herbaceous with small root structures (harvesting wetland plants with extensive root structures is infeasible; without removing roots, much of the stored nutrients are left intact and can be released later).
  - (iv) Cutting or pulling woody species would stimulate herbaceous species that are superior in filtration and plant uptake.

Include a cost-benefit analysis in the harvesting evaluation.
- (d) If harvesting is warranted on the basis of these guidelines and the results of the cost-benefit analysis, and if permission has been obtained from the local government regulatory unit, cut as much of the plant biomass as possible at the end of the growing season and before extensive senescence occurs (during the first month of the fall season). This timing will help to avoid soil compaction and stimulate vegetation vigor and vitality. Compost or dispose of the cuttings in a way so that no pollutants can enter surface waters or ground water.

4.12 Proceed to Guide Sheet 7 to develop a project monitoring plan.

## III-5.2.5 GUIDE SHEET 5

## MANAGING WETLANDS IN A NEWLY DEVELOPING AREA

The guidelines in this sheet are based on two principles that are recognized to create the most effective environmental management: (1) the best management policies for the protection of wetlands and other natural resources are those that prevent or minimize the development of impacts at potential sources; and (2) the best management strategies are self-perpetuating, that is they do not require periodic infusions of capital and labor. To apply these principles in managing wetlands in a newly developing area, carry out the following steps.

- 5.1 Develop a basin or subbasin plan for the drainage catchment containing the wetlands to be managed. Important planning considerations include:
  - (a) Formulate the plan on the basis of clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.
  - (b) Map and assess land suitability for urban uses. Include the following landscape features in the assessment: forested land, open unforested land, steep slopes, erosion-prone soils, foundation suitability, soil suitability for waste disposal, aquifers, aquifer recharge areas, wetlands, floodplains, surface waters, agricultural lands, and various categories of urban land use. When appropriate, the assessment can highlight outstanding local or regional resources that the community determines should be protected (e.g., a fish run, scenic area, recreational area, threatened species habitat, farmland). Mapping and assessment should recognize not only these resources but also additional areas needed for their sustenance.
- 5.2 Maximize natural water storage and infiltration opportunities within the basin and outside of existing wetlands, especially:
  - (a) Promote the conservation of forest cover. Building on land that is already deforested affects basin hydrology to a lesser extent than converting forested land. Loss of forest cover reduces interception storage, detention in the organic forest floor layer, and water losses by evapotranspiration, resulting in large peak runoff increases (Dunne and Leopold 1978; Stoker 1988) and either their negative effects or the expense of countering them with structural solutions.
  - (b) Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Develop and implement policies and regulations to discourage the clearing, filling, and channelization of these features. Utilize them in drainage networks in preference to pipes, culverts, and engineered ditches.
  - (c) In evaluating infiltration opportunities refer to Chapter III-3 and pay particular attention to the selection criteria for avoiding ground water contamination. If necessary, site developments with large amounts of impervious surfaces or a potential to produce relatively contaminated runoff away from ground water recharge areas.
- 5.3 Manage stormwater not only to prevent flooding and stream channel erosion, but also to maintain, to the maximum extent possible, the pre-development hydroperiod, hydrodynamics, and water quality in the wetlands of the urbanizing watershed. Specific considerations of this management task include:

- (a) This provision involves not only management of high runoff volumes and rates of flow during the wet season, but also prevention of water supply depletion during the dry season. The latter guideline may require flow augmentation if urbanization reduces natural surface or ground water inflows.
  - (b) Adopt standards to maintain peak runoff discharge rates from developed sites at no greater than the pre-development rates.
  - (c) Adopt zero-rise floodplain standards.
- 5.4 Establish and maintain buffers surrounding wetlands as required by local regulations or as recommended by the Puget Sound Water Quality Authority's draft wetland guidelines. Also, maintain interconnections among wetlands and other natural habitats to allow for wildlife movements.
- 5.5 Place strong emphasis on water resource protection during construction of the new development. Establish effective erosion control programs to reduce the sediment loadings to receiving waters to the maximum extent possible (refer to Volume II). No pre-existing wetland or other water body should ever be used for the sedimentation of solids in construction-phase runoff.
- 5.6 Stimulate public awareness of and interest in wetlands and other water resources in order to establish protective attitudes in the community. This program should include:
- (a) Education regarding the use of fertilizers and pesticides, automobile maintenance, the care of animals to prevent water pollution, and the importance of retaining buffers;
  - (b) Descriptive signboards adjacent to wetlands informing residents of the wetland type, its functions, the protective measures being taken, etc.
  - (c) If beavers are present in a wetland, educate residents about their ecological role and value and take steps to avoid human interference with beavers.
- 5.7 Take specific management measures to avoid general urban impacts on wetlands (e.g., littering and vegetation destruction).
- 5.8 Assess alternatives for the control of runoff water quantities from the new development according to Guide Sheet 3.
- 5.9 Assess alternatives for the control of runoff water quality from the new development according to Guide Sheet 4.
- 5.10 Review the wetland protection guidelines in Guide Sheet 2 and apply them to the management plan.

III-5.2.6 GUIDE SHEET 6

WETLAND SITE SELECTION CRITERIA

- 6.1 When more than one wetland is under consideration for a stormwater management project, the site selected should be the wetland that best advances the achievement of overall resource protection benefits. From the standpoint of protecting the wetland resources, the preferred site is the wetland that most exhibits the following characteristics:
- (a) The wetland has been deprived of a significant amount of its water supply by draining or previous urbanization (e.g., by loss of ground water discharge), and stormwater can be used to augment the water supply. Consider specifically wetlands that have experienced an increased summer dry period, especially those where the drought has been extended from less than to more than two months.
  - (b) The wetland lies in the natural routing of the runoff.
  - (c) The wetland allows runoff discharge at the natural location.
  - (d) The wetland requires little construction activity for structural or hydrologic modification in order to solve the problem.
  - (e) If all wetlands under consideration would require some modification, the selection should consider the relative qualities of the candidate sites and the relative extent of alteration required. The preferred choice is the wetland that is most degraded or, if several alternatives are similar in that respect, the site requiring the least alteration.
  - (f) If a wetland can provide the required storage capacity by an outlet orifice modification to increase storage of water, it will probably require less construction activity and is therefore preferred to a wetland that requires raising the existing overflow to obtain adequate storage capacity.
  - (g) The wetland's existing hydrodynamic character is to experience a relatively high degree of water level fluctuation and a range of velocities (i.e., a wetland associated with substantially flowing water, rather than one in the headwaters or entirely isolated from flowing water).
  - (h) The wetland has been previously disturbed by human activity, as evidenced by agriculture, fill, ditching, and/or introduced or invasive weedy plant species.
  - (i) The wetland does not exhibit any of the following ecological features:
    - (i) Significant priority peat system or forested zones that will experience a substantially altered hydroperiod as a result of the proposed action;
    - (ii) Regionally unusual biological community types.
    - (iii) Animal habitat features of relatively high value in the region (e.g., a protected, undisturbed area connected through undisturbed corridors to other valuable habitats, an important breeding site for protected species).

- (iv) The presence of protected commercial or sport fish, or the wetland's configuration and topography are such that no significant modification to the wetland will be necessary to avoid fish stranding after the proposed project is installed.
- (j) The wetland is not the subject of a relatively high degree of public interest as a result of, for example, offering valued local open space or educational, scientific, or recreational opportunities, unless the proposed action would enhance these opportunities.
- (k) The wetland is threatened by potential impacts exclusive of stormwater management, and could receive greater protection if acquired for a stormwater management project than if left in existing ownership.
- (l) The wetland lends itself to the effective application of the wetland protection guidelines in Guide Sheet 2.

6.2 Return to the guide sheet on which you were working and continue.



III-5.2.7 GUIDE SHEET 7

MONITORING GUIDELINES

Note: Development of this guide sheet is not complete, pending analysis of what has been learned about cost-effective wetland monitoring during the Puget Sound Wetlands and Stormwater Management Research Program. When it is finished, Guide Sheet 7 will provide full details on the design and performance of a monitoring program. It is anticipated that the guide sheet will have the following characteristics:

1. Some level of monitoring will be specified for all projects that involve existing wetlands and stormwater, in order to ensure maintenance of water quality standards and wetland functions, values, and beneficial uses.
2. Monitoring objectives could encompass information gathering needed for stormwater management purposes, assessment of the effects of management actions on the wetland ecosystem, or both.
3. There will be several levels of monitoring, ranging from minimal to extensive requirements.
4. Baseline monitoring before the implementation of the stormwater management project will be specified when necessary to provide a basis for comparison to assess impacts. Tentatively being considered when baseline monitoring is required are:
  - a. A minimum of one year of at least monthly measurements of wetland water stage and crest stage;
  - b. Plant cover/abundance analysis during at least one summer;
  - c. A minimum of one year of measurements of pH, total phosphorus, nitrate + nitrite-nitrogen, total suspended solids, turbidity, fecal coliform and total zinc concentrations in the wetland open water on at least eight occasions; and
  - d. Measurement of sediment accretion and soil metal concentrations (at least arsenic, copper, and lead) once at several locations in the wetland during at least one year.
5. The minimum level of monitoring after project implementation might involve, for example, observations needed to determine the need for facility maintenance or, for impact assessment, periodic field observation of certain features of the wetland and a photographic record over time. A higher level of monitoring might involve the same measurements specified for baseline monitoring on a repeating schedule.
6. Examples of cases for which relatively little monitoring will be specified are:
  - a. A similar case has already been monitored (e.g., in the Puget Sound Wetlands and Stormwater Management Research Program) and found to involve few or no effects on the wetland (criteria will be specified to judge the degree of similarity of cases);
  - b. The wetland involved was highly degraded before the project;
  - c. There will be very little structural, hydrologic, or water quality modification of the wetland; or

- d. There will be very little chance of violations of state water quality standards or accumulations of toxicants in the wetland.
- 7. Monitoring could involve the wetland only, the success of mitigation, or both.
- 8. The monitoring planning guidelines will include a feedback mechanism to apply monitoring results in fine-tuning management practices.

Do you wish to analyze another management problem? If so, return to Guide Sheet 1, Step 1.3 for directions. If not, the assessment is complete.

AIII-5.1 APPENDIX A

INFORMATION NEEDED TO APPLY GUIDELINES

NOTE: The following information listed for each guide sheet is most essential for applying the Wetlands and Stormwater Management Guidelines. Information need be assembled only for the guide sheets that apply to the project. Additional information, listed at the end, would provide a more comprehensive basis for project analysis and planning. As a start, obtain the relevant soil survey; the National Wetland Inventory, topographic, and land use maps; and the results of any local wetland inventory.

Guide Sheet 1

- 1.1 Statement of project objectives (basin-wide and for specific wetland(s)).
- 1.2 Existing management and monitoring plans.

Guide Sheet 2

- 2.1 Existing and projected watershed land use in the following categories: commercial, industrial, multi-family residential, single-family residential, and undeveloped (expressed as percentages of the total watershed area).
- 2.2 Wetland type and zones present, with special note of estuarine, priority peat system, forested, sensitive scrub-shrub zone, sensitive emergent zone and other sensitive or critical areas designated by state or local government (with dominant plant species).
- 2.3 Maximum existing water level as measured according to the appropriate guidelines in Guide Sheet 7.
- 2.4 Frequency, duration, and timing of projected increase above maximum existing water level.
- 2.5 Fish and wildlife inhabiting the wetland.

Guide Sheet 3

- 3.1 Wetland category (I-IV in draft Puget Sound Water Quality Authority wetland protection guidelines); designation as rare or irreplaceable as defined in Guide Sheet 3. Refer to the Washington Natural Heritage Program data base. If the needed information is not available, a biological assessment will be necessary.
- 3.2 Rare, threatened, or endangered species inhabiting the wetland.

Guide Sheet 4

- 4.1 Water pollution assessment as described in Guide Sheet 4.
- 4.2 Wetland category (I-IV in draft Puget Sound Water Quality Authority wetland protection guidelines); designation as rare or irreplaceable as defined in Guide Sheet 3. Refer to the Washington Natural Heritage Program data base. If the needed information is not available, a biological assessment will be necessary.
- 4.3 Rare, threatened, or endangered species inhabiting the wetland.
- 4.4 Wetland water volume (live storage).
- 4.5 Outflow rate.

- 4.6 Ground water recharge/discharge status.
- 4.7 Wet pool area.
- 4.8 Contributing watershed area.
- 4.9 Inlet and outlet locations.
- 4.10 Winter water depths.
- 4.11 Flow pattern through wetland.
- 4.12 pH.
- 4.13 Surface soil characteristics (general texture, organic content).

Guide Sheet 5

- 5.1 A complete definition of goals.
- 5.2 The presence of various landscape features, as outlined in Guide Sheet 5.
- 5.3 Existing wetland hydroperiod and hydrodynamics.

Guide Sheet 6

No new information in addition to that required for preceding guide sheets.

Supplementary Information (to provide a more comprehensive basis for project analysis and planning).

- S.1 Characteristics of other watershed wetlands.
- S.2 Refined land use description (including agricultural categories, types of undeveloped land, different residential densities, and active and potential construction sites).
- S.3 Hydrologic modeling to provide detailed analysis of existing and projected wetland hydroperiod characteristics.

AIII-5.2 APPENDIX B

DEFINITIONS

**Aggressive plant species:** Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to native species in this manual.

**Bioengineering:** Restoration or reinforcement of slopes and stream banks with living plant materials.

**Constructed wetland:** Those wetlands intentionally created on sites that are not wetlands for the primary purpose of wastewater or stormwater treatment and managed as such. Constructed wetlands are normally considered as part of the stormwater collection and treatment system.

**Created wetland:** Those wetlands intentionally created from nonwetland sites to produce or replace natural habitat (e.g., compensatory mitigation projects).

**Degraded (disturbed) wetland (community):** A wetland (community) in which the vegetation, soils, and/or hydrology have been adversely altered, resulting in lost or reduced functions and values; generally, implies topographic isolation; hydrologic alterations such as hydroperiod alteration (increased or decreased quantity of water), diking, channelization, and/or outlet modification; soils alterations such as presence of fill, soil removal, and/or compaction; accumulation of toxicants in the biotic or abiotic components of the wetland; and/or low plant species richness with dominance by invasive weedy species.

**Enhancement:** To raise value, desirability, or attractiveness of an environment associated with surface water.

**Estuarine wetland:** Generally, an eelgrass bed; salt marsh; or rocky, sandflat, or mudflat intertidal area where fresh and salt water mix. (Specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually semi-enclosed by land but with partly obstructed or sporadic access to the open ocean).

**Existing site conditions means:** (a) For developed sites with stormwater facilities that have been constructed to meet the standards in the Minimum Requirements of this manual, existing site conditions shall mean the existing conditions on the site.

(b) For developed sites that do not have stormwater facilities that meet the Minimum Requirements, existing site conditions shall mean the conditions that existed prior to local government adoption of a stormwater management program. If in question, the existing site conditions shall be documented by aerial photograph records, or other appropriate means.

(c) For all sites in water quality sensitive areas as identified under Minimum Requirement #7, Water Quality Sensitive Areas, existing site conditions shall mean undisturbed forest, for the purpose of calculating runoff characteristics.

(d) For all undeveloped sites outside of water quality sensitive areas, existing site conditions shall mean the existing conditions on the site.

**Forested communities (wetlands):** In general terms, communities (wetlands) characterized by woody vegetation that is greater than or equal to 6 meters in height; in these guidelines the term applies to such communities (wetlands) that represent a significant amount of tree cover consisting of species that offer wildlife habitat and other values and advance the performance of wetland functions

overall.

**Functions:** The ecological (physical, chemical, and biological) processes or attributes of a wetland without regard for their importance to society (see also Values). Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, floodflow alteration, ground water recharge and discharge, water quality improvement, and soil stabilization.

**Hydrodynamics:** means the dynamic energy, force, or motion of fluids as affected by the physical forces acting upon those fluids.

**Hydroperiod:** The seasonal occurrence of flooding and/or soil saturation; encompasses the depth, frequency, duration, and seasonal pattern of inundation.

**Invasive weedy plant species:** Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to non-native species in this manual.

**Mean annual water level fluctuation:** Derived as follows--

- (1) Measure the maximum water level (e.g., with a crest stage gage, Reinelt and Horner 1990) and the existing water level at the time of the site visit (e.g., with a staff gage) on at least eight occasions spread through a year.
- (2) Take the difference of the maximum and existing water level on each occasion and divide by the number of occasions.

**Modification, Modified (wetland):** A wetland whose physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.

**On-site -** The entire property that includes the proposed development.

**Priority peat systems:** Unique, irreplaceable fens that can exhibit water pH in a wide range from highly acidic to alkaline, including fens typified by *Sphagnum* species, *Ledum groenlandicum* (Labrador tea), *Drosera rotundifolia* (sundew), and *Vaccinium oxycoccos* (bog cranberry); marl fens; estuarine peat deposits; and other moss peat systems with relatively diverse, undisturbed flora and fauna. Bog is the common name for peat systems having the *Sphagnum* association described, but this term applies strictly only to systems that receive water income from precipitation exclusively.

**Rare, threatened, or endangered species:** Plant or animal species that are regional relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats. Threatened and endangered species are officially listed by federal and state authorities, whereas rare species are unofficial species of concern that fit the above definitions.

**Regional:** An action (here, for stormwater management purposes) that involves more than one discrete property.

**Restoration:** Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.

**Sensitive emergent vegetation communities:** Assemblages of erect, rooted, herbaceous vegetation, excluding mosses and lichens, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as sundew and,

as well as a number of species of Carex (sedges).

**Sensitive life stages:** Stages during which organisms have limited mobility or alternatives in securing the necessities of life, especially including reproduction, rearing, and migration periods.

**Sensitive scrub-shrub vegetation communities:** Assemblages of woody vegetation less than 6 meters in height, at least some of whose members have relatively narrow ranges of environmental requirements, such as hydroperiod, nutrition, temperature, and light. Examples include fen species such as Labrador tea, bog laurel, and cranberry.

**Unusual biological community types:** Assemblages of interacting organisms that are relatively uncommon regionally.

**Values:** Wetland processes or attributes that are valuable or beneficial to society (also see Functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

**Wetlands:** Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas. This includes wetlands created, restored or enhanced as part of a mitigation procedure. This does not include constructed wetlands or the following surface waters of the state intentionally constructed from sites that are not wetlands: Irrigation and drainage ditches, grass-lined swales, canals, agricultural detention facilities, farm ponds, and landscape amenities.

AIII-5.3 APPENDIX C

REFERENCES

- (1) Dunne, T. and L.B. Leopold. 1978. Water and Environmental Planning. W. H. Freeman and Company, San Francisco.
- (2) Reinelt, L.E. and R.R. Horner. 1990. Characterization and Water Quality of Palustrine Wetlands Affected by Urban Stormwater. Report prepared for the Puget Sound Wetlands and Stormwater Management Research Program, Seattle.
- (3) Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, D.C.
- (4) Stoker, B.A. 1988. Determination of Hydrologic Process Zones for Urban Stormwater Management. M.S.E. Thesis, Department of Civil Engineering, University of Washington, Seattle.
- (5) U.S. Environmental Protection Agency. 1986a. Quality Criteria for Water 1986, EPA 440/5-86-001. Office of Water Regulations and Standards, Washington, D.C.
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## CHAPTER III-6

### BIOFILTRATION SWALES AND VEGETATIVE FILTER STRIPS

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## CHAPTER III-6

## BIOFILTRATION SWALES AND VEGETATIVE FILTER STRIPS

*Editor's Note: This edition of the manual has classified biofiltration swales and vegetative filter strips as two different BMPs. Though their pollutant removal mechanisms are similar, their planning and design criteria are different enough to warrant separation. However, this edition of the manual retains the previous edition's criteria; subsequent editions of this manual will likely reflect changes in planning and design criteria.*

*There are still uncertainties and differences of opinion on how to best design biofiltration swales and vegetative filter strips. In addition, the effectiveness of these BMPs, especially for the treatment of nutrients, is an unresolved issue. As a result of this and other issues, Ecology plans to convene a standing advisory group that will attempt to resolve key technical issues. A review of the latest findings from current biofilter monitoring projects will be conducted and recommendations made regarding the design methodology, planning considerations, construction, and maintenance of biofilters and vegetative filter strips. Subsequent editions of this manual will incorporate such findings.*

## III-6.1 INTRODUCTION

III-6.1.1 Background

Biofiltration swales and vegetative filter strips are two practices which have been used in stormwater management for some years. Only fairly recently have they been studied to determine their effectiveness at treating pollution from stormwater runoff and to assess their abilities to reduce peak flow rates. Because these two BMPs are non-structural, they are considered desirable alternatives to ponds, tanks, and vaults. At this time these two practices are assumed to provide runoff treatment but not streambank erosion control (the latter is an issue that needs further investigation, especially for less intensely developed sites).

III-6.1.2 Purpose and Scope

The purpose of this chapter is to present general and specific criteria for the evaluation, design, construction, and maintenance of biofiltration swales and vegetative filter strips. In particular, this chapter provides guidance on how BMPs can be designed to accomplish one of the two primary stormwater management objectives, *runoff treatment* and *streambank erosion control* (recall that *source control* is another objective which is required in all cases). While streambank erosion control is not generally provided by these BMPs, biofiltration swales can be designed to convey higher flows to BMPs used for streambank erosion control and thus may be incorporated into the primary conveyance/detention system.

Section III-6.2. should be read first as it gives a description of the pollutant removal mechanisms utilized by biofilters and vegetative filter strips to meet Ecology's runoff treatment standard. Sections III-6.3 and III-6.4 provide detailed planning, design, construction, and maintenance criteria for each BMP. A design procedure is described in Appendix AIII-6.1 for both BMPs with an example problem provided in Appendix AIII-6.2.

Figure III-6.1 Biofiltration Swale

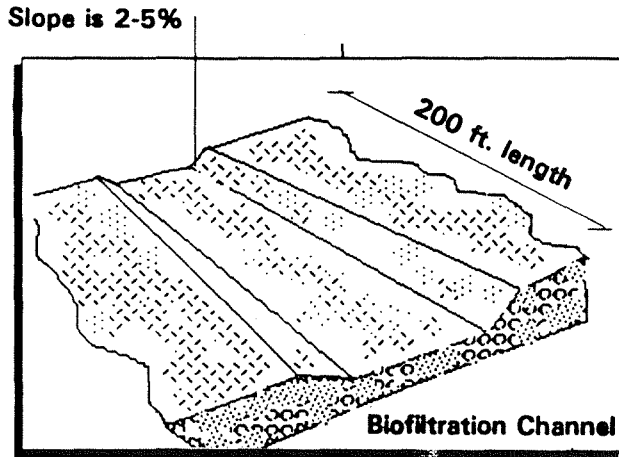


Figure III-6.2 Biofiltration Swale with Underdrain System

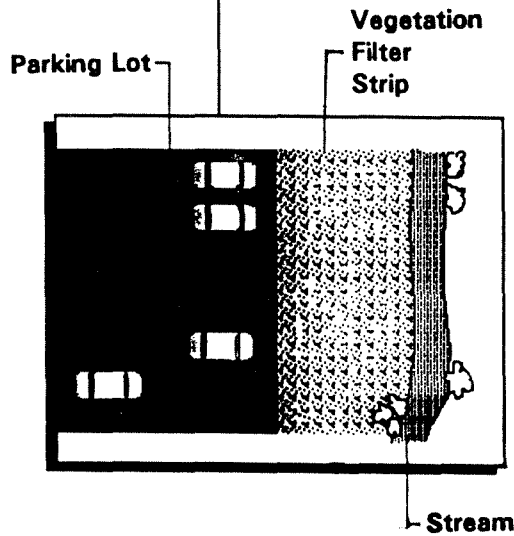
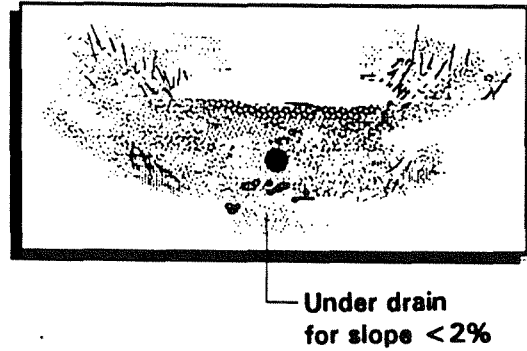


Figure III-6.3 Vegetated Filter Strip

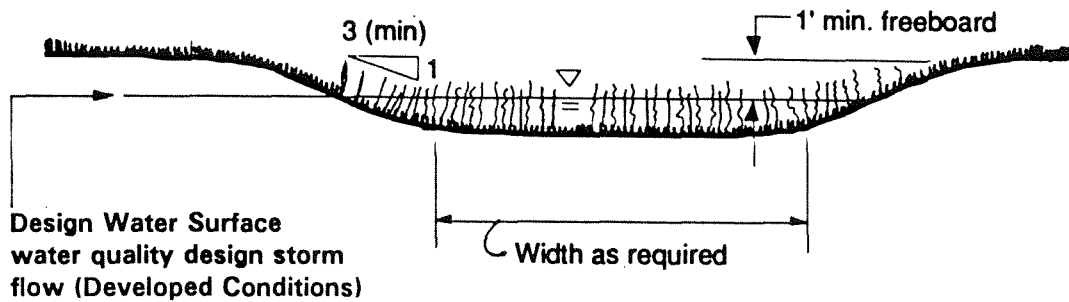


Figure III-6.4 Swale Design Showing Freeboard

## III-6.2 RUNOFF TREATMENT AND CONVEYANCE

### III-6.2.1 Overview

There are two types of biofiltration-type BMPs: the biofiltration swale (BMP RB.05) and the vegetated filter strip (BMP RB.10). Figures III-6.1 through III-6.4 illustrate these BMPs. A biofiltration swale is a vegetated channel that is sloped like a standard storm drain channel; stormwater enters at one end and exits at the other with treatment provided as the runoff passes through the channel. With vegetated filter strips the flow is distributed broadly along the width of the vegetated area; treatment is provided as runoff travels as sheet flow through the vegetation.

Which method to use depends upon the drainage patterns of the site. A vegetated strip would function well where the water can be spread along the length of a parking lot. Gaps in the lot curb provide the entry points. Of course, the grade of the parking lot must be flat immediately parallel to the strip.

For runoff treatment purposes, biofiltration swales and vegetative filter strips are to be designed to treat the 6-month, 24-hour design storm, as required by Minimum Requirement #4 (see Chapter I-2). *Note: This is a change from the previous edition of this manual. Formerly the design storm for biofilters was the 2-year, 24-hour event. The change has been made so that all runoff treatment BMPs will be designed in a consistent manner.*

### III-6.2.2 Mechanisms of Pollutant Removal

Biofiltration swales and vegetative filter strips use similar pollutant removal mechanism, i.e., "biofiltration." The term "biofiltration" has been coined to describe the more-or-less simultaneous processes of filtration, infiltration, adsorption and biological uptake of pollutants in stormwater that take place when runoff flows over and through vegetated treatment facilities. Vegetation growing in these facilities acts as both a physical filter which causes gravity settling of particulates by regulating velocity of flow, and also as a biological sink when direct uptake of dissolved pollutants occurs. The former mechanism is probably the most important in western Washington where the period of major runoff coincides with the period of lowest biological activity.

Another means of removing pollutants occurs as the stormwater contacts the soil surface and infiltrates into the underlying soil. Dissolved pollutants are adsorbed onto soil particles. This is a potentially important removal mechanism for both dissolved heavy metals and phosphorus by undergoing ion exchange with elements in the soil. In addition, biological activity in the soil can metabolize organic contaminants. However, in highly porous soils stormwater can be a threat to shallow ground water since these soils have little treatment capacity. In such instances, biofilter BMPs must meet the General Limitations for infiltration BMPs (see Chapter III-3) or it may be necessary to install a liner to prevent infiltration.

The degree to which the above mechanisms operate will vary considerably depending upon many factors such as the depth and condition of the vegetation, the velocity of the water, the slope of the ground, and the texture of the underlying soil. However, the most important criterion that can be developed from these variables is the residence time of the stormwater in the biofilter, provided there is an adequate stand of vegetation and the underlying soil is of moderate texture. Therefore, to be effective, the biofilter must be designed such that the residence time is sufficient to permit most if not all of the particulates and at least some of the dissolved pollutants to be removed from the stormwater.

Design criteria that will maximize the effectiveness of biofiltration swales and strips are still in the developmental stage because their use for treating

stormwater locally has only been applied and investigated for a relatively short time. They have been largely based on work done in the early 1980s by researchers at the University of Washington for the Washington State Department of Transportation and have relied heavily on the finding that total suspended solids and lead were reduced by at least 80 percent in 200 feet of grass swale (1).

The most recent comprehensive publication dealing with biofiltration systems locally was prepared in 1988 by Horner (2) and the reader is referred to this document for further details including a review of the literature and a survey of operating biofilters.

### III-6.3 BMP RB.05 BIOFILTRATION SWALE

#### Purpose and Definition

A biofiltration swale is designed to provide runoff treatment of conventional pollutants but not nutrients. It does not provide streambank erosion control but can be designed to convey runoff to BMPs designed for that purpose. Biofiltration swales, when used as a primary treatment BMP, should be located "off-line" from the primary conveyance/detention system in order to enhance effectiveness (they can also be made smaller when located "off-line"). If a biofiltration swale is used to protect a water quality infiltration BMP or a sand filtration BMP (see Chapter III-3), then it will be necessary to locate it "off-line."

In cases where a biofiltration swale is located "on-line" it must be sized as both a treatment facility and as a conveyance system to pass the peak hydraulic flows of the 10 and 100-year design storm. **To be effective, the depth of the stormwater during treatment must not exceed the height of the grass.**

#### Planning Considerations

1. *Local governments should maintain the necessary flexibility in ordinances and regulations to permit site-by-site assessment of biofiltration alternatives, and to allow for discretionary design, installation, operating, and maintenance requirements, as long as they do not conflict with the general intent of design and maintenance requirements stated below.*
2. *Biofiltration should be regarded as one possible element of an integrated stormwater management plan for any given site or class of sites. Selection and implementation of alternatives should be based on stated water quality objectives (see Chapter I-4).*
3. *With diverse opportunities existing to apply the variety of biofilter configurations, a creative approach is recommended to obtain the best match of system and conditions.*
4. *Since biofiltration is an on-site rather than a regional technique, localized commitments must be made to maximize its application and effectiveness.*
5. *Since flexibility exists in many design features, biofiltration success depends more on proper construction and maintenance than any other factors; effective inspection and enforcement programs should be emphasized to ensure that approved plans are implemented.*

#### General Technical Recommendations

1. Natural drainage courses should be regarded as significant local resources that are generally to be kept in use for stormwater management, including biofiltration.

2. Roadside ditches should be regarded as significant potential biofiltration sites; road design standards and ditch maintenance programs should be developed to maximize their usefulness in biofiltration.
3. Local governments should resist proposals to enclose open channels in pipes. In addition to offering the opportunity for biofiltration, open channels generally have more capacity than pipes and are easier to inspect and maintain.
4. Retention/detention pond design requirements should recognize and assess the alternative of installing low-flow biofiltration swales within ponds where sufficient land does not exist for both.
5. Opportunities to fit biofiltration retroactively to areas already developed should be exploited whenever possible.
6. Biofilters should generally not receive construction-stage runoff; if they do, presettling of sediments should be provided (see BMPs E3.35 and E3.40 in Chapter II-5). Such biofilters should be evaluated for the need to remove sediments and restore vegetation following construction.
7. Biofilters should be protected from siltation by a permanent presettling basin when the erosion potential is high (see BMP RD.10 in Chapter III-4); otherwise, presettling is not generally needed for normal operation. However, a series arrangement of a retention/detention pond and biofilter has the ability to offer extra protection to a sensitive receiving water, due to the complementary pollutant removal mechanisms that can operate in the two devices.
8. Biofilters must be vegetated in order to provide adequate treatment of runoff. By definition, biofilters require vegetation, and rock-lined or vegetated channels are not biofilters.

## Design Criteria

### Overview

The design, planning, and operation and maintenance details that follow have been adapted directly from Horner's "general recommendations" with minor modifications, and while this is judged to be the best available information, it must be considered as interim and subject to modification. Alternative criteria is being investigated which may be reflected in future editions of this manual.

Questions remain about the nutrient-removing abilities of biofilters in the Pacific Northwest and further work needs to be done to resolve optimal geometry and slopes of swales (2). As this and other information becomes available, especially monitoring data and consequent new ideas on design, they will be incorporated into later editions of this manual.

In summary, the interim criteria have been selected to ensure that the velocity of water does not exceed 1.5 feet per second along a swale of 200 feet in length during the water quality design storm (the 6-month, 24-hour storm). Although the 1990 and 1991 versions of this manual used the 2-year, 24-hour storm, we have chosen to change it to the 6-month, 24-hour storm to make all BMP designs consistent. We do not feel that the decrease in cross-sectional area and residence time are such that the larger size storm design is necessary. An additional requirement for swales designed to convey larger storms (up to the 100-year, 24-hour event) is that the peak velocity for the maximum design storm is kept below erosive levels. Complete details of the criteria are given below, and the appendices give step-by-step procedures for designing strips and swales including an example calculation.

## General Criteria

1. For biofiltration, it is important to maximize water contact with vegetation and the soil surface. Gravelly and coarse sandy soils cannot be used for biofiltration unless the bottom of the swale is lined to prevent infiltration. (Note: Sites that have relatively coarse soils may be more appropriate for stormwater infiltration for streambank erosion control purposes after runoff treatment has been accomplished. In any case the General Limitations in Chapter III-3 will dictate the use of coarse soils for stormwater management purposes). Also, avoid very heavy clay soils that will not support good vegetative growth.
2. Select vegetation on the basis of pollution control objectives and according to what will best establish and survive in the site conditions. Also, consider whether wildlife habitat development can occur in concert with pollution control. If so, consider the needs of such development in vegetation selection. For general purposes, select fine, close-growing, water-resistant grasses. Alternatively, where some period of soil saturation is expected, where particular pollutant uptake characteristics are desired, or both, select emergent wetland plant species. Protect these plants from predation during establishment by netting. See Appendix III-6.1 for specific vegetation selection recommendations.
3. Establish grasses as follows (all weights are per 1,000 square feet):
 

If hydro-seeding -	5 lb. seed mix
	7 lb. 10-20-20 (N-P-K) fertilizer*
	50 lb. wood cellulose fiber mulch
If broadcast seeding -	5 lb. seed mix
	7 lb. 10-20-20 (N-P-K) fertilizer*
	70 lb. wood cellulose fiber mulch

\*Note: this is just an estimate of the amount of fertilizer necessary. Make certain that the proper amount of fertilizer for the soil type is used.
4. Based on observations in this area, select a grass height of 6 inches or less and a flow depth of less than 5 inches. Grasses over that height tend to flatten down when water is flowing over them, which prevents sedimentation. To attain this height requires regular maintenance.
5. Where grasses are to be cultivated, if possible, select an area where moisture is sufficient to provide water requirements during the dry season, but where the water table is not so high as to cause long periods of soil saturation. Irrigate if moisture is inadequate during summer drought. If saturation will be extended and/or the slope is minimal but grasses are still desired, consider subdrains. Alternatively, consider designing a constructed wetland or wet pond that has a substantially longer water residence time than a swale or filter strip (see Chapter III-4). Also see BMPs E1.35 and E1.40 in Chapter II-5 for more information on seeding and sodding.
6. The channel slope should normally be between 2 and 4 percent. A slope of less than 2 percent can be used if underdrains are placed beneath the channel to prevent ponding (Figure III-6.3). A slope of greater than 4 percent can be used if check dams (Figure III-6.4) are placed in the channel to slow the flows accordingly. (see Provisions for Swales #4, below).
7. If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. This requirement can normally be met in the Pacific Northwest by planting during July or August. Sodding is an

alternative when rapid establishment must occur. Where runoff diversion is not possible, cover graded and seeded areas with a suitable erosion control slope covering material (see Chapter II-5).

8. Prevent bare areas in biofilters by avoiding gravel, rocks, and hardpan near the surface; fertilizing, watering, and replanting as needed; and ensuring effective drainage. Note: Fertilizer must only be used at an application rate and formula which is compatible with plant uptake, and in relation to soil type. For example, high application rates of nitrogenous fertilizer in very permeable soils can result in leaching of nitrate into ground water.
9. If flow is to be introduced via curb cuts, place pavement slightly above the biofilter elevation. Curb cuts should be at least 12 inches wide to prevent clogging.
10. Attempt to avoid compaction during construction. If compaction occurs, till before planting to restore lost soil infiltration capacity.

#### Specific Criteria for Biofiltration Swales

1. Design swales for hydraulic capacity and stability according to the method detailed in Appendix AIII-6.1. Base the capacity design for biofiltration on the vegetation height equal to the design flow depth and the 6-month frequency, 24-hour duration storm. Unless runoff from larger events will bypass the swale, base the capacity design for flood passage on the 100-year frequency, 24-hour duration storm, plus 1 foot freeboard (Figure III-6.5).
2. Base the design on a trapezoidal cross-section for ease of construction. A parabolic shape will evolve over time. Make side slopes no steeper than 3 horizontal:1 vertical.
3. Provide a minimum of 200 feet of swale, using a wide-radius curved path, where land is not adequate for a linear swale (avoid sharp bends to reduce erosion or provide for erosion protection). If a shorter length must be used, increase swale cross-sectional area by an amount proportional to the reduction in length below 200 feet, in order to obtain the same water residence time.
4. Install log or rock check dams approximately every 50 feet, if longitudinal slope exceeds 4 percent. Adjust check dam spacing in order not to exceed 4 percent slope within each channel segment between dams.
5. Below the design water depth, install an erosion control blanket, at least four inches of topsoil, and the selected biofiltration seed mix. Above the design water line, use an erosion control seed mix with straw mulch or sod (see BMP E1.15 in Chapter II-5).

#### Construction and Maintenance Criteria

##### Construction

See Appendix AIII-6.1.

##### Maintenance

- Groomed biofilters planted in grasses must be mowed regularly during the summer to promote growth and pollutant uptake. Be sure not to cut below the design flow (maintenance personnel must be made aware of this requirement). Remove cuttings promptly, and dispose in a way so that no pollutants can enter receiving waters.



- If the objective is prevention of nutrient transport, mow grasses or cut emergent wetland-type plants to a low height at the end of the growing season. For other pollution control objectives, let the plants stand at a height exceeding the design water depth by at least two inches at the end of the growing season.
- Remove sediments during summer months when they build up to 6 inches at any spot, cover biofilter vegetation, or otherwise interfere with biofilter operation. Use of equipment like a Ditch Master is strongly recommended over a backhoe or dragline. If the equipment leaves bare spots, re-seed them immediately.
- Inspect biofilters periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or ground water.
- Clean curb cuts when soil and vegetation buildup interferes with flow introduction.
- Perform special public education for residents near biofilters concerning their purpose and the importance of keeping them free of lawn debris.
- See that litter is removed in order to keep biofilters attractive in appearance.
- Base roadside ditch cleaning on an analysis of hydraulic necessity. Use a technique such as the Ditch Master to remove only the amount of sediment necessary to restore needed hydraulic capacity, leaving vegetative plant parts in place to the maximum extent possible.

#### III-6.4 BMP RB.10 VEGETATIVE FILTER STRIP

##### Purpose and Definition

A vegetative filter strip is designed to provide runoff treatment of conventional pollutants but not nutrients. This BMP is not designed to provide streambank erosion control. Also, unlike a biofiltration swale, a vegetative filter strip should not be used for conveyance of larger storms because of the need to maintain sheet flow conditions, plus the filter strip would likely be prohibitively large for this application.

##### Planning Considerations

See BMP RB.05, Biofiltration Swale. Additional planning considerations are provided below.

##### Application

Vegetative filter strips can be effective at pretreating runoff to protect infiltration and filtration BMPs from siltation. It may also be a viable treatment BMP for small, less intensely developed sites. The maximum recommended drainage area for a vegetative filter strip is 5 acres. Vegetative filter strips must not receive concentrated flow discharges as their effectiveness will be destroyed plus the potential for erosion could cause filter strips to become sources of pollution.

##### Slope

Vegetative filter strips should not be used on slopes greater than about 10 percent because of the difficulty in maintaining the necessary sheet flow conditions. Note: This does not mean that vegetated buffers are not suitable for slopes greater than

10 percent; it simply means that effective treatment of runoff is unlikely for slopes greater than 10 percent. Do not confuse a "buffer zone," which is used to protect streams and other environmental resources, with a "vegetative filter strip," which is a runoff treatment BMP.

#### Design Criteria

The design, planning, and operation and maintenance details that follow have been adapted directly from Horner's "general recommendations" with minor modifications, and while this is judged to be the best available information, it must be considered as interim and subject to modification. Alternative criteria is being investigated which may be reflected in future editions of this manual. Questions remain about the nutrient-removing abilities of biofiltration BMPs in the Pacific Northwest and further work needs to be done. As information becomes available, especially monitoring data and consequent new ideas on design, they will be incorporated into later editions of this manual.

In summary, an interim criteria have been selected to ensure that a residence time of 20 minutes for the water as it flows across (perpendicular to) the strip. Complete details of the criteria are given below, and the appendices give step-by-step procedures for designing strips and swales including an example calculation.

#### General Criteria

See BMP RB.05, Biofiltration Swale.

#### Specific Criteria for Vegetative Filter Strips

1. Design vegetative filter strips according to the same method detailed in Appendix AIII-6.1 for biofiltration swales. Calculate the necessary filter strip width (perpendicular to flow) on the basis of the 6-month frequency, 24-hour duration storm and a hydraulic radius (R) approximately equal to the design flow depth (y). Note: The design flow depth (y) will normally be no more than 0.5" (0.04 ft) because of the need to maintain sheet flow over the strip)
2. Calculate the necessary length (parallel to flow) to produce a water residence time of at least 20 minutes (the length should normally be in the range of 100-200 feet).
3. Install a shallow stone trench across the top of the strip to serve as a level spreader or make use of curb cuts in a parking lot. Make provisions to avoid flow bypassing the filter strip.
4. Vegetative filter strips should not be used for slopes in excess of 10 percent, and preferably less, because of the difficulty in maintaining the necessary sheet flow conditions.

#### Construction and Maintenance

See BMP RB.05, Biofiltration Swale.

#### III-6.5 REFERENCES

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- (3) Goldman, S.J., K. Jackson and T.A. Bursztynsky, Erosion and Sediment Control Handbook, McGraw-Hill Book Co., New York, 1986.
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APPENDIX AIII-6.1  
DESIGN PROCEDURE FOR BIOFILTRATION SWALE  
AND VEGETATIVE FILTER STRIP DESIGN

Introduction

This section has been adapted with minor modifications from Appendix D - Application Guide of "Biofiltration Systems for Storm Runoff Water Quality Control" by Dr. Richard R. Horner (2).

This guide provides biofilter design procedures in full detail, along with examples. It can be removed from the manual for convenient use alone, if desired. Refer to Sections III-6.3 and III-6.4 for design criteria and operation and maintenance details.

Procedure

Note: The procedures for swale and filter strip design are basically the same. The steps are given in full for swales, and notes are included to allow the procedure to be applied to filter strips as well. Unless specifically indicated, steps apply to both filter strips and biofilters.

Preliminary Steps (P)

Step #

- P-1. Estimate runoff flow rate (Q) for the 6-month frequency, 24-hour duration storm, according to methods outlined in Chapter III-1.
- P-2. Biofilters should normally be placed on slopes of 2 to 4 percent. If it can be demonstrated that adequate drainage to avoid persistent pooling will occur (using underdrains, if necessary), a slope less than 2 percent can be used. If the site slope exceeds 4 percent, the local government should make a determination of the site's suitability for a biofilter, and, if suitable, what special design features should be included. If the slope exceeds 6 percent, it is recommended that the biofilter traverse the slope or that the site topography be modified to produce a slope under 6 percent. If stepped, each section should slope at less than 6 percent. In any swale application with slope greater than 4 percent, check dams should be placed approximately every 50 feet.
- P-3. Select a vegetation cover suitable for the site.

Refer to Table III-6.1 to select grasses. If the site will be persistently wet, consider wetland genera such as Typha (cattails), Scirpus (bulrushes), and Lemna (duckweed), which have relatively high rates of pollutant uptake. Other wetland plants that have been observed to serve well in biofilters are Carex (sedges), and water cresses (A. Levesque, King County, personal communication). If development of wildlife habitat is an objective, consider habitat needs in selecting vegetation.

**Table III-6.1.  
Characteristics of Grasses Suitable for  
Lining Puget Sound Region Biofilters. (a)**

Common Name	Persistence/ Growth Form	Description	Rating (b)
Annual ryegrass or Italian ryegrass	Annual/bunchgrass	Common erosion control grass; establishes rapidly on bare soils but does not reseed well.	3
Kentucky bluegrass	Perennial/sod- forming	Common turf grass; may require irriga- tion in dry season. May need regular reseeding.	3
Tall fescue	Perennial/ bunchgrass	Common turf grass; can be used alone; may require irriga- tion in dry season.	4
Western wheatgrass	Perennial/ sod-forming	Tolerates drought	3

a. Adapted from Goldman et al. (3). Other recommended grasses and legumes:

Meadow foxtail	Creeping red fescue	Annual ryegrasses
Tall fescue	Timothy	White clover
Redtop	Seaside colonial bentgrass	

Other water-resistant grasses that grow well in regional conditions are Poa trivialis (roughstalk bluegrass) and Lolium perenne (perennial ryegrass) (West. D., Seattle City Light, personal communication).

The seeding mix specified for the parking lot swales at the West Willows Technical Center in Redmond was as follows:

52% perennial rye	
35% winter rye	13% clover

Shapiro and Associates recommends the following seeding mix for this application (Gorski A., Shapiro and Associates, personal communication):

40% redtop bentgrass	20% tall fescue	5% Russian wild rye
30% red fescue	5% perennial rye	

b. Ratings are for erosion protection: 1 - fair; 2 - good; 3 - excellent; 4 - superior.

## Design for Biofiltration Capacity

Note: There are a number of ways of applying the design procedure introduced by Chow (4). These variations depend on the order in which steps are performed, what variables are established at the beginning of the process and which ones are calculated, and what values are assigned to the variables selected initially. The procedure recommended here is an adaptation appropriate for biofiltration applications of the type being installed in the Puget Sound region. This procedure reverses Chow's order, designing first for capacity and then for stability. The capacity analysis emphasizes the promotion of biofiltration, rather than transporting flow with the greatest possible hydraulic efficiency. Therefore, it is based on criteria that promote sedimentation, filtration, and other pollutant removal mechanisms. Since these criteria include a lower maximum velocity than permitted for stability, the biofilter dimensions usually do not have to be modified after a stability check.

## Design Steps (D)

## Step #

D-1. Establish the height of vegetation during the winter and the design depth or flow. Maximizing height advances biofiltration and allows greater flow depth, which reduces the width necessary to obtain adequate capacity. However, if nutrient capture is the principal objective, vegetation should be mowed at the end of the growing season to minimize nutrient release. The design depth of flow should be at least two inches less than the winter vegetation height.  
**Note: Sheet flow (<1 inch deep) generally exists in vegetative filter strips (use 0.5 inch).**

D-2. Select a value of Manning's n. Use one of the following values for an initial analysis (after U.S. Department of Commerce, (5)), or refer to Table III-2.8 in Chapter III-2.

Dense grass up to 6 inches tall - 0.07  
 Vegetation with coarser stems (e.g., wetland plants, woody plants) - 0.07

D-3. Select the swale shape. (Skip this step in filter strip design.)  
 Use a trapezoidal shape for biofilter swales, as is feasible.

Rectangular and V-shapes are the least desirable from the stability standpoint. If one of these shapes is required by the site configuration, specify reinforcement for the side walls in conformance with the standards of the local government.

D-4. Use Manning's equation and first approximations relating hydraulic radius and dimensions for the selected shape to obtain a working value of a biofilter width dimension:

$$Q = \frac{1.486}{n} AR^{0.667} s^{0.5} \quad (6-1)$$

Where: Q = design runoff flow rate (ft<sup>3</sup>/s, cfs)  
 n = Manning's n (dimensionless)  
 A = Cross-sectional area (ft<sup>2</sup>)  
 R = Hydraulic radius = A/wetted perimeter (ft)  
 s = longitudinal slope as a ratio of vertical rise/horizontal run (dimensionless)

Refer to Figure III-6.5 to obtain equations for A and R for the selected shape. In addition to these equations, for a rectangular shape:

$$A = Ty \quad (6-2)$$

$$R = \frac{Ty}{T+2y} \quad (6-3)$$

where: T = width  
y = depth of flow in feet, expressed as a decimal

If these expressions are substituted in Equation 6-1 and solved for T (for previously selected y), the results are complex equations that are difficult to solve manually. However, approximate solutions can be found by recognizing that  $T \gg y$  and  $z^2 \gg 1$ , and that certain terms are nearly negligible. The approximations for the various shapes are:

$$\text{Parabolic:} \quad R \approx 0.67 y \quad (6-4)$$

$$\text{Trapezoidal:} \quad R \approx y \quad (6-5)$$

$$V: \quad R \approx 0.5 y \quad (6-6)$$

$$\text{Rectangular:} \quad R \approx y \quad (6-7)$$

(Also use for vegetative filter strips)

Making these substitutions and those for A from Figure III-6.5, and then solving for T gives:

$$\text{Parabolic:} \quad T \approx \frac{Qn}{0.76 y^{1.667} s^{0.5}} \quad (6-8)$$

$$\text{Trapezoidal:} \quad b \approx \frac{Qn}{1.486 y^{1.667} s^{0.5}} - Zy \quad (6-9)$$

$$V: \quad T \approx \frac{Qn}{0.47 y^{0.667} s^{0.5}} \quad (6-10)$$

$$\text{Rectangular:} \quad T \approx \frac{Qn}{1.486 y^{1.667} s^{0.5}} \quad (6-11)$$

(Also use for vegetative filter strips.)

For trapezoidal and V-shapes, select a side slope Z of at least 3.

Solve the appropriate equation for T or b. For a V-shape, check if  $Z = T/2y$  is at least 3. For a trapezoid, compute b (Step D-4a) and then top width T, where  $T = b + 2yZ$  (Step D-4b).

D-5. Compute A using the appropriate equation from Figure III-6.5 or Equation 6-2.

D-6. Compute the flow velocity at design flow rate:

$$V = \frac{Q}{A} \quad (6-12)$$

This velocity should be less than 1.5 ft/s, a velocity that was found to permit the sedimentation of most particles in typical urban runoff (see (2)). However, the smallest particles (clay and much of the silt fraction) may not be removed. Also, it is not known what velocity will cause grasses to be knocked from a vertical position, thus reducing filtration. Therefore, the velocity should be as low as space allows.

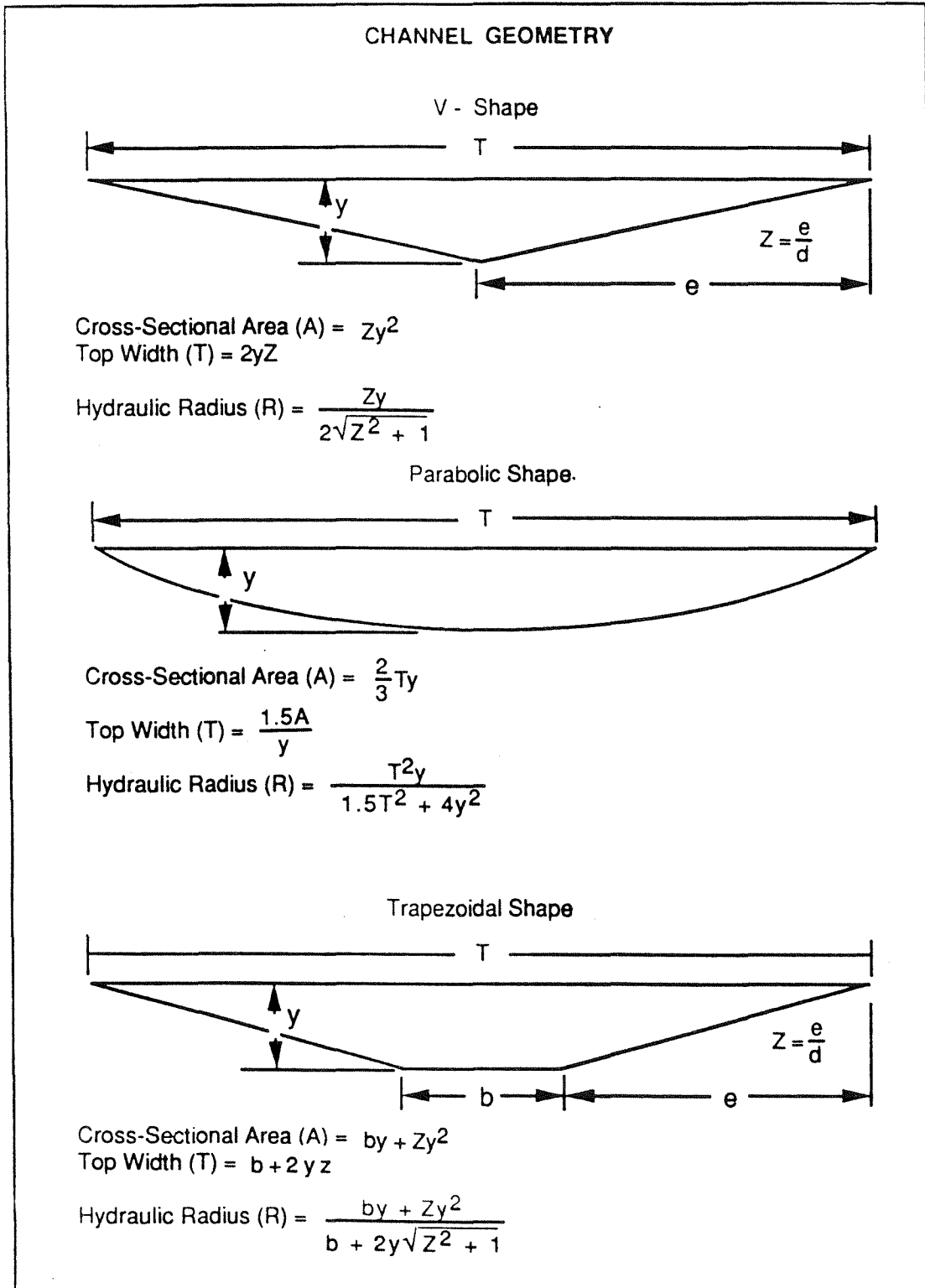


Figure III-6.5 Geometric Formula for Common Swale Shapes  
 (from Livingston et al., 1984).



If  $V > 1.5$ , repeat steps D-1 to D-6 until the condition is met.

- D-7. This approximate analysis tends to produce a design that results in  $V < 1.5$ , often by a substantial margin. This situation is preferred if sufficient space is available. If that is the case, proceed to the stability check. IF NOT, perform a more exact analysis according to steps D-8 to D-15, otherwise go to Step D-16.
- D-8. Estimate the degree of retardance to flow created by the selected vegetation from Table III-6.2. When uncertain, be conservative by selecting a relatively high degree.

Table III-6-2. Guide for Selecting Degree of Retardance (a).

Coverage	Average Grass Height (inches)	Degree of Retardance
Good	2-6	D. Low
	<2	E. Very low
Fair	2-6	D. Low
	<2	E. Very low

- a. After Chow (4). In addition, Chow recommended selection of retardance D for a grass-legume mixture 4-5 inches high. No retardance recommendations have appeared for emergent wetland species. Therefore, judgment must be used. Since these species generally grow less densely than grasses, using a "fair" coverage would be a reasonable approach.

D-9. Refer to Figure III-6.6 and use the selected degree of retardance and Manning's  $n$  from step D-2 to obtain a first approximation of  $VR$ , the product of velocity and hydraulic radius.

D-10. Compute hydraulic radius, using  $V_{max} = 1.5$  ft/s:

$$R = \frac{VR}{V_{max}} \quad (6-13)$$

D-11. Use Manning's equation to solve for the actual  $VR$  associated with this  $R$  and  $n$ :

$$VR = \frac{1.486}{n} R^{1.667} s^{0.5} \quad (6-14)$$

where  $VR$  is in units of  $ft^2/sec$

D-12. Compare the actual  $VR$  from step D-11 and the first approximation of  $VR$  from step D-9. If they do not agree within 5 percent, select a new  $n$  and repeat steps D-9 to D-12 until acceptable agreement is reached.

D-13. Compute the actual  $V$  for the final design conditions (using the actual  $VR$  calculated in Step D-11):

$$V = \frac{VR}{R} \quad (6-15)$$

Check to be sure  $V < 1.5$  ft/s.

D-14. Use the continuity equation to calculate the flow cross-sectional area (A):

$$A = \frac{Q}{V} \quad (6-16)$$

D-15. Use the appropriate equation in Figure III-6.5 or Equation 6-2 to compute T or b. For trapezoidal and V-shapes, use a Z of at least 3, and for trapezoids use  $T = b + 2yZ$ .

D-16. If there is still not sufficient space for the biofilter, the local government and the project proponent should consider the following solutions (listed in order of preference):

- a. Divide the site drainage to flow to multiple biofilters.
- b. Use infiltration to provide lower discharge rates to the biofilter (only if the criteria and General Limitations in Chapter III-3 are met).
- c. Increase vegetation height and design depth of flow (note: the design must ensure that vegetation remains standing during design flow).
- d. Reduce the developed surface area to gain space for biofiltration.
- e. Increase the longitudinal slope.
- f. Increase the side slopes.

Proceed to the stability check.

Check for Stability (Minimizing Erosion)

Notes:

- (1) The stability check must be performed for the combination of highest expected flow and least vegetation coverage and height.
- (2) Maintain the same units as in the biofiltration capacity analysis.

Stability Check Steps (SC)

(Note: Not required for biofiltration BMPs which are located "off-line" from the primary conveyance/detention system, i.e., when flows in excess of the peak flow for the 6-month, 24-hour design storm bypass the biofilter. This is the desired configuration.)

Step #

- SC-1. Unless runoff from events larger than the 6-month, 24-hour storm will bypass the biofilter, perform the stability check for the 100-year, 24-hour storm. Estimate Q for that event as recommended in Preliminary step P-1.
- SC-2. Estimate the vegetation coverage ("good" or "fair") and height on the first occasion that the biofilter will receive flow, or whenever the coverage and height will be least. Attempt to avoid flow introduction during the vegetation establishment period by timing of planting or bypassing.

- SC-3. Estimate the degree of retardance from Table III-6.2. When uncertain, be conservative by selecting a relatively low degree.
- SC-4. Establish the maximum permissible velocity for erosion prevention ( $V_{max}$ ) from Table III-6.3.

Table III-6.3  
Guide for Selecting Maximum Permissible Swale Velocities for Stability Check (a)

Cover	Slope (%)	Maximum Velocity (ft/sec)
Kentucky Bluegrass Tall Fescue	0 - 5	5
Kentucky Bluegrass Tall Fescue Western Wheatgrass	5 - 10	4
Grass-legume Mixture	0 - 5 5 - 10	4 3
Red Fescue Redtop	0 - 5 5 - 10	2.5 Not Recommended

(a) Adapted from references 3, 4, and 6.

- SC-5. Select a trial Manning's n. The minimum value for poor vegetation cover and low height (possibly, knocked from the vertical by high flow) is 0.033. A good initial choice under these conditions is 0.04.
- SC-6. Refer to Figure III-6.6 to obtain a first approximation for VR.
- SC-7. Compute hydraulic radius, using the  $V_{max}$  from step SC-4:

$$R = \frac{VR}{V_{max}} \quad (6-13)$$

- SC-8. Use Manning's equation to solve for the actual VR:

$$VR = \frac{1.486}{n} R^{1.667} s^{0.5} \quad (6-14)$$

- SC-9. Compare the actual VR from step SC-8 and first approximation from step SC-6. If they do not agree within 5 percent, repeat steps SC-5 to SC-9 until acceptable agreement is reached.
- SC-10. Compute the actual V for the final design conditions:

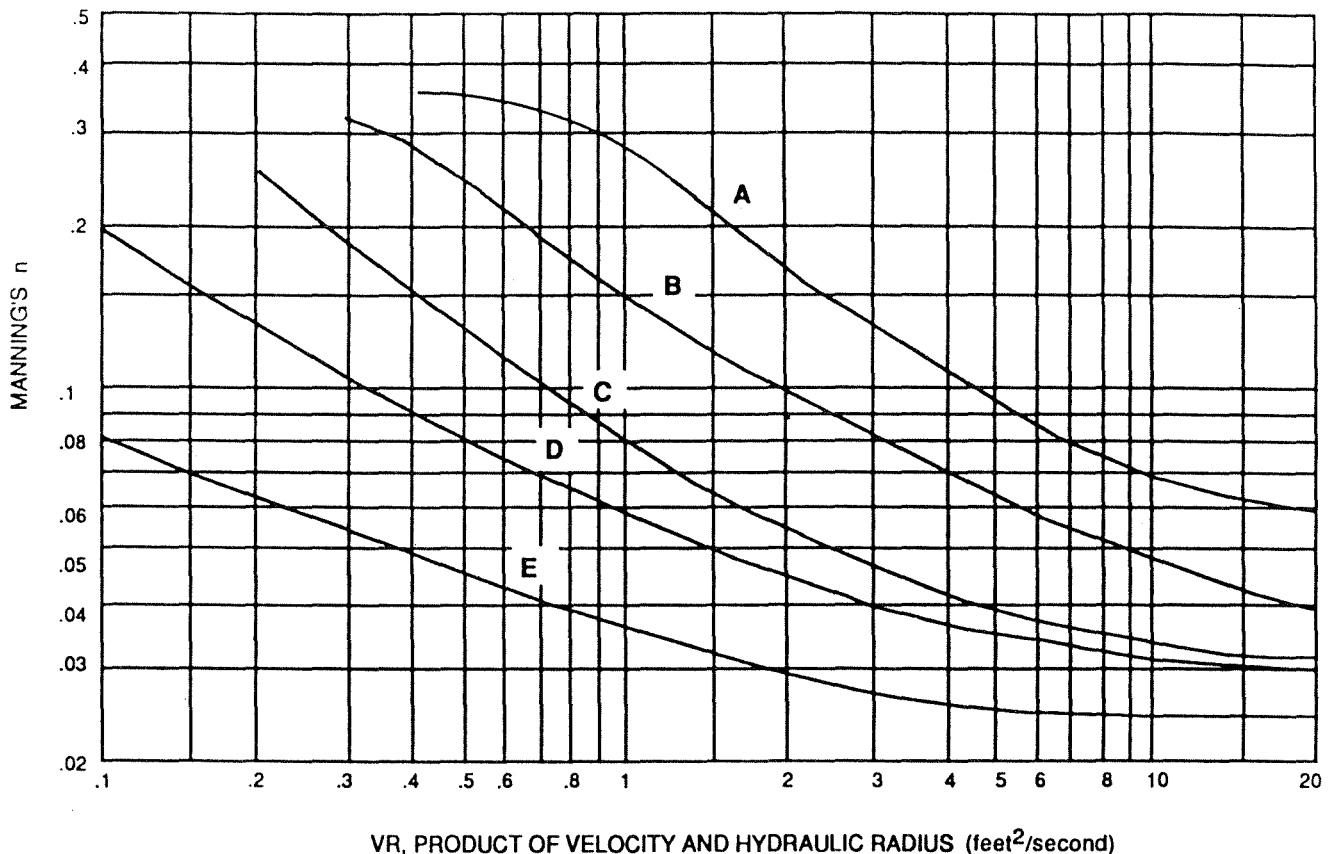
$$V = \frac{VR}{R} \quad (6-15)$$

Check to be sure  $V < V_{max}$  from step SC-4.

- SC-11. Compute the required A for stability:

$$A = \frac{Q}{V} \quad (6-16)$$

Figure III-6.6  
 The Relationship of Manning's n with VR for Various  
 Degrees of Flow Retardance (from Livingston et al.,  
 1984, after U.S. Soil Conservation Service, 1954)



- SC-12. Compare the A computed in step SC-11 of the stability analysis with the A from the biofiltration capacity analysis (step D-5 or D-14).  
 If less area is required for stability than is provided for capacity, the capacity design is acceptable. If not, use A from step SC-11 of the stability analysis and recalculate channel dimensions (refer to Figure III-6.5 or Equation 6-2). Use  $y$  from Step D-1.
- SC-13. Calculate the depth of flow at the stability check design flow rate condition for the final dimensions (refer to Figure III-6.5 or Equation 6-2). (For trapezoids use  $y = (T-b)/2Z$ )
- SC-14. Compare the depth from step SC-13 to the depth used in the biofiltration capacity design (Step D-1). Use the larger of the two and add 1 foot freeboard to obtain the total depth ( $y_t$ ) of the swale. Skip this step in filter strip design. (Editor's Note: If space is limited, calculate the depth needed for the 100-year, 24-hour storm then add this depth again for freeboard, up to a maximum freeboard of 1 foot.)

- SC-15. Recalculate the hydraulic radius (trapezoidal channel - see Figure III-6.5):

$$R = \frac{by_t + zy_t^2}{b + 2y_t(z^2 + 1)^{0.5}}$$

(use b from Step D-4 or D-15 calculated previously for biofiltration capacity, or Step SC-12, as appropriate, and  $y_t$  = total depth from Step SC-14)

- SC-16. Make a final check for capacity based on the stability check design storm and maximum vegetation height and cover (this check will ensure that capacity is adequate if the largest expected event coincides with the greatest retardance). Use Equation 6-1, a Manning's n of 0.1, and the calculated channel dimensions, including freeboard, to compute the flow capacity of the channel under these conditions. Use R from step SC-15, above, and  $A = by_t + Zy_t^2$  using b from Step D-4a, or D-15 or SC-12, as appropriate.

If the flow capacity is less than the stability check design storm flow rate, increase the channel cross-sectional area as needed for this conveyance. Specify the new channel dimensions.

#### Completion Steps (CO)

##### Step #

- CO-1. If the biofilter is a swale, lay out the swale to obtain the maximum possible length. This length should be at least 200 feet. In limited spaces, attempt to attain that length by using a curved path. Use the widest radius bends possible to reduce the potential for erosion of the outside of curved sections. If a length shorter than 200 ft. must be used, increase A by an amount proportional to the reduction in length below 200 ft., in order to obtain the same water residence time. Recalculate channel dimensions from Figure III-6.5 or Equation 6-2.
- If the swale is a vegetative filter strip, select a length for the calculated width that produces at least 20 minutes water residence time (normally 100-200 feet).
- CO-2. If the swale longitudinal slope is greater than 4 percent, design log or rock check dams approximately every 50 feet.

## APPENDIX AIII-6.2

## EXAMPLE PROBLEM SHOWING APPLICATION OF DESIGN PROCEDURE FOR BIOFILTRATION SWALES AND VEGETATIVE FILTER STRIPS

## Preliminary Steps

- P-1. Assume that  $Q$  for the 6-month, 24-hour storm was established by one of the recommended procedures to be 3 cfs.
- P-2. Assume the slope ( $s$ ) is 2 percent.
- P-3. Assume the vegetation will be a grass-legume mixture, with the dominant grass being red fescue.

## Design for Swale Biofiltration Capacity

- D-1. Set the winter grass height at 6 inches and design flow depth ( $y$ ) at 4 inches (i.e. 0.33 feet) (Eq. 6-9). Recall that the design flow must be at least two inches less than the winter grass height.
- D-2. Use  $n = 0.07$
- D-3. Base the design on a trapezoidal shape, with side slope ( $Z$ ) equal to 3.
- D-4a. Calculate the bottom width ( $b$ )

Where:  $n = 0.07$

$$Q = 3 \text{ cfs} \quad b = \frac{Qn}{(1.486y^{1.667}s^{0.5}) - Zy} \quad (6-9)$$

$$y = 0.33'$$

$$s = 0.02$$

$$Z = 3$$

or

$$b = 5.24 \text{ feet}$$

- D-4b. Calculate the top width ( $T$ )
- $$T = b + 2yZ = 5.24 + [2(0.33)(3)] = 7.24 \text{ feet}$$
- D-5. Calculate the cross-sectional area ( $A$ )

$$A = by + Zy^2 = (5.24)(0.33) + (3)(0.33^2) = 2.06 \text{ ft}^2$$

(from Fig. III-6.5)

- D-6. Calculate the flow velocity ( $V$ )

$$V = Q/A = \frac{3}{2.06} = 1.46 \text{ ft/s} < 1.5, \text{ so OK} \quad (6-12)$$

Proceed directly to stability check.

A top width of 6 to 10 feet is typical of many swales surveyed in the area, and should fit within most sites. For the example, assume that it does so. The calculation procedure of steps SC-8 through 15 will be demonstrated in the stability check.

Check for Channel Stability

- SC-1. Base the check on passing the 100-year, 24-hour storm runoff flow through the swale. Assume that  $Q$  for that storm was established by one of the recommended procedures to be 16 cfs.
- SC-2. Base the check on a grass height of 3 inches with "fair" coverage (lowest mowed height and least cover, assuming flow bypasses or does not occur during grass establishment).
- SC-3. Table III-6.2: Degree of retardance = D (low)
- SC-4. From Table III-6.3, set  $V_{max} = 3$  ft/sec since the vegetation is a combination of red fescue ( $V_{max} = 2.5$  ft/sec) and legumes ( $V_{max} = 4$  ft/sec).
- SC-5. Select trial Manning's  $n = 0.04$
- SC-6. Figure III-6.6  $VR = 3$  ft<sup>2</sup>/s
- SC-7. Eq. 6-13  $R = \frac{VR}{V_{max}}$   
 $R = 1.0$  ft
- SC-8. Eq. 6-14  $VR = \frac{1.486}{n} R^{1.667} S^{0.5}$   
 $VR = 5.25$  ft<sup>2</sup>/sec
- SC-9.  $VR$  from step SC-8  $<VR$  from step SC-6 by  $> 5\%$ .  
 Select new trial  $n = 0.047$   
 from Figure III-6.6  $VR = 1.7$  ft<sup>2</sup>/s  
 Eq. 6-13  $R = 0.57$  ft.  
 Eq. 6-14  $VR = 1.75$  ft<sup>2</sup>/s (within 5% of  $VR = 1.7$ )
- SC-10. Eq. 6-15  $V = VR/R = 1.75/0.57$   
 $V = 3.07$  ft/s  $< 5$  ft/s (OK)
- SC-11. Eq. 6-16  $A = Q/V = 16/3.07 = 5.21$  ft<sup>2</sup>
- SC-12. For stability check,  $A = 5.21$  ft<sup>2</sup> from Step SC-11, which is greater than the capacity from Step D-5 (2.06 ft<sup>2</sup>). Therefore, recalculate channel dimensions using  $A$  from Step SC-11 and referring to Figure III-6.5.

$$A = by + Zy^2$$

where:  $A = 5.21$  ft<sup>2</sup>  
 $Z = 3$   
 $y = ?$   
 $b = ?$

(Note: both depth and width dimensions can be varied to obtain needed value of  $A$ , which is 5.21 ft<sup>2</sup> in this example.)

For this example, choose  $y = 0.67$  ft. (note that  $y$  was originally set at 0.33 ft. in Step D-1) then calculate value for  $b$ .

$$\begin{aligned} \text{For } y &= 0.67 \text{ ft.}, b = 5.81 \text{ ft.} \\ T = b + 2yZ &= 9.81 \text{ ft.} \end{aligned}$$

SC-13. Calculate depth of flow at the stability design flow rate condition.

For trapezoids use  $y = (T-b)/2Z$  from Figure III-6.5, and  $b = 5.81$  ft and  $T = 9.8$  ft from Step SC-12.

$$y = (9.81 - 5.81)/6 = 0.67 \text{ ft.}$$

SC-14. The value for  $y$  calculated in SC-13 (0.67 ft.) is greater than that used in Step D-1. Use the greater value, and add 1 foot freeboard to give a total depth ( $y_t$ ) of 1.67 feet.

SC-15. Recalculate hydraulic radius ( $R$ ) where

$$\begin{aligned} b &= 5.81 \text{ ft (from Step SC-12)} \\ y_t &= 1.67 \text{ ft (from Step SC-14)} \\ Z &= 3 \text{ (from Step D-3)} \end{aligned}$$

$$R = \frac{by_t + Zy_t^2}{b + 2y_t(Z^2 + 1)^{0.5}} = 1.1 \text{ feet}$$

SC-16. Recalculate  $Q$  where:

$$Q = \frac{1.486}{n} AR^{0.667} s^{0.5} \quad (\text{Eq. 6-1})$$

$$\begin{aligned} \text{where: } n &= 0.07 \\ A &= by_t + Zy_t^2, \text{ using } b \text{ from Step SC-12} \\ R &= 1.1 \text{ feet (from Step SC-15)} \\ s &= 0.02 \text{ (from Step P-2)} \end{aligned}$$

$$A = (5.81)(1.67) + (3)(1.67^2) = 18.1 \text{ ft}^2$$

$$Q = \frac{1.486}{0.07} (18.1) (1.1)^{0.667} (0.02)^{0.5} = 57.9 \text{ cfs}$$

This is  $> 16$  cfs for 100-year, 24-hour storm if it coincides with maximum flow retardance. Therefore, channel dimensions are okay.

Completion Steps

CO-1 Assume 200 feet of swale length is available. The final channel dimensions are:

$$\begin{aligned} \text{Bottom width} &= 5.81 \text{ feet} \\ \text{Depth} &= 1.67 \text{ feet} \\ \text{Top width} &= b + 2yZ = 15.8 \text{ feet} \end{aligned}$$

CO-2 No check dams are needed for a 2% slope.



CHAPTER III-7

OIL/WATER SEPARATORS

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## CHAPTER III-7

## OIL/WATER SEPARATORS

## III-7.1 OVERVIEW

Oil/Water Separators have limited application in stormwater treatment because their treatment mechanisms are not well-suited to the "wastewater" characteristics of stormwater runoff (i.e., highly variable flow with high discharge rates, turbulent flow regime, low oil concentration, high suspended solids concentration). In addition, separators can require intensive maintenance, further restricting their desirability as a stormwater treatment BMP. The primary use of oil/water separators will be in cases where oil spills are a concern, in which case a spill control (SC-type) separator may be specified. There will be but a few other cases where an oil/water separator would be required, as other BMPs are more appropriate for controlling oil. Source control in particular should be the first option and may negate the need for special treatment. Other than to capture spills, the use of oil/water separators will be restricted to development sites that have high oil and grease loadings, such as petroleum storage yards and vehicle storage and/or maintenance facilities (see Chapters I-4 and IV-2 for land uses which require oil/water separators). There may be some cases that warrant the use of oil/water separators due to high vehicular traffic. These will have to be assessed on a case-by-case basis by the local government.

Sand filtration and oil absorbent materials are being investigated as alternatives to oil/water separators. While there is very limited data on the effectiveness of sand filtration for treating oil, this practice does have an established record of treatment of other pollutants and effective treatment of oil may also be accomplished. Sand filtration is to be considered an alternative to oil/water separators on an interim basis until further data is collected. See Chapter III-3 for details on sand filtration BMPs.

Absorbent materials are another alternative whose use has been pioneered by METRO in King County. Widely used for controlling spills, these "pillows" have been installed in storm drain inlets as a mechanism to absorb free oil from surface water runoff. Limited data is available to assess their effectiveness and some operational problems have occurred. The disposal of these pillows once they are exhausted can be a problem as well.

Three types of oil/water separators are discussed in this chapter:

BMP RO.05	Spill Control (SC-type) Separator
BMP RO.10	API Separator
BMP RO.15	Coalescing Plate Separator (CPS)

See Figures III-7.1, III-7.2, and III-7.3 for illustrations of these BMPs.

Because separators are usually manufactured units rather than constructed units, only limited details will be provided in this chapter. If oil/water separators are to be used, then an appropriate manufacturer or supplier should be contacted.

For a useful discussion of oil treatment of stormwater runoff the reader is referred to the publication "Oil and Water Don't Mix: The Application of Oil-Water Separation Technologies in Stormwater Quality Management" (METRO, October, 1990).

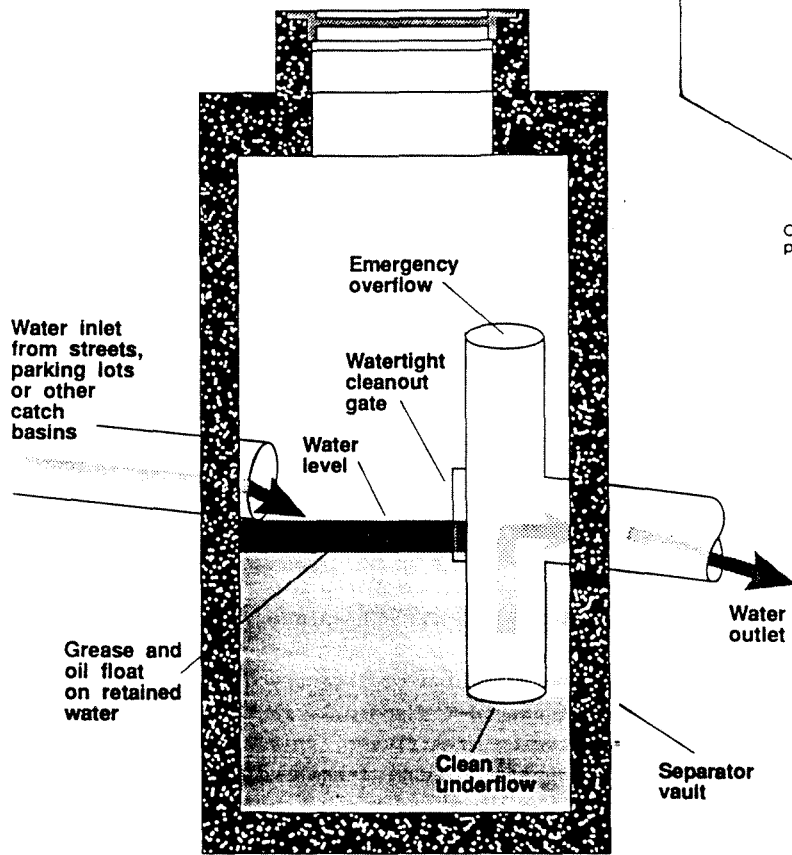


Figure III-7.1  
SC-Type Separator

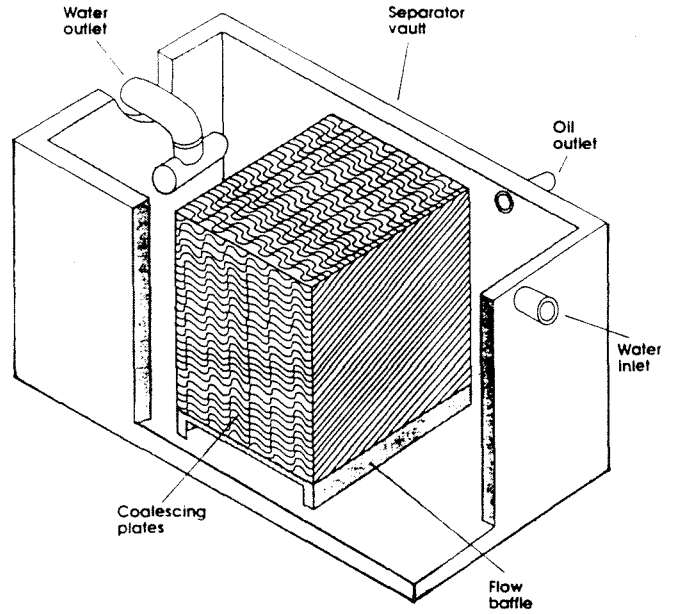


Figure III-7.3  
CPS Separator

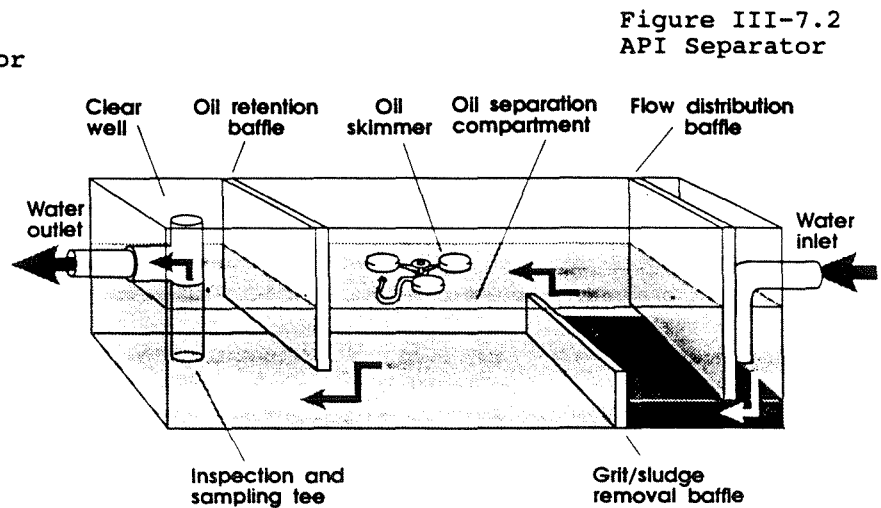


Figure III-7.2  
API Separator

### III-7.2 PLANNING CONSIDERATIONS AND GENERAL DESIGN CRITERIA

If an oil/water separator is used primarily for treatment (and not spill control), it should be located off-line from the primary conveyance/detention system. The contributing drainage area should be completely impervious and as small as necessary to contain the sources of oil. Non-source contributing areas only increase the size (and cost) of the separator and do not improve effectiveness. Under no circumstances should any portion of the contributing drainage area contain disturbed pervious areas which can be sources of sediment.

Description There are three general types of separators. The first type is the spill control separator (SC). It is a simple underground vault or manhole with a "T" outlet (Figure III-7.1). The SC-separator is effective at retaining only small spills. The SC-separator will not remove diluted oil droplets spread through the stormwater from oil-contaminated pavement.

The other two types of separators can remove dispersed oil: the American Petroleum Institute (API) separator (Figure III-7.2) and coalescing plate separator (CPS - Figure III-7.3).

The API-separator is a long vault or basin with baffles to improve the hydraulic conditions for treatment. Large API-separators may have sophisticated mechanical equipment for removing oil from the surface and settled solids from the bottom. However, most applications will use the simple system as illustrated.

The CPS-separator contains a bundle of plates made of fiberglass or polypropylene. The plates are closely spaced. Depending on the manufacturer and/or application, the plates may be positioned in the bundle at an angle of 45 to 60° from the horizontal.

The closely spaced plates improve the hydraulic conditions in the CPS-separator promoting oil removal. The primary advantage of the CPS-separator is its ability to theoretically achieve equal removal efficiencies with one-fifth to one-half the space needed by the API separator, when designed to remove the same size droplets.

#### Type of Separator Required

Land uses that must use an API or CPS-separator are identified in Chapter I-4 and in Chapter IV-2. The owner may choose between the API or CPS-separator using the design criteria outlined below. Other land uses or businesses should use the SC-separator for spill control as needed.

#### Effluent Guideline

Ecology requires that stormwater have no visible sheen, average less than 10 mg/l daily and at no time exceed a daily maximum of 15 mg/l.

#### Design Criteria

Requirements regardless of separator type

1. Separators should precede all other treatment and streambank erosion control BMPs.
2. Appropriate removal covers must be provided that allow access for observation and maintenance.

3. Stormwater from building rooftops and other impervious surfaces not likely to be contaminated by oil shall not discharge to the separator.
4. Any pump mechanism shall be installed downstream of the separator to prevent oil emulsification.

Additional requirements for API and CPS-separators

1. Separators are to be sized for the 6-month, 24-hour design storm. Larger storms shall not be allowed to enter the separator; the use of an isolation/diversion structure is recommended (see Chapter III-3 for details).
2. Separators shall have a forebay to collect floatables and the larger settleable solids. Its surface area shall not be less than 20 square feet (ft<sup>2</sup>) per 10,000 ft<sup>2</sup> of the area draining to the separator.

Additional requirements for CPS-separators

1. Plates shall not be less than 3/4 inch apart.
2. The angle of the plates shall be from 45° to 60° from the horizontal.

Absorbent pillows may be used in separators. For API and CPS-type separators they should be placed in an afterbay. With the SC-separator, absorbent materials should be placed in the manhole/vault. Used absorbent pillows will need to be properly disposed of.

Sizing Procedure

Oil droplets exist in water in a wide distribution of sizes. The separator therefore is sized to remove all droplets of particular size and greater which will ensure that sufficient oil is removed to achieve the effluent standard.

API-separators are usually sized to remove oil droplets 150 micron in size and larger. Smaller droplets rise so slowly as to require a relatively large vault. CPS-separators are commonly sized to remove 60 or 90 micron and larger oil droplets.

There are no data on the size distribution of dispersed oil in stormwater from commercial or industrial land uses with the exception of petroleum products storage terminals. These data indicate that by volume, about 80 percent of the droplets are greater than 90 micron. Less than 30 percent are greater than 150 microns. For this manual both the API and CPS-separator are sized to remove 60 microns and larger droplets at a temperature of 10°C giving a rise rate of 0.033 feet per minute. The requirement for treatment of 60 micron and larger sized droplets may preclude the use of API separators.

API-Separator Sizing

API-separators are sized using these general guidelines.

- Horizontal velocity: 3 fpm or 15 times the rise rate whichever is smaller (rise rate of 0.033 ft/min is recommended)
- Depth of 3 to 8 feet
- Depth to width ratio of 0.3 to 0.5
- Width of 6 to 16 feet

- Baffle height to depth ratios of 0.85 for top baffles and 0.15 for bottom baffles

The separator is first sized for depth using the equation:

$$\text{Depth} = (Q/2V_h)^{1/2}$$

where: Q = design flow (cfm)

V<sub>h</sub> = design horizontal velocity (fpm) = 0.50 (15 times 0.033)

Calculate the width using the above ratios (i.e., 0.3 to 0.5 depth-to-width ratio).

Then calculate length using the equation:

$$\text{Length} = \frac{\text{Depth}}{\text{Rise Rate}} * V_h = \frac{(Q/2V_h)^{1/2}}{0.033} * 0.50 = \frac{(Q/2V_h)^{1/2}}{0.066}$$

CPS-Separator Sizing

Calculate the projected (horizontal) surface area of plates required using the following equation:

$$A_p = \frac{Q}{\text{Rise Rate}}$$

Where A<sub>p</sub> = projected surface area of the plate (ft.<sup>2</sup>); note that the actual surface area, A<sub>a</sub> = A<sub>p</sub> \* cosine H

H = angle of the plates with the horizontal in degrees, usually varies from 45-60 degrees.

Q = design flow (cfm).

Rise rate - recommend using 0.033 ft/min.

Manufacturers of plate packs provide standard size packages which are rated at a particular flow (usually in gpm). However, as the manufacturer's flow rating is for conditions different than used above, the engineer must compare the plate surface area with the above calculation. Do not confuse the projected plate area with actual plate area (see Figure III-7.4).

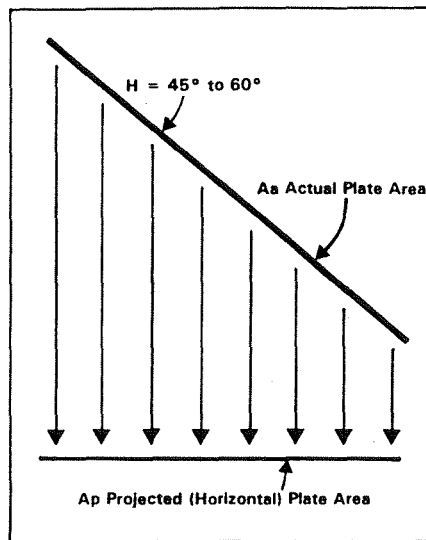
The width, depth, and length of the plate pack and the chamber in which the plate pack is placed is completely flexible and is a function of the plate sizes provided by the particular pack manufacturer and standard size vaults that are available for small sites.

**III-7.3 CONSTRUCTION AND MAINTENANCE**

Construction Specifications

There are no special construction considerations.

Figure III-7.4 Cross-Section of CPS Oil/Water Separator



### Maintenance

Oil/water separators must be cleaned frequently to keep accumulated oil from escaping during storms. They must always be cleaned by October 15 to remove material that has accumulated during the dry season, and again after a significant storm. In addition:

1. The facility shall be inspected weekly by the owner.
2. Oil absorbent pads are to be replaced as needed but shall always be replaced in the fall prior to the wet season and in the spring.
3. The effluent shutoff valve is to be closed during cleaning operations.
4. Waste oil and residuals shall be disposed in accordance with current local government Health Department requirements.
5. Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at a discharge location approved by the local government.
6. Any standing water removed shall be replaced with clean water to prevent oil carry-over through the outlet weir or orifice.

CHAPTER III-8

STREAMSIDE STABILIZATION

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## CHAPTER III-8

## STREAMSIDE STABILIZATION

## III-8.1 OVERVIEW

The streamside stabilization BMPs presented in Volume II for erosion and sediment control can also be considered as permanent BMPs that can be used to meet Minimum Requirement #5, "Streambank Erosion Control." Streambanks which have existing erosion problems will likely need to apply these techniques along with techniques described in Chapters III-3 and III-4 to control peak flow rates.

Three streamside stabilization BMPs are presented in this chapter; they are identical to those in Chapter II-5 and so noted in parentheses:

BMP RS.05 Vegetative Streambank Stabilization (BMP E2.80)  
BMP RS.10 Bioengineering Methods of Streambank Stabilization (BMP E2.85)  
BMP RS.15 Structural Streambank Stabilization (BMP E2.90)

Note that any of these methods may be adapted for use with unstable slopes; see BMP E2.45 in Chapter II-5.

A primary cause of stream channel erosion is the increased frequency of bank-full flows which results from upstream development. Most natural stream channels are formed with a bank-full capacity to pass the runoff from a storm with a 1.5 to 2-year recurrence interval. However, in a typical urbanizing watershed, stream channels may become subject to a 3 to 5-fold increase in the frequency of bank-full flows if stormwater runoff is not properly managed. As a result, stream channels that were once parabolic in shape and covered with vegetation may be transformed into wide rectangular channels with barren banks.

In recent years, a number of structural measures have evolved to strengthen and protect the banks of rivers and streams. These methods, when employed correctly, immediately ensure satisfactory protection of the banks. However, many such structures are expensive to build and to maintain. Without constant upkeep, they are exposed to progressive deterioration by natural agents. The materials used often prevent the reestablishment of native plants and animals, especially when the design is executed according to standard cross-sections which ignore natural variations of the stream system. Very often these structural measures destroy the appearance of the site. Additionally, structural stabilization and channelization can alter the hydrodynamics of a stream and only serve to transfer erosion potential and associated problems downstream.

In contrast, the utilization of living plants instead of or in conjunction with structures has many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. The repair and maintenance of structures is minimal where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective when the cover consists of natural plant communities adapted to their site. However, care must still be taken not to alter the hydrodynamics of the stream.

In summary, vegetative stabilization techniques are strongly preferred over structural techniques. If streamside stabilization is required then the first priority shall be either BMP RS.05, Vegetative Streambank Stabilization, or BMP RS.10, Bioengineering Methods of Streambank Stabilization.

**III-8.2 BMP RS.05: VEGETATIVE STREAMBANK STABILIZATION**

Definition and Purpose: Vegetative streambank stabilization is the use of vegetation as building material to stabilize streambanks against erosion and restore landscapes. This BMP is applicable to water areas and all land uses. It is to be used to stabilize banks in swales, creeks, streams, and rivers as well as man-made ditches, canals and impoundments, including ponds and storage basins.

See BMP E2.80 in Chapter II-5 for planning consideration, design criteria, construction and maintenance criteria, and other relevant information.

**III-8.3 BMP RS.10: BIOENGINEERING METHODS OF STREAMBANK STABILIZATION**

Definition and Purpose: Bioengineering methods combine vegetative and mechanical techniques to stabilize eroding streams. They provide protection of critical sections of streambank where ordinary vegetative means of protection are not feasible or offer insufficient protection. This BMP is to be used in streams with swift flow where the flow/soil conditions exceed the stabilizing effect of purely vegetative channel protection.

See BMP E2.85 in Chapter II-5 for planning consideration, design criteria, construction and maintenance criteria, and other relevant information.

**III-8.4 BMP RS.15: STRUCTURAL STREAMBANK STABILIZATION**

Definition and Purpose: Structural streambank stabilization methods utilize non-vegetative means to stabilize banks and streams. They do not provide the multiple benefits of other streamside stabilization BMPs and are to be used only when the erosive forces of moving water are such that vegetative or bioengineered methods are insufficient or infeasible.

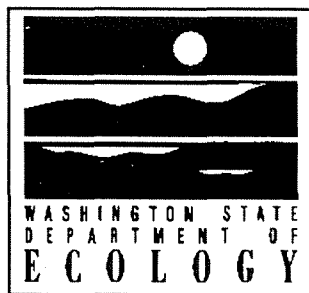
See BMP E2.90 in Chapter II-5 for planning consideration, design criteria, construction and maintenance criteria, and other relevant information.

# **Stormwater Management Manual for the Puget Sound Basin**

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(The Technical Manual)

*Volume IV - Urban Land Use  
BMPs*



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## FOREWORD

### Purpose of This Volume

The purpose of this volume of the stormwater manual is to provide technical information on source control BMPs for many types of urban land uses. Runoff treatment BMPs referred to are not dealt with specifically in this volume, but are found in Volume III, "Runoff Quality and Quantity Control." Prior to the selection of BMPs in this volume, Chapter I-2, "Minimum Technical Requirements" and Chapter I-4, "Selection Process for Best Management Practices" should be read. These chapters provide an overview of the necessary requirements and the basis for the proper selection of BMPs to fit a particular site.

### Chapter Contents

Chapter IV-1 provides an overview of the rest of this volume in addition to a review of information on typical pollutants found in stormwater, BMP preferences, the requirements of other regulatory agencies and instruction on how to use this volume.

Chapter IV-2 covers categories of manufacturing businesses, wholesale and retail businesses, transportation and communication, and service businesses. Many specific business types are included in each category. Business functions, materials used, wastes generated, source control BMPs and other applicable regulations are all included. Stormwater treatment BMPs are listed by the appropriate section in Volume III.

Chapter IV-3 covers the functions of public agencies in the same manner that businesses are covered. BMPs are also provided for each type of activity, such as vehicle and equipment maintenance shops, open space areas, and maintenance of roadside vegetation and ditches.

Chapter IV-4 provides specific information for the implementation of source control BMPs for businesses. Each source control BMP is described, and methods are given to implement the BMP. In some cases BMPs are required; in others there are choices given so that an individual business can tailor a set of practices which will be the most use for that individual business.

Chapter IV-5 provides brief explanations of other regulatory requirements which may have to be considered by a business or agency. General information is given on such regulations as air quality regulations, NPDES stormwater permits, WSDA pesticide regulations, fire code requirements, and hazardous waste generation.

This volume of the manual was compiled almost entirely by Dr. Gary Minton of Resource Planning Associates. It was expanded and adapted from the BMP manual which he prepared for the City of Seattle.

Other sources that were used are referenced at the end of each chapter or at the end of the volume. Members of the technical advisory group include:

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CHAPTER IV-1 INTRODUCTION

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## CHAPTER IV-1 INTRODUCTION

## IV-1.1 STORMWATER POLLUTANTS AND THEIR EFFECTS

To appreciate the need for **Best Management Practices** to minimize pollution of urban stormwater runoff we begin with an overview of the types of pollutants commonly found in this runoff.

- **Oil and grease:** Concentrations in stormwater from commercial and industrial areas often exceed the Washington Department of Ecology (Ecology) guideline of 10 mg/l.
- **Nutrients:** Phosphorus and nitrogen can cause excessive or accelerated growth of aquatic vegetation. Such growth can significantly affect lakes and may also be of concern in Puget Sound.
- **Oxygen demanding organics:** Natural organic materials washed from paved surfaces are consumed by bacteria present in receiving waters. Oxygen may be depleted in the process, threatening higher organisms such as fish.
- **Toxic organics:** A recent study (4) found 19 of the U.S. Environmental Protection Agency's 121 priority pollutants present in the runoff from Seattle streets. The most frequently detected pollutants were pesticides, phenols, and polynuclear aromatic hydrocarbons (PAHs).
- **Metals:** Stormwater contains metals such as lead, zinc, cadmium, and copper at concentrations that often exceed water quality criteria.

Research in Puget Sound has found that metals and toxic organics concentrate in sediments and at the water surface (microlayer) where they interfere with the reproductive cycle of many biotic species as well as cause tumors and lesions in fish.

- **Bacteria and viruses:** Research has shown that stormwater contains disease-causing bacteria and viruses, although not at concentrations found in sanitary sewage. Shellfish along Puget Sound near urban areas are usually unsafe for consumption.
- **Eroded soil:** Erosion of soil during construction carries soil particles into streams. These sediments destroy the desired habitat conditions for fish. The sediment may be carried to lakes or Puget Sound where they may be toxic to marine life and make dredging necessary.

## IV-1.2 TYPICAL POLLUTANT CONCENTRATIONS

Research in Western Washington has shown that the concentrations of pollutants in stormwater from residential, commercial, and industrial areas exceed Ecology's water quality standards and guidelines. Examples are shown in Table IV-1.1. Although little data exist for specific land uses such as shopping centers, it is expected that research would produce similar results.

## IV-1.3 WHAT ARE BMPs?

In its long range plan, the Puget Sound Water Quality Authority has stormwater control as one of 12 key action programs. Their control strategy is to emphasize the use of **Best Management Practices**.

Best Management Practices (BMPs) are defined as physical, structural, and/or managerial practices, that when used singly or in combination, prevent or reduce pollution of water and have been approved by Ecology.

Table IV-1.1 Comparison of Typical Stormwater Pollutant Concentrations to Water Quality Criteria<sup>A</sup>

Pollutant	CONCENTRATIONS (ug/l or ppb)				Particulate Fraction <sup>C</sup>	ECOLOGY/USEPA STANDARD <sup>D</sup>			
	Commercial <sup>B</sup>	Industrial	Residential	Highway		Freshwater		Saltwater	
						Acute	Chronic	Acute	Chronic
Cadmium	5	5	<3	<10	60	0.6	0.32	43.0	9.3
Copper	245	105	20	100	60	3.9	3.0	2.9	2.9
Lead	380	245	210	1780	90	10.5	0.41	140.0	5.6
Zinc	275	275	120	400	60	30.0	27.0	95.0	86.0
Oil/Grease	15	--	--	--	--	10. <sup>E</sup>	--	--	--
Fecal Coliform	980 orgs./ 100 mls	--	--	--	--	50orgs./100mls <sup>F</sup>		--	--

(A) See Chapter IV-5 for data sources.

(B) Geometric mean values for commercial areas; concentrations of individual samples often exceed the mean by a factor of 5 to 10.

(C) Particulate fraction values apply to concentration data for commercial and industrial land uses only.

(D) Acute criteria for freshwater at a hardness of 20 ppm.

(E) Ecology effluent guideline (mg/l); all other values are receiving water standards.

(F) Ecology criteria for class AA waters.

BMPs may be placed into two general groups: source control BMPs and runoff treatment BMPs. The former group includes those BMPs which keep a pollutant from ever coming in contact with stormwater; the latter group consists of various methods of treating stormwater.

Source control BMPs are preferred as they are generally less expensive and frequently are very effective in eliminating the source of pollution prior to its entry into runoff.

#### IV-1.4 BMP STRATEGIES AND PREFERENCES

There are many types of BMPs, and some general strategies, listed below in order of preference:

Alter the activity: The preferred option is to alter any practice that may contaminate surface water or ground water by either not producing the pollutant to begin with or by controlling it in such a way as to keep it out of the environment. An example would be recycling used oil rather than dumping it down a storm drain.

Illicit or unintentional connection of indoor drains to the storm drain, rather than to the sanitary or process sewer is a significant source of stormwater contamination. Research and local experience have demonstrated the importance of identifying and correcting these connections.

Enclose the activity: If the practice cannot be altered, it should be enclosed in a building. Enclosure accomplishes two things. It keeps rain from coming into contact with the activity, and since drains inside a building must discharge to sanitary or process wastewater sewers or a dead-end sump, any contamination of runoff is avoided.

Cover the activity: Placing the activity inside a building may be infeasible or prohibitively expensive. A less expensive structure with only a roof may be effective although it may not keep out all precipitation. Internal drains must be connected to the sanitary sewer to collect water used to wash down the area as well as any rain that may enter along the perimeter.

Segregate the activity: Segregating an activity that is the most significant source of pollutants from other activities that cause little or no pollution may lower the cost of enclosure or covering to a reasonable level.

If the segregated activity cannot be covered, it may be possible in certain situations to connect the area to the public sanitary sewer subject to the approval of the local Sewer Authority. Or, drains may be connected to a business' own process wastewater system if the business operates independently of the local authority.

Discharge stormwater to the process wastewater treatment system: Many industries have their own process wastewater treatment system with final disposal directly to the receiving water. Here, stormwater from areas of significant pollution sources can be plumbed to the process treatment system as long as its capacity is not exceeded.

Discharge small, high frequency storms to public sanitary sewer: This BMP would be limited to those few outside activities that contribute unusually high concentrations of pollutants and/or pollutants of unusual concern. Limited entry of these few special cases may not overtax the public sanitary sewer. It is important, however, to first have the approval of the local Sewer Authority.

The entry of stormwater to the sanitary or combined sewer can be limited to the small high-frequency storms that carry off the majority of pollutants over time. Storm flows in excess of the hydraulic capacity of the sanitary or combined sewer would be discharged to the storm drain.

Discharge small, high frequency storms to a dead-end sump: This BMP would be limited to those few activities which contribute unusually high concentrations of pollutants and/or pollutants of unusual concern. This option would be used when discharge into a sanitary sewer or process wastewater treatment is not available or feasible. This option requires the capability to have the sump pumped out regularly and the pumpage disposed of in an appropriate manner.

Treat the stormwater with a stormwater treatment BMP: The treatment of stormwater is the least-preferred option for several reasons. As noted previously, source control BMPs keep the pollutants completely away from stormwater. In contrast, stormwater treatment devices are not 100% effective. Note from Table IV-1.1 that even if a stormwater treatment system is 75 percent effective, freshwater criteria may still not be met for commercial areas. In addition, inadequate maintenance can reduce a system's expected efficiency.

#### IV-1.5 THE IMPORTANCE OF EFFECTIVE MAINTENANCE

BMPs require regular attention to ensure their effectiveness. For example, containers for Dangerous Wastes must be kept closed if they are stored outside. Allowing the entry of rain to an open container may cause the overflow of its contents to nearby street drains.

Stormwater treatment devices such as oil/water separators must be cleaned frequently. Unfortunately, due to lack of experience or oversight by the owner, inadequately maintained facilities are common.

King County has found that public and private storm drainage control systems must be inspected by the public authority at least annually to insure proper maintenance.

#### IV-1.6 THE REQUIREMENTS OF OTHER REGULATORY AGENCIES

It has been noted above that the local Sewer Authority has the responsibility to control all discharges to sanitary and combined sewers. It is one of several regulatory agencies or departments whose requirements must be taken into consideration when implementing Volume IV.

The requirements of agencies or departments of local government are introduced here, indicating their relationship to the possible actions to control stormwater pollution, with more detail presented in Chapter IV-5.

Public sanitary or combined sewers - local Sewer Authority: Drains located inside a building or covered area must connect to the public sanitary or combined sewer, except for businesses that discharge directly to a receiving water or a dead-end sump. Any discharge to a public system must meet the discharge requirements of the local Sewer Authority.

If the discharge is non-sanitary, that is, process wastewater, the discharge must comply with the USEPA/Ecology pretreatment requirements. The pretreatment requirements specify the allowable concentrations of particular pollutants (see R.1 in Chapter IV-5).

Peak-rate drainage control - local Public Works Department: All local governments in the Puget Sound drainage basin will require that new developments install facilities to control the rate of stormwater discharge as per Minimum Requirement #3 set out in Chapter I-2. If properly designed, peak-rate control and stormwater treatment can be achieved in the same facility (see Volume III, Runoff Control).

Flammable materials - Fire Department: Any business that stores a flammable, ignitable, or reactive material must comply with the local fire code (see R.2 in Chapter IV-5).

Dangerous wastes - Ecology: The Washington State Department of Ecology is responsible for enforcing the state regulations on Dangerous Wastes. With few exceptions, Ecology's activities in this area encompass the federal laws on hazardous wastes. This volume provides BMPs for the temporary storage of accumulated wastes until it is removed to a hazardous waste treatment and disposal site.

As described in R.3 of Chapter IV-5, the requirements and Ecology's involvement in their implementation varies with the quantity generated and the length of the temporary storage period.

Under certain circumstances relating to the quantity of waste generated and the temporary storage period, the waste generator must obtain an identification number and a storage permit. Ecology can therefore specify the appropriate BMPs and make the appropriate inspections. However, as the permit requirements are stringent, generators are motivated to move their wastes within the specified time limits.

A recent survey found that small generators frequently do not properly store or dispose of Dangerous Wastes. Although the generators must still comply with Ecology requirements, Ecology will not see to their implementation because the Department is not aware of the activity. Therefore, with this manual local government can insure that the appropriate BMPs are implemented by the small generators.

Other solid wastes - Health Department: Regulations of the local Health Department provide specifications to insure the integrity of containers. Containers failing to meet these requirements must be replaced (see R.4 in Chapter IV-5).

Liquid transfer from marine vessels - Coast Guard: A system that transfers petroleum products to or from marine vessels to shore tanks must comply with Coast Guard requirements. Transfer of other liquid chemicals is not covered by current federal or state laws (see R.5 in Chapter IV-5).

Underground storage tanks - Ecology: Underground tanks for the storage of chemicals or petroleum must comply with federal and state requirements. Some tanks are excluded from this requirement as explained in R.6 in Chapter IV-5.

Spill control and cleanup plans: Businesses and public agencies that generate Dangerous Wastes and/or produce, transport or store petroleum products are required by state and federal law to prepare spill control and cleanup plans. Other types of liquids are not covered by state or federal law (see R.7 in Chapter IV-5).

Pesticide<sup>1</sup> use: Vegetation management, important in such diverse activities as golf courses and roads, commonly employs pesticides that can contaminate surface and ground waters. The Washington Department of Agriculture is the primary regulator of pesticide use (see R.8 in Chapter IV-5).

Air quality - Local Air Pollution Agency: Air pollution is a source of stormwater contaminants. Several areas in the Puget Sound region do not meet air standards with regard to fugitive particulates. Air authorities require some industries to pave or treat the surface of unpaved areas, and/or sweep. The air authority also regulates painting and abrasive blasting (see R.9 in Chapter IV-5).

Some heavy industries whose air emissions contaminate stormwater may find it cost-effective to achieve water quality objectives by further reducing air emissions beyond that required by air regulations.

Waste reduction - Ecology: As part of its solid waste program, Ecology encourages and provides technical guidance to reduce the quantity of solid and liquid wastes.

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<sup>1</sup> The term pesticide as used here includes insecticides, herbicides, rodenticides and fungicides.

Reducing the quantity reduces the potential for the contamination of stormwater by these wastes (see R.10 in Chapter IV-5).

NPDES Stormwater permits: On November 16, 1990, the U.S. EPA promulgated final NPDES regulations for stormwater discharges to waters of the United States from municipalities serving populations greater than 100,000 and certain industries. NPDES refers to the National Pollutant Discharge Elimination System, a Federal regulation administered by Ecology. The final regulations outline permit application requirements and identify which dischargers are required to apply for NPDES permits. NPDES permits for stormwater discharges may specify BMP requirements and/or allowable concentrations of particular pollutants (effluent limitations). In Chapter IV-2, all industries that are required to have NPDES permits are indicated by a double asterisk ("\*\*"). Those who require permits only if potential pollutants are stored outside are indicated with a single asterisk (\*). Further information can be found in Chapter IV-5 and Chapter II-4 (for construction sites).

#### IV-1.7 SUBJECTS THIS VOLUME DOES NOT COVER

The manual does not provide BMPs for the control of discharges to public sanitary sewers. This is the responsibility of the local Sewer Authority. However, there are BMPs in this volume that may also be appropriate for controlling pollutants discharged to sanitary sewers.

This volume also does not include BMPs for businesses that transport, treat, process and/or permanently store Dangerous or Extremely Hazardous Wastes. This topic is covered in other Ecology publications and regulations. For further information, contact the Hazardous Substance Information Hotline, 1-800-633-7585.

#### IV-1.8 WHERE BMPs ARE NOT REQUIRED

BMPs are not necessary where all business activities including parking, loading or unloading of liquids, or temporary storage of liquid or solid wastes are totally enclosed within a building.

Stormwater treatment is not required for parking lots with less than 20 stalls, except for a simple oil spill control separator (BMP RO.05 in Volume III, Runoff Control), unless it is a retail business that experiences a high turnover of vehicles. These exceptions are noted in Chapter IV-2.

#### IV-1.9 HOW TO USE THIS VOLUME

Figure IV-1.1 illustrates how this volume is to be used. Many land uses have similar activities. For example, general purpose gas stations are not the only type of business that dispense vehicle fuels. Fuel pumps are found at rental car agencies, 24-hour convenience stores, truck freight companies, public works shops and construction companies. Therefore, in STEP 1 the user identifies key activities that may result in stormwater contamination. These possible activities are listed in the enclosed checklist (Table IV-1.2).

If the user is a private business, STEP 2 is to examine the Table of Contents of Chapter IV-2, "Businesses and Required BMPs," to locate the particular grouping within which that business falls, then turn to the appropriate page in Chapter IV-2 to identify the required BMPs.

If the user is a public agency, STEP 2 is to examine the Table of Contents in Chapter IV-3 and then turn to the appropriate page in Chapter IV-3 to identify the required BMPs.

STEP 3 is to obtain details on each of the required BMPs by referring to the appropriate section of the Manual. Details on source control BMPs are provided in

Chapter IV-5 of this volume. Details on stormwater treatment BMPs are provided in Volume III, Runoff Control. STEP 4 is to refer to Chapter IV-6 for the requirements of other agencies. An effort has been made to incorporate these requirements into the discussion of each BMP.



Figure IV-1.1 How to Use This Volume

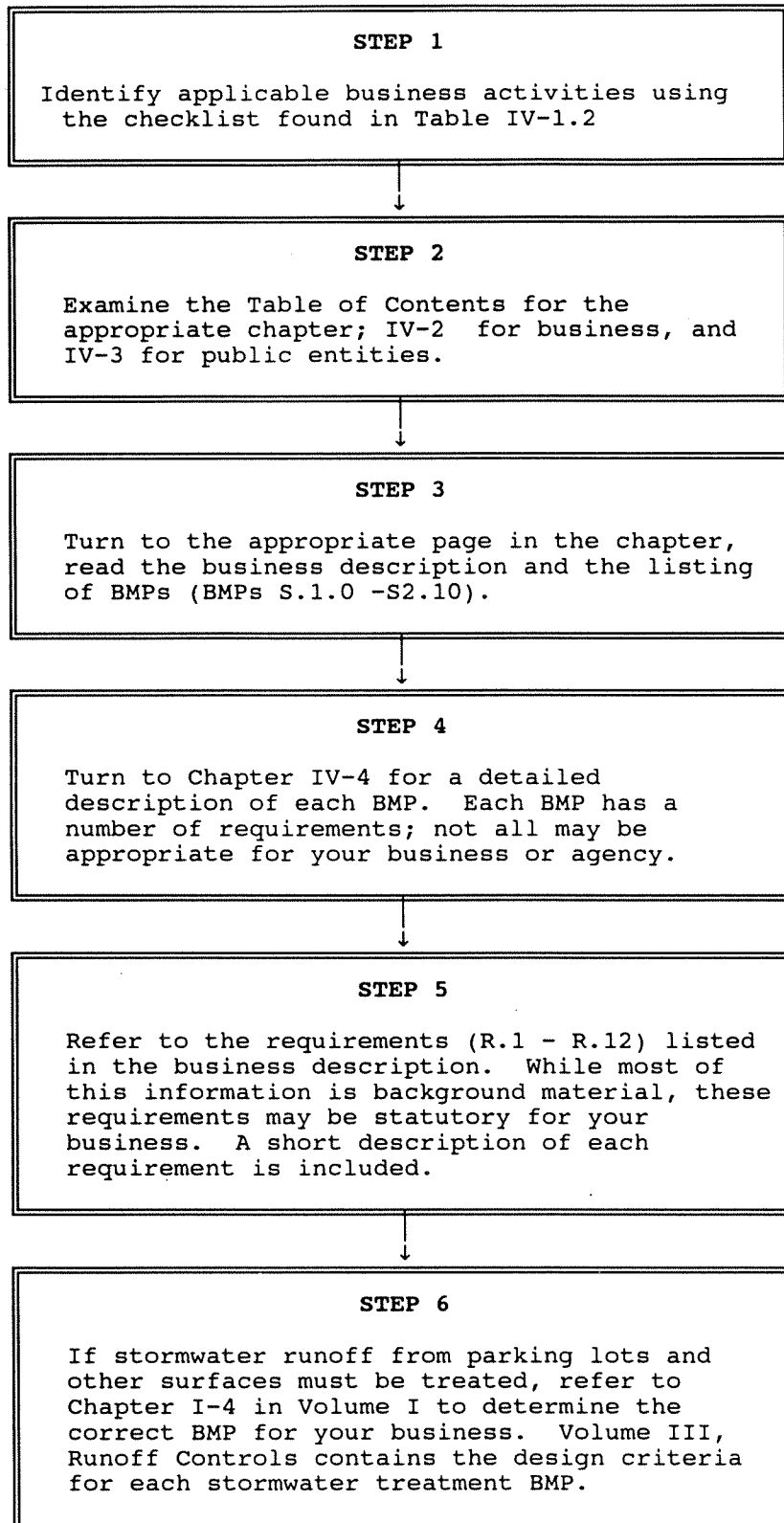


Table IV-1.2 Activities Checklist

CHECK ACTIVITIES THAT ARE OCCURRING OR WILL BE OCCURRING  
 (see Chapter IV-2 for the appropriate land use, and Chapter IV-5  
 for relevant BMPs)

- Uncovered vehicle parking \_\_\_\_\_
- Indicate number of parking spaces \_\_\_\_\_
- Washing of vehicles or equipment \_\_\_\_\_
- Vehicle or equipment fueling \_\_\_\_\_
- Loading or unloading of liquid materials \_\_\_\_\_
- Storage of raw materials, byproducts or products  
of manufacturing processes \_\_\_\_\_
- Above-ground bulk storage of fuel, petroleum  
or chemicals \_\_\_\_\_
- Use of underground tanks \_\_\_\_\_
- Use of pesticides or fertilizers \_\_\_\_\_
- Livestock husbandry \_\_\_\_\_
- Temporary storage of liquid or solid wastes \_\_\_\_\_
- Indicate type of waste:
- Dangerous/Extremely Hazardous waste \_\_\_\_\_
- Food wastes \_\_\_\_\_
- Used oil \_\_\_\_\_
- Other (briefly describe) \_\_\_\_\_

Do you have or will you be obtaining a permit from the Department of Ecology to store Dangerous or Extremely Hazardous wastes? \_\_\_\_\_

Do you intend to connect inside drains to the public sanitary sewer? Will you be discharging process water directly to a surface water? \_\_\_\_\_

DESCRIBE ANY OTHER OUTSIDE ACTIVITIES NOT COVERED ABOVE \_\_\_\_\_

CHAPTER IV-2 BUSINESSES AND REQUIRED BMPs

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CHAPTER IV-2

BUSINESSES AND REQUIRED BMPs

Chapter IV-2 provides descriptions of different business groups and their required BMPs. The source control BMPs referred to are found in Chapter IV-4 and are listed in numerical order for convenience. Descriptions of regulations that are specifically referred to can be found in Chapter IV-5. Again, these are listed in numerical order. If stormwater treatment BMPs are required, they will generally be found in Volume III, Runoff Control.

Each group of businesses is listed in the following way:

- Title of business group
- Standard Industrial Code (SIC) (note: a single asterisk ("\*") indicates that a business may require an NPDES permit if it stores pollutants outside; a double asterisk ("\*\*") indicates that a business or industry is required to obtain an NPDES permit.)
- Description of business activities
- Characteristics of materials used and wastes generated
- Required source control BMPs
- Required stormwater treatment BMPs

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## IV-2.1 MANUFACTURING BUSINESSES

### IV-2.1.1 CEMENT

SIC: 3241\*\*

**DESCRIPTION:** These businesses produce Portland cement, the binder used in concrete for paving, buildings, pipe and other structural products.

**MATERIALS USED AND WASTES GENERATED:** The raw materials vary with the particular plant but may be limestone, chalk, marl, or shale. Waste materials from other industries are often used such as slag, fly ash and spent blasting sand.

Raw materials are crushed, mixed and fed into a kiln, a long cylindrical shell, in which the material is heated to produce the correct chemical composition. Natural gas has generally replaced coal as the heat source. The kiln is angled and as it rotates the material passes through by gravity. The output of the kiln is a clinker which is ground to produce the final product.

The basic process may be wet or dry. In the wet process water is mixed with the raw ingredients in the initial crushing operation and in some cases is used to wash the material prior to use. Water may also be used in the air pollution control scrubber. The most significant by-product of cement production is the kiln dust. Kiln dust can be difficult to dispose of.

Stormwater may be contaminated by the raw materials, kiln dust or the product. Analysis of stormwater samples from cement plants in the Seattle area has found the pH to be above 10 and metals concentrations to exceed acute water quality criteria.

Concrete products may also be produced on site such as ready-mix concrete. Refer to "Concrete Products" for a description of the BMPs appropriate to these activities.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine applicable actions.*

*Regulatory Requirements: See R.1, R.3, R.4, R.9, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** This industry is one of seven industrial groups for which effluent standards have been set for stormwater quality. According to Federal Regulation 40 CFR 411 the stormwater from a new cement plant is to have these characteristics: total suspended solids are not to exceed 50 mg/l and the pH shall range between 6.0 and 9.0. In addition, the stormwater treatment system must be sized to handle at least a 10-year, 24-hour storm.

Stormwater draining from the plant site (including parking lots) shall be treated by one of the treatment systems described in Volume III, Runoff Control. Cement plants may control the pH of stormwater runoff by adding sulfuric acid subject to site-specific approval by Ecology. Any design for a detention system should take this factor into consideration. A conventional wet pond will likely be the most logical choice for efficient treatment of stormwater (see BMP III-RD.05, Chapter III-4 in the Runoff Control Volume).

Stormwater runoff from rooftops may be discharged to the storm drains below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

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**IV-2.1.2 CHEMICALS**

SIC: 2800\*\*, 3861\*\*

**DESCRIPTION:** This group involves the manufacturing of chemicals, or products based on chemicals. This includes the production of acids, alkalis, inks (2893)\*\*, chlorine, industrial gases, pigments, chemicals used in the production of synthetic resins (2869\*\*), fibers and plastics, synthetic rubber, soaps and cleaners (2840)\*\*, pharmaceuticals (2834)\*, cosmetics, paints (2850)\*, varnishes and resins (2861)\*. Included here are photographic materials and chemicals (3861). Also made in this region are organic chemicals (2869)\*\*, agricultural chemicals (2879)\*\*, adhesives and sealants (2891)\*\*, and ink (2893)\*\*.

**MATERIALS USED AND WASTES GENERATED:** The types of processes, materials and wastes generated are too numerous to catalog here. Wastewater can contain heavy metals and a variety of toxic organics.

Activities that may occur outside the manufacturing building include: bulk storage of liquid feedstock, other raw materials, by-products or products; loading and unloading of liquid materials from truck or rail; washing of equipment outside the building; waste oil and solvents from cleaning manufacturing equipment; used equipment temporarily stored on site that could drip oil and residual process materials; and temporary storage of Dangerous Wastes.

With few exceptions all of these industries require treatment of wastewater prior to disposal. Such processes produce contaminated sludges which must be properly stored until disposed of. The wastewater treatment processes may not be enclosed and therefore spillage to pavement and/or ground water contamination can occur.

Chemical businesses in the Seattle area surveyed for Dangerous Wastes have been found to produce caustic solutions and soaps, solutions with heavy metals, inorganic and organic chemicals, solvents, acid and alkaline wastes, waste paints and varnishes, waste pharmaceuticals and inks.

**Source Control BMPs:** See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine applicable actions.

**Regulatory Requirements:** See R.1, R.2, R.3, R.4, R.6, R.7, R.9, R.10, and R.11 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drains below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

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IV-2.1.3 CONCRETE PRODUCTS

SIC: 3270\*\*

DESCRIPTION: Businesses that manufacture concrete blocks and bricks, concrete sewer or drainage pipe, septic tanks, and prestressed concrete building components. Concrete is prepared on-site and poured into molds or forms to produce the desired product.

This group also includes the production of ready-mix concrete and gypsum products.

MATERIALS USED AND WASTES GENERATED: The basic ingredients of concrete are sand, gravel, Portland cement, and reinforcing steel for some products. Most businesses do not produce their own concrete; it is produced and delivered by ready-mix concrete plants.

Sources of pollution can include the loss of raw materials from stockpiles, washing of waste concrete from trucks, forms, equipment and the general work area, and water from the curing of concrete products. Besides the basic ingredients for making concrete products, chemicals used in the curing of concrete and the removal of forms may end up in stormwater.

Trucks and equipment maintained on-site will generate waste oil and solvents, and other related waste materials.

Although there is no stormwater quality data from concrete product businesses, it is likely the quality will be similar to that found at cement plants. Analysis of stormwater samples from cement plants in the Seattle area has found the pH to be above 10 and metals concentrations to exceed chronic water quality criteria.

Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine applicable actions.

Regulatory Requirements: See R.1, R.3, R.4, R.9, R.10 and R.11 in Chapter IV-5.

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from the general plant site and/or parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drains below the treatment system as long as the local Public Works Department's drainage requirements are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

Ready-mix plants typically have settling basins to treat wash water from the cleaning of trucks. This function may be integrated with the treatment requirements specified above for stormwater depending on the requirements of the local government and/or other agencies.

IV-2.1.4 ELECTRICAL PRODUCTS

SIC: 3600\*, 3800\*

DESCRIPTION: In the Puget Sound region a variety of products are produced including electrical transformers and switchgear (3610)\*, communications equipment for radio and TV stations and systems (3660)\*, electronic components and accessories including semiconductors (3670)\*, printed board circuits, electromedical and eletrotherapeutic apparatuses (3690)\*, and electrical instrumentation (3800)\*.

Specialized processing that can produce waste materials includes etching, acid and alkaline cleaning, and electroplating.

MATERIALS USED AND WASTES GENERATED: Materials used include metals, ceramics, quartz, silicon, oxides, acids, alkaline solutions, arsenides and phosphides, cyanides, solvents, and other inorganic liquid chemicals.

Wastewater consists of solutions and rinses from electroplating operations, and the cleaning waters described above. Water may also be used to cool saws and grinding machines. Sludges are produced by the wastewater treatment process.

Activities that may occur outside the manufacturing building include: bulk storage of raw materials, by-products or finished products; loading and unloading of liquid materials from truck or rail; temporary storage of waste oil and solvents from cleaning manufacturing equipment; used equipment temporarily stored on site that could drip oil and residual process materials; and temporary storage of Dangerous Wastes. Spillage from any of these activities can contaminate surface or ground waters.

Waste liquids that may be temporarily stored on site include spent acetone and solvents, ferric chloride solutions, soldering fluxes mixed with thinner or alcohol, spent acids, and oily waste. Several of these liquid wastes contain chlorinated hydrocarbons, ammonium, and metals such as chromium, copper, lead, nickel, and tin. Waste solids include soiled rags and sanding materials.

Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

Regulatory Requirements: See R.1, R.2, R.3, R.4, R.10 and R.11 in Chapter IV-5.

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).



IV-2.1.5 FOOD PRODUCTS

SIC: 2000\*

**DESCRIPTION:** Includes any business that produces a finished food product including meat packing plants, poultry slaughtering and processing, sausage and prepared meats, dairy products, preserved fruits and vegetables, flour, bakery products, sugar and confectioneries, vegetable and animal oils, beverages, canned, frozen or fresh fish, pasta products, snack foods, and manufactured ice.

**MATERIALS USED AND WASTES GENERATED:** With most food processors all processing occurs inside buildings. Exceptions are meat packing plants where live animals may be kept, and fruit and vegetable plants where the raw material may be temporarily stored outside. Storm runoff from animal containment or transit areas and vegetable storage areas will be contaminated, the latter from earth attached to the vegetables and vegetable wastes. The nature of contamination of stormwater passing over fruits is unknown but is not likely to be significant as fruit is usually picked clean.

Wine processors often crush grapes outside the process building and/or store equipment outside when not in use. Some wine producers use juice from grapes crushed elsewhere. Significant liquid transfer will occur with some processors. Some vegetable and fruit processing plants use caustic solutions.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas used to store food products shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.6 GLASS PRODUCTS

SIC: 3210\*\*, 3220\*\*, 3230\*\*

**DESCRIPTION:** Manufacturers of glass and glass products from raw materials and/or recycled glass. The glass form produced may be flat or window glass, safety glass, container glass, tubing, glass wool or fibers. Glass containers may also be produced on the same site.

The raw materials are mixed and heated in a furnace. The resulting molten material is shaped by processes that vary with the intended product. The cooled glass may be edged, ground, polished, annealed and/or heat treated to produce the final product. Air emissions from the manufacturing buildings are scrubbed to remove particulates.

**MATERIALS USED AND WASTES GENERATED:** The basic raw materials are sand mixed with a variety of oxides such as aluminum, antimony, arsenic, lead, and barium. Metal salts for coloring such as copper or cobalt oxide may be used.

Raw materials are generally stored in silos except for crushed recycled glass. Consequently, contamination of stormwater and/or ground water is limited to raw material lost during unloading operations, errant flue dust, and engine fluids from mobile lifting equipment that is stored outside. The maintenance of the manufacturing equipment will produce used lubricants and cleaning solvents. The flue dust is likely to contain heavy metals such as arsenic, cadmium, chromium, mercury, and lead.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from the general plant site including parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.7 INDUSTRIAL MACHINERY AND EQUIPMENT, TRUCKS AND TRAILERS,  
AIRCRAFT, PARTS AND AEROSPACE, RAILROAD EQUIPMENT

SIC: 3500, 3713/14\*, 3720\*, 3740\*, 3760\*, 3800\*

**DESCRIPTION:** Businesses that manufacture a variety of equipment including engines and turbines, farm and garden equipment, construction and mining machinery, metal working machinery, pumps, computers and office equipment, automatic vending machines, refrigeration and heating equipment, and equipment for the manufacturing industries described elsewhere. This group also includes many small machine shops. Also included here is the manufacturing of trucks, trailers, and parts. Manufacturing processes will include various forms of metal working and finishing, and the production of plastic and fiberglass parts. This group also includes manufacturing of airplanes and parts, missiles, spacecraft, and railroad equipment and instruments.

**MATERIALS USED AND WASTES GENERATED:** Manufacturers of engines or engine-driven equipment can be expected to have fueling facilities. Larger equipment may be stored outside. Outside storage of gasoline, diesel, and cleaning fluids may occur. In contrast, smaller businesses may only have outside containers for temporary storage of waste products.

Businesses making equipment in the Puget Sound area that were surveyed for Dangerous Wastes have been found to produce waste acids, used solvents, paints, metal chips with machine oil, various chemicals, and used oil.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.6, R.7, R.9, R.10 and R.11 in Chapter IV-5.*

Stormwater Treatment BMPs: Stormwater from outside equipment storage areas where dripping of oil or hydraulic fluids is likely to occur shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.8 LOG STORAGE AND SORTING YARDS, DEBARKING

SIC: 2411\*\*, 2499\*\*

**DESCRIPTION:** Although log yards are located at sawmills, and sometimes at pulp and paper mills, they are presented separately because of their unique BMP requirements. Log yards may exist as entirely separate businesses, for example at ports where exporting occurs.

Log storage and sorting yards can cover very large areas. Large mobile equipment is used to move the logs. The equipment is maintained on or within the vicinity of the site. The logs may be debarked.

**MATERIALS USED AND WASTES GENERATED:** Large amounts of bark are produced, either in the storage area from log handling or when it is removed by a debarking operation. Rain, if allowed to pool around bark and logs, may be a significant source of organic color, tannins, and BOD. Small pieces of bark are carried off by the stormwater.

In the past, debarking was done using high pressure water jets. However, because of the difficulty of handling the contaminated water, mechanical debarking has become the common procedure. The debarking operation may be located in the open and any oil which drips from the equipment can reach stormwater.

Breakage of hydraulic lines on the mobile equipment occurs and is another source of oil. Equipment maintenance generates by-products common to all vehicle and equipment maintenance operations. See "Vehicle Maintenance and Repair" (Section IV-2.4.9) for a complete description of waste products.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine applicable actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.8, R.10, R.11 and R.12 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from log storage areas, parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater from outside equipment storage, maintenance and debarking areas where dripping of oil or hydraulic fluids is likely to occur shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.9 METAL PRODUCTS

SIC: 2514, 2522\*, 2542\*, 3312\*\*, 3314-17\*\*, 3320\*\*, 3350\*\*, 3360\*\*, 3400\*, 3590\*

**DESCRIPTION:** This group includes mills that produce basic metals and primary products, as well as foundries, electroplaters, and fabricators of final metal products.

Basic metal production includes steel, copper, and aluminum. Mills that transform metal billets, either ferrous or nonferrous such as aluminum, to primary metal products are included. Primary metal forms include sheets, flat bar, building components such as columns, beams and concrete reinforcing bar, and large pipe.

Steel mills in the Pacific Northwest use recycled metal and electric furnaces. The molten steel is cast into billets or ingots which may be reformed on site or taken to rolling mills that produce primary products. As iron and steel billets may sit outside before reforming, surface treatment to remove scale may occur prior to reforming. The final product may also be stored outside.

Foundries pour or inject molten metal into a mold to produce a shape that cannot be readily formed by other processes. The metal is first melted in a furnace. The mold is made of sand or metal die blocks that are locked together to make a complete cavity. The molten metal is ladled in and the mold is cooled. The rough product is finished by quenching, cleaning and chemical treatment. Quenching involves immersion in a plain water bath or water with an additive.

Businesses that fabricate metal products from metal stock provide a wide range of products. The raw stock is manipulated in a variety of ways including machining of various types, grinding, heating, shearing, deformation, cutting and welding, soldering, sand blasting, brazing, and laminating. This group includes businesses that make metal furniture.

Fabricators may first clean the metal by sand blasting, descaling, or solvent degreasing. Final finishing may involve electroplating, painting, or direct plating by fusing or vacuum metalizing. Painting may involve paints, varnish, lacquer, shellac, or plastics. Finishing may occur on-site or at a specialized business.

**MATERIALS USED AND WASTE GENERATED:** Raw materials, in particular recycled metal, are stored outside prior to use as are billets before reforming. The descaling process may use salt baths, sodium hydroxide, or acid (pickling).

Primary products often receive a surface coating treatment. Prior to the coating the product surface may be prepared by acid pickling to remove scale or alkaline cleaning to remove oils and greases. The two major classes of metallic coating operations are hot and cold coating. Zinc, terne and aluminum coatings are applied in molten metal baths, while tin and chromium are usually applied electrolytically from plating solutions.

In rolling operations where various steel products are made wastewater is produced from immersing the steel into an oil/water emulsion.

In foundries, the metal may be steel, iron, aluminum, copper, magnesium, zinc, lead or brass. Wastewaters come from quenching, cooling and rinsing operations. Lubricants are also used, and are often recycled within the plant. Foundries use sand and bentonite to make molds. Chemicals may be used to set the molds.

Fabricators produce wastewater from the rinsing of work pieces, cooling and lubrication, spray booths, quenching, and general cleanup. This wastewater may receive pretreatment from which sludges are produced. Other waste products include scrap metal, used oil, acid and alkaline wastes, heavy metal and cyanide-bearing wastes, dyes, spent solvents, waste paints and other surface treatment materials.

Electroplating businesses produce acid and alkaline solutions, cyanide plating solutions and sludges.

Foundries and fabricators in the Puget Sound area were surveyed for Dangerous Wastes and have been found to produce waste acids, solvents, and various chemicals as well as used oil which is not a Dangerous Waste if properly recycled.

For all businesses in this group, activities that may occur outside include: bulk storage of chemicals, storage of metal feedstock, byproducts and finished products; unloading of chemical feedstocks and loading of waste liquids such as spent pickle liquor by truck or rail; quenching; waste oil and solvents from cleaning manufacturing equipment; and temporary storage of Dangerous Wastes, which may be either liquid or solid. Steel mills will produce slag and dust from the air scrubber.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine applicable actions.*

*For more information on disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.9, R.10 and R.11 in Chapter IV-5.*

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur or raw materials or products are stored shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.10 PAPER AND PULP MILLS

SIC: 2610\*\*, 2620\*\*, 2630\*\*

**DESCRIPTION:** Large industrial complexes in which pulp, pulp and paper, or just paper or paperboard are produced. The chips for pulping may be produced on-site from logs, and/or imported.

Process wastewater is usually treated and discharged at the business site; a public sanitary sewer system is typically not used.

**MATERIALS USED AND WASTES GENERATED:** Logs may be stored, debarked and chipped on site. Stormwater runoff from these areas can be a significant source of pollution. Large quantities of chips are stored in the open. Although this can be a source of pollution, the volume of stormwater flow is relatively small because the majority of precipitation is retained by the chip pile.

Mobile equipment such as forklifts, log handlers, and chip dozers are a source of hydraulic fluids and oil from normal dripping as well as from hydraulic line breakage. The equipment is fueled and maintained on site.

The large process equipment used for pulping is not enclosed. Thus, precipitation falling over these areas will become contaminated. Maintenance of the process equipment produces waste products similar to that produced from vehicle and mobile equipment maintenance.

Air and process wastewater treatment systems produce sludges.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.8, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Log storage and process equipment areas should be covered where possible and their drainage channelled to a retention/detention facility and/or through a biofilter prior to discharge.

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.11 PAPER PRODUCTS

SIC: 2650\*, 2670\*

**DESCRIPTION:** Included here are pulp, paper and paperboard mills. Also included are businesses that take paper stock and produce basic paper products such as cardboard boxes and other containers, and stationery products such as envelopes and bond paper.

**MATERIALS USED AND WASTES GENERATED:** The basic feedstock is chips if paper is being produced, or paper stock. Repair and maintenance of manufacturing equipment will generate used oils and solvents. Coating operations can produce waste inks.

Outside activity is limited to unloading of liquid chemicals. Paper firms surveyed in the Puget Sound area for Dangerous Wastes have been found to produce waste solvents and caustic solutions, as well as used oil which is not a Dangerous Waste if properly recycled.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).



IV-2.1.12 PETROLEUM PRODUCTS

SIC: 2911\*\*, 2950\*\*

**DESCRIPTION:** The petroleum refining industry manufactures gasoline, kerosene, distillate and residual oils, lubricants and other related products from crude petroleum. Also included here is the production of asphalt paving and roofing materials that use asphalt. Businesses that do the actual paving or seal roofs with asphalt roofing are discussed under "Construction Businesses" (Section IV-2.4.10).

**MATERIALS USED AND WASTES GENERATED:** Although petroleum is the primary raw material, petroleum refining also uses other materials such as natural gas liquids, benzene, toluene, chemical catalysts, caustic soda and sulfuric acid. Wastes may include filter clays, spent catalysts, sludges, and oily water.

Asphalt paving consists of sand, gravel and the petroleum-based asphalt that serves as the binder. Therefore located at such a business are stockpiles of sand and gravel. The asphalt emulsion is stored in above-ground tanks. The business may own trucks that are maintained on-site.

Waste products may include small dumps of unused asphalt and the usual materials from vehicle maintenance (see "Vehicle Maintenance and Repair", Section IV-2.4.9). Spillage of the asphalt emulsion could occur during transfer to the business site.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine applicable actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.5, R.6, R.7, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Stormwater from areas where contamination is possible from asphalt materials (either raw materials or final products) shall be treated by an API or CPI-type oil/water separator or equivalent (Volume III, Runoff Control).

Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

Effluent guidelines for stormwater discharges from these types of plants have been established under 40 CFR Part 419.

IV-2.1.13 PRINTING AND PUBLISHING

SIC: 2700

**DESCRIPTION:** Preparation of newspapers, periodicals, and commercial printing. This group includes both businesses that do their own printing as well as those that perform services for the printing industry, for example bookbinding. Processes include typesetting, engraving, photograving, and electrotyping.

**MATERIALS USED AND WASTES GENERATED:** Various materials used in modifying the paper stock include inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers. Waste products may include waste inks and ink sludges, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, zinc, lead, spent formaldehyde, silver, and plasticizers. All of these waste products are Dangerous Wastes. Used lubricating oils are also produced.

As the printing operations occur indoors, the only likely points of potential contact with stormwater are the temporary storage of waste materials outside the business owner's building and offloading of chemicals through external unloading bays.

Printing and publishing businesses surveyed in the Puget Sound area for Dangerous Wastes were found to produce photographic chemicals and ink.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*For more information on disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.14 RUBBER AND PLASTIC PRODUCTS

SIC: 3000

**DESCRIPTION:** Although different in basic feedstocks and processes used, businesses that produce rubber, fiberglass and plastic products belong to the same SIC group and therefore are grouped in this manual.

The rubber industry includes a wide variety of production activities ranging from polymerization reactions to extrusion of a rubber product from natural or synthetic stock.

**MATERIALS USED AND WASTES GENERATED:** The industry may use natural or synthetic rubber, new or recycled. Other materials used include pigments, paints, various fillers and curing agents.

Activities that may occur outside the manufacturing building include: bulk storage of liquids, other raw materials or by-products; unloading of liquid materials from truck or rail; washing of equipment outside the building; waste oil and solvents produced by cleaning manufacturing equipment; used equipment temporarily stored on site that could drip oil and residual process materials; and temporary storage of Dangerous Wastes.

Producers of plastic products in the Puget Sound area surveyed for Dangerous Wastes have been found to generate waste oils, solvents, inks and paints.

*Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.5, R.6, R.7, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where products are stored shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.15 SHIP AND BOAT BUILDING AND REPAIR YARDS  
SIC: 3730\*\*

DESCRIPTION: Businesses that build or repair ships and boats. Some provide a mobile service in which they come and work on the boat at its moorage. Repairs occur to the vessel hull, interior and engines. Typical activities include hull scraping, sandblasting, finishing, metal fabrication, electrical repairs, engine overhaul, and welding, fiberglass repairs, hydroblasting and steam cleaning.

A draft NPDES permit for these facilities is currently under development. The following information is the text of the fact sheet.

As of this writing the permit is at EPA for review. Once that review is done, a series of public hearings will be held and a responsiveness summary compiled. The estimated date for completion is April 30, 1992. Further information and a copy of the draft permit can be obtained from Kevin Fitzpatrick, (206) 649-7037.

Draft of 12/18/91

**FACT SHEET**

**STATE OF WASHINGTON  
DEPARTMENT OF ECOLOGY**

**GENERAL PERMIT NUMBER: WA-GXX 0000**

**FACT SHEET--FOR NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) GENERAL PERMIT TO DISCHARGE POLLUTANTS FROM BOATYARDS TO STATE WATERS PURSUANT TO THE PROVISIONS OF CHAPTER 90.48, REVISED CODE OF WASHINGTON AND THE FEDERAL WATER POLLUTION CONTROL ACT AS AMENDED.**

The Department of Ecology (WDOE) has tentatively determined to issue a general permit to boatyards operating in the State of Washington authorizing discharges by listed applicants subject to certain effluent limitations which may require the implementation of Best Management Practices, installation of treatment facilities, and other conditions necessary to carry out the provisions of state and federal law. These proposed limitations, schedules and conditions are tentative.

**PUBLIC COMMENT AND INFORMATION**

Interested persons are invited to submit written comments regarding the proposed permit. Comments should be submitted within thirty (30) days of the issuance date of the public notice for this application. Comments should be sent to:

Washington State Department of Ecology  
Northwest Regional Office  
3190 - 160th Avenue SE  
Bellevue, Washington 98008-5452

Presuming that comments received will indicate significant public interest in the proposed permit and that useful information would be produced thereby, the director of Ecology intends to hold a public hearing(s) on the general permit. Public notice regarding any hearing will be circulated at least thirty (30) days in advance of the hearing.

The application, proposed permit, and related documents are available for inspection and copying between the hours of 8:00 a.m. and 4:30 p.m. weekdays at the aforementioned regional office of the Department. A copying machine is available for use at a charge of 20 cents per copy sheet.

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TECHNICAL INFORMATION

**PERMIT GOAL:** The goal of this general permit is to control the discharge of pollutants associated with Washington State boat yard activities. WDOE anticipates that boat yard facilities in Washington State which are covered and in compliance with the terms and conditions of this general permit should not violate state water quality standards.

**RCW 90.48.080 Discharge of polluting matter in water prohibited.** "It shall be unlawful for any person to throw, drain, run or otherwise discharge into any of the waters of this state, or to cause, permit or suffer to be thrown, run, drained, allowed to seep or otherwise discharged into such waters any organic or inorganic matter that shall cause or tend to cause pollution of such waters according to the determinations of the Department, as provided for in this chapter."

**RCW 90.48.160 Waste disposal permit -- Required--Exemptions.** "Any person who conducts a commercial or industrial operation of any type which results in the disposal of solid or liquid waste material into the waters of the state, including commercial or industrial operators discharging solid or liquid waste material into sewerage systems operated by municipalities or public entities which discharge into public waters of the state, shall procure a permit from either the Department or the thermal power plant site evaluation council as provided in RCW 90.48.262(2) before disposing of such waste material: ..."

**RCW 90.48.520 Review of operations before issuance or renewal of wastewater discharge permits -- Incorporation of permit conditions.** "In order to improve water quality by controlling toxicants in wastewater, the Department of Ecology shall...incorporate permit conditions which require all known, available, and reasonable methods to control toxicant in the applicants wastewater. Such conditions may include, but are not limited to: (1) Limits on the discharge of specific chemicals, and (2) limits on the overall toxicity of the effluent. The toxicity of the effluent shall be determined by techniques such as chronic or acute bioassays. Such conditions shall be required regardless of the quality of receiving water and regardless of the minimum water quality standards. In no event shall the discharge of toxicant be allowed that would violate any water quality standard, including toxicant standards, sediment criteria, and dilution zone criteria."

The goals of this permit are to be achieved primarily through "Best Management Practices" (BMPs) designed to minimize or eliminate the discharge of pollutants.

**TECHNICAL ADVISORY COMMITTEE:** A technical advisory committee, which will be referred to in this document as TAC, was formed to assist WDOE in drafting this fact sheet and permit. TAC consisted of representatives from local, state and federal agencies, maritime associations and boatyard operators. The TAC members are listed in the acknowledgements section (last page of fact sheet).

TAC asked WDOE to make the following reminder, noting that criminal and civil violations of the Federal Water Pollution Control Act are more severe.

**RCW 90.48.140 Penalty.** Any person found guilty of wilfully violating any of the provisions of this chapter, or any written orders or directive of the department or a court in pursuance thereof shall be deemed guilty of a crime, and upon conviction thereof shall be punished by a fine of up to ten thousand dollars and the costs of prosecution, or by imprisonment in the county jail for not more than one year, or both such fine and imprisonment in the discretion of the court. Each day upon which a willful violation of the provisions of this chapter occurs may be deemed a separate and additional violation.

**METRO TREATMENT STUDY:** METRO (Municipality of Metropolitan Seattle) received a National Estuary Grant to do a treatment study of Puget Sound shipyard and boatyard waste and storm waters. The study involves sampling of pressure washing wastewater from a number of these facilities, and testing prototype collection and treatment systems to determine what methods can consistently meet state and local standards.

METRO will be producing an analytical report of their findings and developing a guidance manual which will be distributed to shipyards, boatyards and publicly owned treatment works (POTW). The manual will include options for treatment and discharge of pressure wash wastes, bilge and ballast water and contaminated storm water to either receiving waters, municipal treatment plants, or off-site treatment facilities.

METRO's work is expected to clarify and expand the list of options for treatment and disposal of boatyard wastewaters. The treatment study project has been closely aligned with the development of the general NPDES permit for boatyards. The study's project manager and project coordinator have made valuable contributions to the general permit development by assisting WDOE in establishing standards for best available technology practices for boatyards.

**BACKGROUND:** Under P-20 of the Puget Sound Water Quality Authority Plan WDOE was directed to carry out a program for detection and identification of unpermitted discharge sources. One of the significant point source unpermitted discharge groups found by the Elliott Bay and Lake Union Urban Bay Action Teams was the boat yard industry.

WDOE signed a Memorandum of Agreement with the United States Environmental Protection Agency (EPA) for development and issuance of a general permit for small shipyards. During the development of this permit it was decided to describe facilities in this segment of the Ship and Boat Building and Repairing industry as boatyards. There are approximately 500 - 600 boatyards in Washington State.

The principal focus of the proposed permit is to regulate wastewater discharges to waters of the state from water dependent facilities. During the development of this permit it has become evident that other facilities in the category but not located on a shoreline or near shore, could be covered with incidental additional effort. Application from all facilities in the category will be invited. The final decision on who is covered by the general permit will be based on the completed application.

Questions have also been asked about potential coverage for related facilities, such as a repair shop for marine engines. As originally conceived it was not the intention of WDOE or EPA that this permit provide coverage to ancillary or related industrial or commercial facilities. Those facilities may be covered under other wastewater discharge permits, if necessary.

The Standard Industrial Classifications, SIC, distinguishes between these related industries by type of work as follows:

SIC No. 3731 Ship Building and Repairing: "Establishments primarily engaged in building and repairing all types of ships, barges, and lighters, whether propelled by sail or motor power or towed by other craft. This industry also includes the conversion and alteration of ships."

SIC No. 3732 Boat Building and Repairing: "Establishments primarily engaged in building and repairing all types of boats."

Further distinctions between ships and boats are provided by others, such as the U. S. Coast Guard, which define boats as vessels of less than 65 feet. Shipyards and boatyards can also be distinguished by the prevalence of steel hulled vessels at shipyards versus the prevalence of fiberglass, wood and aluminum hulls at boatyards.

With only a few exceptions, such as luxury yachts, it is appropriate to use the term boatyard for the industrial group covered by this general NPDES permit.

A boatyard, defined for purposes of this permit, is a service business primarily engaged in new construction and repair of small vessels 65 feet or less in length. Services provided may include, but are not limited to: pressure washing, bottom and top side painting; engine, prop, shaft, and rudder repair and replacement; hull repair, joinery, bilge cleaning, fuel and lubrication system repair or replacement, welding and grinding on the hull, buffing and waxing, top-side cleaning, MSD (marine sanitation device) repair or replacement, and other activities necessary to maintain a vessel.

A boatyard may employ one or more of the following to remove or return a vessel to the water: marine railway, crane, hoist, ramp, or vertical lift. Some yards may build a limited number of custom boats usually constructed of fiberglass or aluminum. Permanent moorage facilities are not usually a feature of a boatyard though a few boatyards do have such facilities. Nevertheless, they are still boatyards.

Historically boat repair has been done outdoors on the waterfront. The vessel was supported in a cradle, on barrels, or in a sling while work was done on the hull. Some facilities are endeavoring to change operations in order to do the boat repair under cover. This will contribute to quality control, reduce transportation of waste to the environment, and improve worker safety.

Not all work areas are paved and not all have drainage systems. When the work area is neither paved nor drained, storm water runoff is typically via sheet flow through a gravel surfacing. Some pollutants tend to adhere or get trapped in the gravel or crushed rock surfacing. Because there is a high potential for soil contamination with an unpaved work area, some facilities are using plastic sheeting and other materials to keep pollutants from intermingling with the soil.

Discussions within TAC indicate a need to define some terms for the benefit of laymen and people more familiar with shipyards. The draft EPA "Development Document for Shipbuilding and Repair," EPA 440/1-70/076-b uses the term hydroblasting to mean the use of a cold water pressure washer to remove paint from a vessels' hull. Generally, local shipyards use a pressure in excess of 2000 psi. The pressure washer commonly removes biological growth and the outermost coat of antifouling paint. If the pressure is high enough, hydroblasting may be used to remove all paint down to bare steel. If hydroblasting is used to remove paint down to bare steel, a light abrasive blast will follow to remove any rust and ensure proper surface texture. The paint system may involve several coats of paint, including primer, anticorrosive and antifouling paints.

Most boatyards do not "hydroblast." For boatyard applications, the water pressure is seldom above 2000 psi. The basic intent is to remove any biological growth on the vessel. Boatyard operators do not consider paint removal to be an objective of this type of pressure washing. The METRO treatment study has found that low pressure washing with scrubbing results in a greater concentration of metals in the wastewater and is less selective for marine growth removal than "hydroblasting."

If abrasive blasting is used to remove paint, walnut shells or other "soft" abrasives that won't damage fiberglass or aluminum are used for the abrasive. In addition, to control pollutant transport, a water spray forming a cone around the blasting nozzle is used at some yards. In the EPA document, this is referred to as "wet abrasive blasting."

This document will use the generic terms pressure washing and pressure wash wastewater for all pressure washing activities (to include wastewater from hand washing of hulls).



**POLLUTANT SOURCES:** Wastes generated by boatyard activities include spent abrasive grits, spent solvent, spent oils, wash water, paint over spray, various cleaners and anti-corrosive compounds, paint chips, scrap metal, welding rods, wood, plastic, resins, glass fibers, and miscellaneous trash such as paper and glass. These pollutants may enter the wastewater stream through the application and preparation of paints and the painted surface; the handling, storage and accidental spills, leaks or drips of paints, solvents, thinners; the fracturing and breakdown of abrasive grits, and the repair and maintenance of mechanical equipment.

Hull preparation for painting will commonly be by sanding or scraping and some abrasive blasting. Boatyards are relatively small generators of spent grits, paint chips and particulate debris compared to a shipyard.

The primary source of wastewater is storm water runoff. Secondary sources are pressure washing, cooling water, pump testing, grey water, sanitary waste, washing down the work area, and engine bilge water. Engine room bilge water and oily wastes are typically collected and disposed of through a licensed contracted disposal company.

Pressure wash wastewaters have been sampled by WDOE, local shipyards and METRO. The effluent quality has been highly variable and frequently exceeds water quality criteria for copper, lead and zinc.

From monitoring results received to date, metal concentrations typically range from 5 to 10 mg/L, but have gone as high as 190 mg/L for copper. The average concentration for copper has been 55 mg/l. Two prime sources of copper are leaching of copper from anti-fouling paint and wastes from hull maintenance.

While the intent of pressure washing may not be to remove paint from a vessel hull, receiving water sampling by Ecology does substantiate that paint removal can occur.

**RECEIVING WATER:** State waters impacted by this permit and the activities of the permit applicants are the fresh and marine waters of the state of Washington.

WDOE has published "Lists of Waterbodies Required Under Section 304 (L)," Volume I and Volume II. Some boatyards intended to be covered by this general permit lie in several of the urban receiving waters listed for water quality violations of acute and chronic criteria for heavy metals such as copper, lead, zinc, and cadmium. While boatyards are not implicated in the report, it would be inappropriate to allow discharges with heavy metal concentrations above the respective water quality criterion from them.

Also cited for some receiving waters were other indicators such as high mortality in sediment bioassays, depressed benthic communities, and evidence of bioaccumulation of toxic compounds in some aquatic species. The indicators indirectly measure the impairment of the beneficial uses of the waterway.

In WAC 173-201-045 State waters are classified as AA (extraordinary), A (excellent), B (good), C (fair), and Lake. The characteristic beneficial uses of state waters are domestic, industrial and agricultural water supply; the spawning, rearing, migration and harvesting of fish; the spawning, rearing, and harvesting of shellfish; wildlife habitat, recreation (primary & secondary contact, sport fishing, boating, aesthetic enjoyment), commerce and navigation. Primary contact recreation, such as swimming, is not a beneficial use of class B or C waters.

**WATER QUALITY IMPACTS - Pressure Wash Wastewater:** WDOE (Elliott Bay and Commencement Bay Action Teams) has taken a few samples of wastewater plumes from untreated pressure washing of wood boat hulls in both marine and freshwater. Fresh water quality criteria were exceeded for arsenic, chromium, copper, lead, and zinc in the Lake Washington Ship Canal (Seattle). In the Shilshole (Seattle) area, copper and lead exceeded the marine criteria while zinc and selenium concentrations

roughly matched the criteria.

Copper significantly exceeded the criterion with concentrations in the sampled discharge plumes being 1000 times the water quality criteria.

METRO has been sampling pressure washing wastewaters at both boatyards and shipyards. A summary of the analytical data from boatyards is given below.

PRESSURE WASHING ANALYTICAL DATA SUMMARY BOATYARD DATA				
Parameter	Untreated Maximum mg/l	Total Average mg/l	Treated Average mg/l	Dissolved Average mg/l
SS	840	520	---	---
Cd	0.009	0.004	0.002	0.002
Cr	2.7	0.45	0.081	0.024
Cu	72	43	2.3	1.7
Ni	0.07	0.04	0.01	0.01
Pb	14	2.2	0.1	0.05
Zn	22	6.2	3.2	1.12
Sn	1.4	0.61	0.1	0.067
As	0.05	0.05	0.05	0.05

Table-1

Comparing the Untreated Maximum data recorded above in Table-1 with the Acute Water Quality Criteria listed in Table-4 shows that without treatment and the benefit of a dilution zone in the receiving water, the discharges from the represented pressure washing wastewater would exceed water quality criteria. Fresh water criteria exceeded in the discharge would be for chrome, copper, lead and zinc. Acute criteria exceeded in marine waters would be copper, lead and zinc.

**WATER QUALITY IMPACTS - Storm Water:** The Commencement Bay Urban Bay Action Team has sampled storm water effluent from shipyards in Tacoma. Sampling for a NPDES permit application found that storm water had copper and zinc concentrations in the discharge exceeding both acute and chronic marine criteria. Concentrations of cadmium, lead, mercury and nickel also exceeded the chronic marine criteria. Once again, the most significant offender was copper.

Dr. Eric Crecelius<sup>1</sup> from Battelle did water quality, sediment and sediment trap sampling at Port Townsend and Cap Sante Marinas for the EPA Region X Estuary program. Both marinas have boat repair facilities associated with the marina. The mean concentrations of composite samples collected at the marinas' entrances as well as net flux of contaminants are summarized in Tables 2 & 3 below.

PORT TOWNSEND*						
	TSS mg/l	Cu ug/l	Pb ug/l	Zn ug/l	PAH ug/l	TBT ug/l
Ebb	2.2	1.41	0.12	1.36	<25	7
Flood	3.65	1.10	0.10	0.94	<25	5
Ebb-Flood	-1.53	0.31	0.02	0.42	<25	2
Net Flux (g/day)	-0.000046	93	6	126	<8	0.6

Table-2 \*Source: Winter 1990 Puget Sound Notes.

CAP SANTE*						
	TSS mg/l	Cu ug/l	Pb ug/l	Zn ug/l	PAH ug/l	TBT ug/l
Ebb	2.46	1.47	0.15	1.22	58	20
Flood	3.32	0.72	0.06	0.71	28	6
Ebb-Flood	-0.86	0.75	0.09	0.52	30	14
Net Flux (g/day)	-0.000046	400	48	270	16	7

Table-3 \*Source: Winter 1990 Puget Sound Notes.

Despite the limited number of samples, the figures in the above table indicate that the receiving water in the vicinity of boatyard/marinas can be adversely impacted.

The EPA and state criteria, WAC 173-201-047(1), for acute toxic effects due to copper in marine water is 2.9 ug/L. EPA has not yet published criterion for chronic effects due to copper in marine water, but it can be expected to be less than 2.9 ug/L. The chronic criterion is presumed to be protective if the criterion is not exceeded by the four day average concentration more than once in three years on average and the acute criterion is not exceeded by the one hour average concentration more than once in three years on the average.

Dr Crecelius' reported mean copper concentration does not exceed currently published acute criterion. Nevertheless, if this sampling is representative of copper concentrations in the receiving water over the summer boating season, it at least indicates a need to minimize the input of copper to the receiving water.

This is particularly true if the assumptions about the frequency and duration of exposure of an organism to a toxicant are invalid for the local receiving water.

**BENTHIC SURVEY AND RECEIVING WATER SEDIMENT QUALITY MANAGEMENT:** Water quality standards specifically state that the department is to protect the beneficial use of state waters for shellfish. Washington's water pollution control law, Chapter 90.48.520 RCW also specifically directs the department to protect sediments. Sediment quality standards (WAC 173-204) have been adopted in order to assist in implementing this directive.

Clean up activities for existing sediment pollution is not appropriate to address under this permit. However, facilities covered and in compliance with this permit

are not expected to add to current sediment pollution problems.

For this permit the issue is whether the permit requires the permittee to evaluate the status of the sediment. The evaluation would determine (1) if BMPs and structural controls including pressure wash water treatment are sufficient to protect sediment quality. Or, (2) if the assessment and verification deferred until maintenance dredging is performed, or (3) whether to defer assessment and verification until sediment testing and analysis has been performed at several other local shipyards having individual NPDES permits, or (4) whether to defer assessment and verification until the Toxics Cleanup Program has reason to look at a specific site.

WDOE prefers to wait until sediment sampling has been done at several shipyards having current NPDES permits. If there is sediment contamination and it is evident ongoing contamination is a problem, then WDOE will reassess whether sediment sampling should be done at boatyards.

If violations of water quality or sediment standards are found and determined to be due to insufficiently stringent permit conditions, WDOE retains the right to issue an individual NPDES permit for the "problem" facility.

**TREATMENT:** RCW 90.48.010, 90.52.040 and 90.54.020 require the use of all known, available and reasonable methods (AKART) to prevent and control the pollution of waters of the state. In a similar fashion EPA guidance for storm water permitting is emphasizing the use of structural controls and Best Management Practices (BMPs) to prevent the discharge of pollutants via storm water runoff.

The draft EPA "Development Document for Shipbuilding and Repair," EPA 440/1-70/076-b, recommends BMPs as the primary method of controlling waste discharges from shipyards to the waters of the state. BMPs achieve pollution control through careful management of the product streams, segregation of potential pollutants in waste streams, and prevent or minimize contact between water and waste material.

40 CFR 122.2 defines BMPs as schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce pollution of "waters of the United States." BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

EPA, in its draft "Development Document for Shipbuilding and Repair," has determined that BMPs constitute BPT (Best Practicable Control Technology) for the shipyard industry. WDOE has concluded that BMPs constitute BPT for the boatyard industry and that collection and treatment of pressure wash wastewaters constitutes BAT (Best Available Technology Economically Achievable). Further, it is WDOE's present determination that full implementation of BMPs and effective collection and treatment of pressure wash wastewaters will result in discharges in compliance with State water quality standards.

Under 40 CFR 125.3, compliance with BPT and BAT controls to achieve effluent limitations established on a case-by-case Best Professional Judgement (BPJ) basis is to be achieved no later than March 31, 1989. Regulatory agencies cannot establish compliance schedules in permits which go beyond the statutory deadlines for meeting technology-based limitations. WDOE has determined that the BMPs proposed in the draft permit represent application of BAT/BPT. However, discharges from this industry have not previously been regulated by NPDES permits in Washington State. Furthermore, WDOE anticipates that the industry as a whole will require a reasonable period of time to fully implement the BMPs and construct necessary wastewater collection and treatment facilities. Therefore, WDOE proposes to exercise prosecutorial discretion in enforcing compliance with permit conditions for a period of one year from permit issuance for implementation of BMPs and two years from permit issuance to provide collection and treatment of pressure wash waters.

Facilities are required to apply for coverage under this permit within 9 months of permit issuance.

BMPs to collect, and contain wastes and minimize waste generation during vessel repair and maintenance work have been researched, compiled and distributed in Washington by WDOE, the Lake Union Association Water Quality Committee and the Puget Sound Shipbuilders Association with funding assistance from the Puget Sound Water Quality Authority. These BMPs are very similar to the BMPs published by the state of Virginia for its shipyard industry.

WDOE has determined that for most wastewaters from the boatyard industry the BMPs, coupled with collection and treatment of pressure wash wastewater included in the proposed general permit, constitute AKART.

Many of the sources discussed in the Pollutant Sources section above can be contained, controlled or substantially reduced by the implementation of BMPs. BMPs are an essential component of the proposed general NPDES permit. Facilities to be covered by the general permit will be required to implement them as specified in the permit. The BMPs in the general permit will include requirements for:

- Compliance with Best Management Practices
- Education of Employees and Customers
- Yard Cleaning and Sweeping
- Sediment Traps
- Dust and Overspray Control
- Maintenance of Hoses and Piping
- Bilge Water
- Paint and Solvent Use
- Use of Antifouling Paints
- Prohibition on use of Tributyltin
- Cleanup of Debris and Spent Paint
- Chemical Storage
- Waste Disposal
- Dangerous Waste Handling & Reporting
- Recycling of Spilled Chemicals and Rinse Water
- Accidental Oil Discharge
- Oil, Grease, and Fuel Transfers

To encourage the regulated industry to implement BMPs WDOE, EPA, and many local solid waste utilities provide waste information exchange with advice on pollution prevention, waste reduction and recycling options. In addition, a waste disposal exchange service, Industrial Materials Exchange Service (IMEX), is available to help industries find buyers for surplus/waste products, locate inexpensive materials, conserve energy, and otherwise promote waste reduction and recycling. An informational packet accompanying the permit will contain phone numbers for IMEX, technical assistance and hazardous waste disposal, reuse prevention and recycle.

Implementation of BMPs is anticipated to minimize or eliminate contamination of storm water from most areas of boatyards. But, contaminated wastewater may still be present from pressure washing of hulls. Therefore, collection and treatment of the pressure washing wastewater will be required to protect receiving waters.

Pressure washing, referred to as hydroblasting in the EPA "Development Document for Shipbuilding and Ship Repair," was researched and discussed minimally. Research was conducted for WDOE by the University of Washington to provide WDOE a basis to define "AKART" for pressure washing wastewaters. Until other research efforts are concluded, the present preference for treating and disposing of pressure washing wastewater are:

- (1) recycle/conservation,
- (2) collect and discharge (with pretreatment

as necessary) the wastewater to the sanitary sewer, (3) collect and treat the wastewater by sedimentation, or (4) collect and treat the wastewater by chemical (alum) addition followed by sedimentation.

#### Option 1 - Recycle/conservation

The preferred means of preventing pollution from pressure washing anti-fouling paint is recycling of pressure wash wastewater. This method is also referred to as "a total closed loop system" or "zero discharge". The recycled water does eventually become dirty, requiring disposal or treatment.

For boatyard facilities which have the ability to connect to a POTW (Publicly Owned Treatment Works) recycling, with occasional discharge of dirty recycle water to the POTW, would be the best treatment and conservation method.

For facilities which are unable to physically connect to a POTW, recycling is probably the only economically feasible option. The dirty recycle water must be hauled to a treatment facility.

The guidance manual being developed by METRO will give a more detailed discussion of recycling options for pressure wash wastewaters.

Also being discussed and evaluated is a means to avoid or minimize the leaching of copper ions from the boat bottom. This technique requires developing substitutes for cuprous oxide anti-fouling paint. Alternatives such as copper sheathing and imbedding the copper in an epoxy resin are available, but so far are used only on a limited basis. The alternatives to anti-fouling paints have proven to be problematic in their application and use.

#### Option 2 - Discharge to POTW

A few boat repair yards have received authorization to discharge a portion of their wastewater, including pressure wash wastewater and some storm water from a restricted work area, to the local POTW. Others are seeking to construct boat wash down facilities discharging to the POTW.

The POTW limits in Table-5 were adopted from METRO's limits. Other POTW's are expected to have similar limit requirements for discharge to their systems.

Option 2 has some regulatory constraints. Sewerage authorities must protect their sludge quality while also protecting water quality. Proposed treatment plants and sludge quality regulations severely limit sludge disposal options for sludge containing excessive amounts of heavy metals. Therefore, it may be necessary to pretreat the pressure wash wastewater to meet the POTW limits.

Information on the effectiveness of the pretreatment options and experience with the operation and maintenance of pretreatment systems is minimal. The METRO treatment study should help the industry and local sewer authorities rectify this.

Other constraints include prohibitions regarding the disposal of tributyltin (TBT) paints. Basically, it is illegal to dispose of TBT except at regulated sanitary landfills and through thermal destruction or other approved equivalent processes. TBT use is allowed on aluminum vessels which are common in the local fishing fleets. Therefore care must be exercised to keep TBT out of the sludge to maintain inexpensive sludge disposal options.

#### Option 3 - Sedimentation/Filtration

Because of the low specific gravity of the solid particles removed (1.000 to 1.005) and the mean size (40 microns) sedimentation alone (option 3) as a treatment method

is believed to have limited effectiveness. METRO's research should determine sedimentation's effectiveness.

Option 4 - Chemical Treatment

The main drawback to chemical (alum) treatment of the pressure washing wastewaters (option 4) is the lack of information on cost and effectiveness.

**PERMIT REQUIREMENTS AND BASES FOR LIMITATION - General:**

Effluent monitoring is used to verify that pollutants are not being discharged to a receiving water via direct process water discharges and storm water flows.

Typically effluent limits are determined from technology based standards of established effluent guidelines. Effluent limits for this permit are based on the water quality standards including the characteristic uses defined in WAC 173-201-045 and the toxicant control provisions of RCW 90.48.520.

Water quality criteria are established for heavy metals in saltwater and freshwater. Table-4 lists the water quality criteria for metals which have been identified as pollutants of concern for facilities covered under this general permit. In freshwater the criterion varies with the hardness. For this discussion a hardness of 50 mg/L as CaCO<sub>3</sub> is assumed. This conservative assumption has been selected because of the wide variety of (fresh water) receiving waters impacted by the boatyard industry.

WATER QUALITY CRITERIA for HEAVY METALS				
Metal*	Acute [ug/l]		Chronic [ug/l]	
	Fresh	Salt	Fresh	Salt
TR As	360.0	69.0	190.0	36.0
TR Cu	9.2	2.9	6.5	none
TR Pb	33.8	140.0	1.3	5.6
TR Zn	65.0	95.0	58.9	86.0

Table-4 \*TR means total recoverable.

**PERMIT REQUIREMENTS AND BASES FOR LIMITATION - Pressure Wash Waste Water:** The primary source of the heavy metals in wastewater is from paint applied to the boat hull. In waste stream sampling to date, copper has exceeded the water quality criteria by several orders of magnitude. Compliance with effluent limits for copper are the clearest indicator that water quality has been protected. However, sampling and analysis of additional metals would provide increased quality assurance. The next most common metals, by frequency and in magnitude, in boatyard and shipyard wastewater (or contaminated storm water) are zinc and lead.

Effluent limits for heavy metals in boat wash down water or from pressure washing are intended to protect water quality. Treatment of the pressure wash wastewater from boat hulls is necessary to avoid pollution of local receiving waters. At a minimum, treatment will include sedimentation requiring a tank and possibly chemical addition. Therefore, it is feasible to discharge treated effluent at a low rate, such as 10 gpm or less, to allow for some dilution. Proposed permit effluent limits reflect a 10 to 1 dilution. This is based on low flows associated with pressure wash operations and (for the most part) large receiving waters associated with most boatyards. WDOE recognizes the conservative nature of this estimate dilution

barring site specific dilution zone studies.

Previous analyses of ship/boat wash down water indicate that heavy metals in the waste stream are concentrated to approximately 1000 times the water quality criterion. WDOE finds it appropriate to monitor concentrations of heavy metals present in pressure wash water discharged to state waters by boatyards. Monitoring of pressure wash waters discharged to surface waters will be reduced over time. Reduction will only be allowed if monitoring demonstrates that pressure wash water treatment is effective in protecting water quality and the operation and maintenance of treatment facilities is effective.

**PERMIT REQUIREMENTS AND BASES FOR MONITORING - Storm Water:** The EPA has published a draft general permit for storm water discharges. Two industrial categories, "Primary Metal Industries" and "Other Facilities" provide guidance on additional parameters to be monitored. Both require monitoring for oil and grease; five day biological oxygen demand (BOD5); chemical oxygen demand (COD); total suspended solids (TSS); total kjeldahl nitrogen (TKN); nitrate plus nitrite nitrogen ( $\text{NO}_3+\text{NO}_2$ ); total phosphorus and pH. At primary metal industries, the EPA is also interested in total copper, total lead, total arsenic, total chromium and total cadmium.

For the boatyard industry WDOE has determined that monitoring will be required for copper, TSS, and oil and grease.

Copper was selected as a monitoring parameter because it is often identified as a pollutant of industrial storm waters. Also, the METRO study has shown (to date) that copper is the most prevalent metal found in boatyard wastewaters. Therefore it is a prime indicator metal in determining if an individual boatyard has properly instituted BMPs.

Oil and grease monitoring is necessary because of the volume of petroleum products stored and handled at boatyards. For example routine boat maintenance and repair operations include: engine maintenance, fuel, hydraulic, and lube oil transfers.

TSS is defined as residual non-filterable solids (particulate matter) retained from a water sample by a glass-fiber filter and dried at a constant temperature at 103 to 105 degrees C. Particulate matter blankets the bottom of water bodies. It adsorbs contaminants, damages the invertebrate populations (resulting in high mortalities), and blocks gravel spawning beds.

TSS is a parameter requiring monitoring because of grinding, sanding and sand blasting operations associated with boatyard activities. Without implementation of BMPs, boatyard activities contribute to the presence of TSS in storm water.

To satisfy EPA requirements, annual monitoring of storm water discharges (see table-5) will be required at boatyards covered under this permit. WDOE will compare the results of this monitoring with State water quality standards.

**PROPOSED EFFLUENT LIMITS AND MONITORING REQUIREMENTS:** Monitoring samples shall be taken at the waste water and storm water outfalls, but before these water streams have reached state receiving waters. Dilution of waste water and storm water samples will be prohibited under the requirements of this permit.



PROPOSED LIMITS & MONITORING REQUIREMENTS for PRESSURE WASH WASTEWATER DISCHARGE				
PARAMETER	SAMPLE TYPE	TO MARINE WATERS <sup>1</sup> (daily maximums)	TO FRESH WATERS <sup>1</sup> (daily maximums)	TO POTW <sup>2</sup>
Flow	Meter or calculate	10 gpm	10 gpm	N/A
TR Cu <sup>3</sup>	Grab	30 ug/l	90 ug/l	2.4 mg/l
TR Zn	Grab	950 ug/l	650 ug/l	3.3 mg/l
TR Pb	Grab	1400 ug/l	340 ug/l	1.2 mg/l
TR As	Grab	690 ug/l	3600 ug/l	3.6 mg/l

Table-5

- NOTES:
- (1) Weekly monitoring is required if the boatyard covered under this permit pressure washes more than 10 vessels per week; otherwise, monitoring frequency is every 10th vessel, whichever is less.
  - (2) Semi-annual monitoring is required. The sampling frequency may be more frequent at the discretion of the local sewerage authority.
  - (3) TR means total recoverable.

PROPOSED MONITORING REQUIREMENTS for STORM WATER DISCHARGE		
Parameter	Minimum Frequency	Sample Type
Flow	annually	estimate
Oil & Grease <sup>1</sup>	annually	grab
TSS	annually	grab
TR Copper	annually	grab

Table-6

Note: (1) Discharges shall not have, nor cause a visible oil sheen in the receiving waters.

**IMPLEMENTATION:** TAC has recommended that compliance verification rely on inspections by WDOE, imposition of BMPs and structural controls. Structural controls include catch basins and drains, berms, dikes and other containment for oils, chemicals and wastes; roofed storage areas, wastewater treatment facilities, etc. Some structural controls are required to implement the BMPs. Others are needed to collect and treat wastewater and some storm waters.

WDOE has determined that in most cases implementing the BMPs will be sufficient to prevent contamination of storm water. Some facilities that may need additional structural controls to supplement the BMPs in pollution prevention, will need cooperation from property owners, leasing agents, and local shoreline and building departments.

WDOE anticipates it may take facilities requesting coverage under this general permit 9 months to 1 year to institute BMPs. WDOE will exercise discretionary enforcement during this time.

For the existing boatyards needing treatment facilities for pressure washing wastewater, a generic engineering report recommending several treatment options is feasible and desirable. The METRO treatment study will fulfil this need. Boatyard operators, individually or collectively, will be able to select a treatment option identified in the engineering report and procure an engineer to prepare plans and specifications locating and implementing the chosen option for each facility.

Individual facilities to be covered under this general permit will be required to obtain a spill control plan and keep a copy of it on site. Based on its experience with spill control plans for shipyards, WDOE believes a general spill control plan can be prepared for boatyards collectively.

In a similar manner it is WDOE's opinion that a generic solid waste disposal plan can be developed for the boatyard industry. A copy of the solid waste disposal plan shall also be kept on site.

**ENFORCEMENT:** The proposed permit intends to rely on BMPs to prevent negative water quality impacts. Effluent monitoring is provided for verifying the effectiveness of the BMPs. If routine inspections of boatyards identify recalcitrant businesses which have not fully implemented pollution prevention practices including BMPs and appropriate structural controls then enforcement actions will be taken as the situation warrants.

**RECOMMENDATIONS:** A general NPDES permit should be issued which requires implementation of BMPs and effluent monitoring to prevent or control pollution of the waters of the state from boatyards. Boatyards applying and eligible for coverage under this permit will be issued a general permit to expire at no more than five years after date of issuance.

#### REFERENCES

- 1) E. Crecelius, et. al., "Contaminant Loading to Puget Sound from Two Marinas," Puget Sound Notes, Winter , 1990
- 2) Aime Ontario Fraser, "Plastic Media," Professional Boatbuilder, October 1990.
- 3) Sven Donaldson, "Alternative Antifouling Systems," Professional Boatbuilder, October 1990.
- 4) Kenneth C. Alexander, "Characterization and Treatability of Hydroblast Waste water," University of Washington, August 1988.
- 5) "Best Management Practices for Ship and Boat Building and Repair Yards," Puget Sound Shipbuilders Association & Puget Sound Water Quality Authority, May 1990.
- 6) Bengston, et. al., "Best Management Practices Manual for the Shipbuilding and Repair Industry," Commonwealth of Virginia, Virginia Water Control Board, DRAFT August 1989.
- 7) "Development Document for Shipbuilding and Repair," EPA 440/1-70/076-b, 1978.
- 8) Communication from John Wiley, Metro Environmental Laboratories, July 30, 1991

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IV-2.1.16 WOOD PRODUCTS

SIC: 2420\*\* - 2450\*\*, 2434\*, 2490\*\*, 2511/12\*, 2517\*, 2519\*, 2521\*, 2541\*

DESCRIPTION: This group includes sawmills, and all businesses that make wood products using cut wood, with the exception of wood treatment businesses. Wood treatment as well as log storage and sorting yards are covered separately in Sections IV-2.1.17 and IV-2.1.8, respectively.

Included in this group are planing mills, millworks, and businesses that make wooden containers and prefab building components, mobile homes, and glued-wood products like laminated beams, as well as office and home furniture, partitions, and cabinets.

All businesses employ cutting equipment whose by-products are chips and sawdust. Finishing occurs in many operations.

MATERIALS USED AND WASTES GENERATED: Primary sources of contaminants are the trucks transporting stock lumber into and products from the businesses. Maintenance and repair of manufacturing equipment will produce waste oil and cleaning solvents that may be temporarily stored outside. Businesses may have finishing operations that produce waste paints and paint thinners, turpentine, shellac, and varnishes.

Source Control BMPs: See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

Regulatory Requirements: See R.1, R.2, R.3, R.4, R.10, R.11 and R.12 in Chapter IV-5.

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur or raw logs and/or products are stored shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

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IV-2.1.17 WOOD TREATMENT  
SIC: 2491

**DESCRIPTION:** This grouping includes both anti-staining and wood preserving. The businesses usually work with wood stock purchased from a mill. The lumber is stored on-site, outside the process building. It must be brought to the proper moisture content prior to treatment, which is achieved by either air-drying or kiln drying. Some wood trimming may occur. After treatment, the product is typically stored outside. Forklifts are used to move both the raw and finished product.

Wood treatment consists of a pressure process using the chemicals described below. Anti-staining treatment is done using dip tanks or by spraying.

**MATERIALS USED AND WASTES GENERATED:** The wood preserving industry produces a special set of liquid wastes. The raw materials used to preserve wood are creosote, creosote/coal tar, or pentachlorophenol dissolved in a petroleum-based solvent, copper naphthenate or inorganic arsenicals such as chromated copper arsenate dissolved in water. The use of pentachlorophenol is declining in the Puget Sound region.

Potential sources of stormwater and/or ground water contamination include spills from around the retort area, drippings from treated wood, equipment leaks, and spills from the unloading and use of the preservative.

**Source Control BMPs:** See BMPs S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions. In addition, the following BMPs are specifically required where wood treatment occurs:

- Ground areas around dip tanks, spray booths, retorts, and any other process equipment shall be paved, and sloped and drained in a manner that allows the capture and return of treatment chemicals back to the wood treatment process.
- Dipped lumber shall be required to drip over the dip tank, or be placed on an inclined ramp for a minimum of 30 minutes to allow return of the excess chemical to the dip tank.
- Treated lumber either from dip tanks or retorts shall be placed in a covered paved storage area for at least 24 hours before placement in outside storage. A longer storage period shall be used during cold weather unless the temporary storage building is heated. The wood shall be drip free and surface dry before it is moved elsewhere.
- Eliminate non-process traffic on and off the drip pad. A fork lift should be dedicated to the drip pad.
- Remove and properly dispose of soils with visible surface contamination (green soil) to decrease the spread of chemicals to ground water and/or surface water via stormwater runoff. Take steps to prevent future occurrences.
- Keep treated wood out of areas where surface water drainage is apparent.
- Scrub down non-dedicated lift trucks on the drip pad.
- Design improved runoff and process water collection facilities for roofs/asphalt, and any ponding areas. Improvements may include segregating clean rain water (e.g. rain water from rooftops) from process water. Ensure all process water is collected and recycled to the process treatment system.
- If any wood is observed to be contributing chemicals to the environment in the treated wood storage area, relocate it on a concrete chemical containment

*structure until the surface is clean and until it is drip free and surface dry. Clean up, remove and properly dispose of any contaminated soil from the treated wood storage area.*

- *Seal any holes which can allow stormwater to migrate from the asphalted area to the soil.*

*Regulatory Requirements: See R.1, R.2, R.3, R.7, R.10, R.11 and R.12 in Chapter IV-5.*

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur or lumber is stored shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.1.18 OTHER MANUFACTURING BUSINESSES

SIC: 2200\*, 2300\*, 2873/74\*\*, 3100\*, 3200\*\*, 3250-69\*\*, 3280\*\*, 3290\*\*

**DESCRIPTION:** Includes manufacturing of textiles and apparel, agricultural fertilizers, leather products, clay products such as bricks, pottery, bathroom fixtures; and nonmetallic mineral products.

All of the above manufacturers are represented in the Puget Sound region. The manufacturing businesses specifically excluded from consideration in this group were listed in Chapter IV-1.

**MATERIALS USED AND WASTES GENERATED:** A survey of businesses in the Seattle area found Dangerous Wastes being generated by all of the above types of manufacturers.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.70, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine what BMPs are applicable to the specific manufacturer.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.5, R.6, R.7, R.8, R.9, R.10, R.11 and R.12 in Chapter IV-5 as applicable.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

## IV-2.2 TRANSPORTATION AND COMMUNICATION

### IV-2.2.1 AIRFIELDS AND AIRCRAFT MAINTENANCE

SIC: 4513\*\*, 4515\*\*

**DESCRIPTION:** There are both public and private airfields in the Puget Sound basin. Aircraft maintenance at public airfields is usually a private business. Fueling of aircraft occurs.

**MATERIALS USED AND WASTES GENERATED:** The large areas used for taxiing takeoffs and landings are usually paved except at the smallest private airfields. Fueling is accomplished by tank trucks at the aircraft and is a source of spills. Dripping of fuel and engine fluids from the aircraft is a source of stormwater contamination.

Aircraft maintenance produces a wide variety of waste products, similar to those found with any vehicle or equipment maintenance: used oil and cleaning solvents, paints, oil filters, and soiled rags. Aircraft are washed producing soapy wastewater.

**Source Control BMPs:** See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4.

Additionally, the following BMPs shall be implemented.

- *Fueling of aircraft shall be done with the utmost care to avoid spillage. Large airfields where the fueling of large multi-engine aircraft occur shall have incorporated in their storm drainage system a low-flow collection system that allows for the separate collection and treatment (see Stormwater Treatment BMPs, below) of spilled fuel. Smaller airfields shall have suitable materials available for cleanup when spills occur.*
- *Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.*
- *The airfield owner shall post in prominent locations or otherwise promulgate at least once a year to its tenants, both aircraft owners and maintenance businesses, the above list of BMPs that relate to the prevention of spillage and storage and disposal of waste products.*

**Regulatory Requirements:** See R.1, R.2, R.3, R.6, R.7, R.11 and R.12 in Chapter IV-5.

**Stormwater Treatment BMPs:** For small airfields, stormwater from the paved surfaces shall be treated using biofilters given that large grassed areas are typically available around such fields (Volume III, Runoff Control).

For large airfields, stormwater from parking and maintenance areas where dripping oil or hydraulic fluids is likely to be occurring shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control). Stormwater from employee parking lots shall be treated using one of the systems described in Volume III.

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no storm sewer to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see BMPs RI.15 and RI.16 in Chapter III-3 of the Runoff Control Volume).



IV-2.2.2 FLEET VEHICLE YARDS

SIC: 4100\*\*, 4210\*\*, 4230\*\*, 7381/2, 7510

**DESCRIPTION:** Includes all businesses which own, operate and possibly maintain or repair large vehicle fleets, including taxis, buses, truck freight service, courier and armored car service, as well as the renting or leasing of cars, trucks, and trailers.

Such businesses are likely to maintain, wash and fuel their own vehicles on-site and therefore will possess many of the characteristics of general service gas stations or vehicle repair service shops. Washing may take place in enclosed and fully automated systems like commercial vehicle washers, or by hand in the parking area. Truck and bus engines and engine parts are often steam cleaned. Some fleet owners may store retired vehicles on site to be stripped for parts. A common practice with taxi fleets, this may result in the spilling of engine fluids.

**MATERIALS USED AND WASTES GENERATED:** Both solid and liquid wastes are produced. Waste materials generated by the various operations include: used oils, oil filters, antifreeze, solvents, brake fluid, and batteries, sulfuric acid, battery acid sludges, empty contaminated containers and soiled rags. Spillage of gasoline and diesel fuels occurs from pumps and during transfer from tanker trucks to underground storage tanks. Leaking underground storage tanks can cause ground water contamination and is a safety hazard.

Stormwater can be contaminated by: fuels and oil spilled on exposed paved surfaces; by solid and liquid wastes (noted above) that are not properly stored while awaiting disposal or recycling; dirt, oils and greases from steam cleaning and vehicle washing that occurs outside; and dripping of these same materials from parked vehicles. Stormwater contaminated by fuels may contain significant concentrations of dissolved organics that cannot be removed by an oil/water separator. Water is produced from vehicle and parts washing and steam cleaning.

Research by the Municipality of Metropolitan Seattle (Metro) of its bus bases indicates that mean concentrations of oil and grease typically range from 10 to 20 mg/l with individual samples commonly exceeding 50 mg/l. This level greatly exceeds Ecology's guideline of no more than 10 mg/l and indicates need for conscientious source control measures.

Deliberate disposal of materials to the storm sewer may occur, in particular used oils and brake fluid, used antifreeze and radiator flush. In many areas of the Puget Sound basin used oil and antifreeze are regularly recycled. Contact the appropriate local government for information on recycling of these wastes, or call Ecology's Recycling Hotline at 1-800-RECYCLE.

It is common practice to temporarily store used oils, brake fluid, and solvent in underground fixed tanks although the latter is usually stored in steel drums.

**Source Control BMPs:** See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

- In addition, retired vehicles kept on-site must be emptied of unused gas, transmission and hydraulic fluid, and radiator coolant. All fluids should be disposed of properly, preferably through recycling.
- Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.

*For more information on automotive repair and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.6, R.7, R.10 and R.11 in Chapter IV-5.*

Stormwater Treatment BMPs: Stormwater from parking and maintenance areas where dripping oil or hydraulic fluids is likely to be occurring shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control). Stormwater from employee parking lots shall also be treated either in with or separately from the fleet vehicle parking areas using one of the systems described in Volume III.

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.2.3 RAILROADS

SIC: 4011\*\*/13\*\*

**DESCRIPTION:** Railroad activities are spread over a large geographic area: along railroad lines, in switching yards, and in maintenance yards. Railroad activity occurs on both property owned or leased by the railroad and at the loading or unloading facilities of its customers. The BMPs presented here are for those activities that occur on property owned by the railroad, and therefore are its responsibility to implement. Employing BMPs at commercial or public loading and unloading areas is the responsibility of the particular property owner.

**MATERIALS USED AND WASTES GENERATED:** Along railroad lines and in switching yards, there are six potential sources of nonpoint pollution: herbicides used for vegetation management, dripping of vehicle fluids onto the road bed, leaching of wood preservatives from the railroad ties, human waste disposal, litter, and the erosion and loss of soil particles from the bed. The latter is both a source of sediment pollution and the mechanism by which vehicle fluids and wood preservatives reach a receiving water. The significance of each of these sources is not known. Human wastes may be disposed of while a train is enroute, over bridges or near water bodies.

Activities in the maintenance yards are similar to those found in businesses that maintain trucks and heavy construction equipment, and therefore the wastes are similar. In addition to the railroad stock, the maintenance shops service highway vehicles and other types of equipment. Waste materials can include waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions, brake fluids, soiled rags, oil filters, sulfuric acid and battery sludges, and machine chips with residual machining oil.

**Source Control BMPs:** See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions. In addition, the following specific BMPs shall be used:

- *Use railroad ties constructed with a material other than wood, or use ties that have been preserved with chemicals less toxic than creosote or pentachlorophenol, such as inorganic arsenicals and copper naphthelate.*
- *Develop a written policy with maintenance guidelines and an implementation schedule that insures erosion and/or loss of fine sediments from railroad beds is minimized, particularly in the vicinity of surface waters. The policy shall satisfy the General Criteria for Erosion and Sediment Control in Chapter II-4 of Volume II. Additionally, debris should not be discarded along the tracks during maintenance.*
- *Toilet tanks shall not be emptied while a train is in transit. Instead, pumpout facilities should be available to service these units.*

**Regulatory Requirements:** See R.1, R.2, R.3, R.7, R.8, R.10, and R.11 in Chapter IV-5.

**Stormwater Treatment BMPs:** Stormwater from parking and maintenance areas where dripping oil or hydraulic fluids are likely to occur shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.2.4 PRIVATE UTILITY CORRIDORS

SIC: 4610, 4922, 4941

DESCRIPTION: Utility corridors include lines for petroleum and petroleum products , natural gas, and electrical power.

MATERIALS USED AND WASTES GENERATED: Two potential sources of nonpoint pollution include herbicides used for vegetation management and the erosion and loss of soil particles from the unpaved access roads.

At pump stations waste materials generated during maintenance activities may be temporarily stored outside the station rather than being removed immediately for disposal. Storage facilities must be adequate to prevent both surface and/or ground water contamination.

Additional potential sources of stormwater and/or ground water contamination in electric transmission systems include the leaching of preservatives from wooden utility poles, PCBs in older transformers, and water that is removed from underground transformer vaults, and potential for leakage of petroleum products from pipelines.

Source Control BMPs: See BMPs S1.50, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

In addition, the following BMPs also apply:

- *Develop a written policy with maintenance procedures and an implementation schedule to minimize bare or thinly vegetated ground surfaces within the corridor where erosion will result in the entry of sediments into adjacent surface waters.*
- *The above policy shall satisfy the Erosion and Sediment Control Requirements (Minimum Requirement #1) in Chapter I-2.*
- *Do not temporarily store waste materials around pump stations and unstaffed electric substations.*
- *Electric utilities should use power poles made with a material other than wood, or use poles that have been preserved with chemicals less toxic than creosote or pentachlorophenol, such as inorganic arsenicals and copper naphthelate.*
- *Water removed from electric transformer vaults should first be analyzed for the presence of Dangerous Wastes. Water removed shall only be disposed of to a sanitary sewer consistent with pretreatment requirements imposed by the local Sewer Authority (R.1 in Chapter IV-5) if these wastes are uncontaminated by PCBs or other materials. If contaminated, they shall be treated as Dangerous Waste and disposed of appropriately.*
- *Remove all litter caused by wire changes etc.*
- *Maintenance practices shall insure that stormwater does not accumulate and drain across and/or onto roadways but instead through roadside ditches and culverts. The road shall be crowned, outsloped, water barred or otherwise left in a condition not conducive to accelerated erosion. Grass-lining and appropriately maintaining a roadside ditch discharging to surface water is an effective way of removing some pollutants associated with particulates carried by the stormwater.*

- *Ditches and culverts shall be maintained at the appropriate frequency to insure that plugging and flooding across the roadbed does not occur.*
- *When applying pesticides, comply with Ch. 17.21 RCW and Ch. 16-228 WAC (see R.8 in Chapter IV-5 and BMP S1.90 in Chapter IV-4).*

*Regulatory Requirements: See R.1, R.3, and R.7 in Chapter IV-5.*

Stormwater Treatment BMPs: No stormwater treatment BMPs are required.

IV-2.2.5 WAREHOUSES AND MINIWAREHOUSES

SIC: 4220\*\*

DESCRIPTION: Businesses that store goods.

MATERIALS USED AND WASTES GENERATED: Warehouse businesses that only provide storage will not produce any pollutants of concern except from the accidental spillage of liquids from containers that are dropped during loading and unloading. General stormwater contaminants will come from the paved areas surrounding the warehouse, especially if there are large areas of impervious surface or high amounts of vehicular traffic. Some warehouse businesses own their own fleet of trucks. Consequently, their characteristics will be similar to "Fleet Vehicle Yards."

Source Control BMPs: Mini-warehouses used by the public are not required to install any BMPs with two exceptions: A SC-type oil/water separator (BMP RD.35 in the Runoff Control Volume and/or a biofilter (BMP RB.05 in the Runoff Control Volume) shall be installed, and the paved area surrounding the warehouse shall be swept at appropriate intervals to remove debris.

If the warehouse business owns a fleet of vehicles, refer to "Fleet Vehicle Yards" Section IV-2.2.2 for the appropriate BMPs. The following BMPs are for businesses that provide a warehouse service.

*Commercial warehouses shall refer to the following BMPs found in Chapter IV-4: S1.30, S1.50, S1.80, S2.00 and S2.20.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.7, and R.11 in Chapter IV-5.*

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to a storm drain or combined sewer below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.2.6 OTHER TRANSPORTATION AND COMMUNICATION

SIC: 4700-4900

**DESCRIPTION:** This group includes travel agencies, communication services such as TV and radio stations, cable companies, and electric and gas services. It does not include railroads, airplane transport services, airlines, pipeline companies, and airfields.

**MATERIALS USED AND WASTES GENERATED:** Gas and electric services are likely to own vehicles that are washed, fueled and maintained on site. A survey of communication service companies in the Puget Sound area has found the generation of used oils and Dangerous Wastes.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.7, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Stormwater from parking lots shall be treated by one of the treatment systems described in Volume III, Runoff Control.

Stormwater runoff from rooftops may be discharged to the storm drain or combined sewer below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

#### IV-2.3 WHOLESALE AND RETAIL BUSINESSES

##### IV-2.3.1 GAS STATIONS

SIC: 5540

**DESCRIPTION:** Gasoline service stations primarily sell gasoline and lubricating oils. Most perform minor repair and maintenance including: servicing of engine hydraulic systems, brakes, transmission, and differential; replacement of engine coolant; lubrication of the body chassis and wheel bearings; engine cleaning; servicing of the air-conditioning system; and the servicing of tires and batteries.

Ancillary activities often present are: car washing and/or steam cleaning that may occur within the building or outside on the paved area; sale of food products; and the rental of trucks or trailers.

**MATERIALS USED AND WASTES GENERATED:** Both solid and liquid wastes are produced, as well as stormwater runoff from the paved surfaces. Waste materials generated by the various operations include: used oils, oil filters, antifreeze, solvents, brake fluid, and batteries, sulfuric acid, battery acid sludges, empty contaminated containers and soiled rags. Spillage of gasoline and diesel fuels occurs, from the pumps and during transfer from tanker trucks to the underground storage tanks. Leaking underground storage tanks can cause surface and/or ground water contamination as well as being a safety hazard.

Stormwater can be contaminated by: fuels and oil spilled on exposed paved surfaces; by solid and liquid wastes (noted above) that are not properly stored while awaiting disposal or recycling; dirt, oils and greases from steam cleaning and vehicle washing that occurs outside; and dripping of these same materials from parked vehicles. Stormwater and/or ground water contaminated by fuels may contain significant concentrations of dissolved organics that cannot be removed by an oil/water separator.

Deliberate disposal of materials to the storm drain can occur, in particular used oils and brake fluid, used antifreeze and radiator flush. It is currently common practice to temporarily store used oils, brake fluid, and solvent in underground fixed tanks although the latter is more frequently stored in steel drums.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Additionally:*

- *Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.*

*For more information on automotive repair and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.6, R.7, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Stormwater from parking and maintenance areas where dripping oil or hydraulic fluids is likely to be occurring shall be treated by an API or CPS-type oil/water separator or equivalent (Chapter III-7 in Volume III, Runoff Control).



Stormwater runoff from rooftops may be discharged to the storm sewer below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.3.2 RECYCLERS AND SCRAP YARDS

SIC: 5093\*\*, 5015\*\*

**DESCRIPTION:** Businesses that reclaim various materials for resale: construction materials, metals, beverage containers and papers. This group also includes businesses that strip and sell parts from automobiles, trucks, and construction equipment.

**MATERIALS USED AND WASTES GENERATED:** These businesses generally conduct their operations in uncovered areas. The type of waste materials and contamination of stormwater and/or ground water will vary widely with the type of business. However, in general it can be expected that both may be contaminated by metals, trace organics, BOD, suspended solids, and oil.

**Source Control BMPs:** See BMPs S1.20, S1.30, S1.40, S1.50, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

*Additionally,*

- *Gas, oil, and other fluids shall be drained from vehicles being scrapped. These fluids shall be disposed of properly, preferably by recycling.*
- *Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.*

*For more information on disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

**Regulatory Requirements:** See R.1, R.2, R.3, R.4, R.7, R.10 and R.11 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside processing areas shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm sewer below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.3.3 RESTAURANTS/FAST FOOD

SIC: 5800

**DESCRIPTION:** Businesses that provide food service to the general public.

**MATERIALS USED AND WASTES GENERATED:** Fast food restaurants experience very heavy usage. Two potential sources of stormwater contamination are the parking lots and garbage dumpsters exposed to precipitation. The cleaning of cooking vent filters in the parking lot can cause cooking grease to be discharged to the storm drains.

*Source Control BMPs: See BMPs S1.30, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*The following BMP is also required:*

- *Air filters from cooking grills shall not be washed in a location where the cleaning water and grease can reach a storm drain. Discharge shall be to a sanitary sewer.*

*Regulatory Requirements: See R.1, R.2, R.4, and R.10 in Chapter IV-5.*

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain or combined sewer below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.3.4 RETAIL GENERAL MERCHANDISE

SIC: 5300, 5600, 5700, 5900, 5990

**DESCRIPTION:** This group includes general merchandising stores such as department stores, shopping malls, variety stores, 24-hour convenience stores, and general retail stores that focus on a few product types such as clothing and shoes. It also includes furniture and appliance stores.

**MATERIALS USED AND WASTES GENERATED:** Of particular concern are the parking lots of shopping malls and 24-hour convenience stores. Because of heavy vehicle usage, the concentration of oil and grease in stormwater may exceed the Ecology guideline of 10 mg/l. Although there are no local data to confirm this view, limited research in the San Francisco Bay area found the mean concentration of oil and grease in stormwater to exceed 10 mg/l. Larger stores may own delivery vehicles. It is likely that servicing these vehicles occurs elsewhere and is not done by the owner.

Furniture and appliance stores may provide repair services in which Dangerous Wastes may be produced. Department stores and shopping malls may have restaurants that generate waste food.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.3.5 RETAIL/WHOLESALE VEHICLE AND EQUIPMENT DEALERS

SIC: 5010, 5080, 5500 excluding gas stations (5540)

**DESCRIPTION:** This group includes all retail and wholesale businesses that sell cars, trucks, boats, trailers, mobile homes, motorcycles and recreational vehicles. It includes both new and used vehicle dealers. It also includes sellers of heavy equipment for construction, farming, and industry.

With the exception of motorcycle dealers, these businesses have large parking lots. Most retail dealers that sell new vehicles also provide repair and maintenance service. Sellers of large equipment may also provide maintenance and repair services.

**MATERIALS USED AND WASTES GENERATED:** Storm runoff from the parking areas will be contaminated by oil and other materials that have dripped from parked vehicles. Vehicles are washed regularly generating vehicle grime and detergent pollutants. The storm or washwater runoff will contain oils and various organics, metals, and phosphorus.

Repair and maintenance services generate a variety of waste liquids and solids including used oils and engine fluids, solvents, waste paint, and soiled rags, and dirty used engine parts. Many of these materials are Dangerous Wastes.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*The following BMPs are also required:*

- *If possible, vehicles should be washed in an area that is tied directly into the sanitary sewer per the guidelines of the local Sewer Authority. The detergents in wash water from vehicles which runs into the stormwater treatment systems will render oil/water separators useless otherwise.*
- *Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.7, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III). Areas of high traffic shall use an API or CPS-type oil/water separator (see Chapter III-7).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.3.6 RETAIL/WHOLESALE NURSERIES AND BUILDING MATERIALS

SIC: 5030, 5198, 5210, 5230, 5260

**DESCRIPTION:** These businesses are placed in a separate group as they are likely to store much of their merchandise outside of the main building. They include nurseries, and businesses that sell building and construction materials and equipment, as well as paint (5198, 5230) and hardware.

**MATERIALS USED AND WASTES GENERATED:** Storm runoff from exposed storage areas will contain suspended solids, oil and grease from vehicles and forklifts, and other pollutants. Runoff from nurseries may contain nutrients, pesticides and/or herbicides. Some businesses may have small fueling capabilities for forklifts and may also maintain and repair their equipment. They may have delivery vehicles.

Some businesses may have unpaved areas, offering the potential to contaminate surface and/or ground water through stormwater runoff or by leaching of nutrients, pesticides, and herbicides.

Businesses in this group surveyed in the Puget Sound area for Dangerous Wastes were found to produce waste solvents, paints and used oil.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.50, S1.60, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*For more information on pesticide application and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.7, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where products are stored shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.3.7 RETAIL/WHOLESALE CHEMICALS AND PETROLEUM

SIC: 5160, 5170

**DESCRIPTION:** This group of businesses sells plastic materials, chemicals and related products. The group also includes the bulk storage and selling of petroleum products such as diesel oil, automotive fuels, etc. Therefore, liquid transfer and storage are the major activities.

**MATERIALS USED AND WASTES GENERATED:** The general areas of concern are the spillage of chemicals or petroleum during loading and unloading, and the washing and maintenance of tanker trucks.

The concentration of oil in untreated stormwater is known to exceed the water quality effluent guideline for oil and grease. Runoff is also likely to contain significant concentrations of benzene, phenol, chloroform, lead, and zinc. There is great potential for contamination of surface and/or ground water. There are specific stormwater effluent guidelines for petroleum refineries found under 40 CFR Part 419.

A survey of these businesses in the Puget Sound area found waste oil and solvents from vehicle and equipment maintenance.

The fire code requires that vegetation be controlled within a tank farm to avoid a fire hazard; herbicides are typically used.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.5, R.6, R.7, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside loading/unloading areas shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

Stormwater from petroleum storage facilities shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

IV-2.3.8 RETAIL/WHOLESALE FOODS AND BEVERAGES

SIC: 5140, 5180

**DESCRIPTION:** Included are businesses that provide retail food stores including general groceries, fish and seafood, meats and meat products, dairy products, poultry, soft drinks, and alcoholic beverages.

**MATERIALS USED AND WASTES GENERATED:** These businesses are likely to own their delivery vehicles. Vehicles may be fueled, washed and maintained at the business. Spillage of food and beverages may occur. Waste food and broken contaminated glass may be temporarily stored in containers located outside.

**Source Control BMPs:** See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

**Regulatory Requirements:** See R.1, R.2, R.3, R.4, and R.10 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).



IV-2.3.9 OTHER RETAIL/WHOLESALE BUSINESS

SIC: 5010 (not 5012), 5040, 5060, 5070, 5090

**DESCRIPTION:** This group includes all wholesale businesses not listed in any previous group. Examples are sellers of vehicle parts, tires, furniture and home furnishings, photographic and office equipment, electrical goods, sporting goods and toys, paper and paper products, and drugs and apparel.

**MATERIALS USED AND WASTES GENERATED:** The main source of stormwater pollutants is the parking lot. Some businesses own delivery vehicles which may be fueled, washed and maintained on premises.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Regulatory Requirements: See R.1, R.2, R.3, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

#### IV-2.4 SERVICE BUSINESSES

##### IV-2.4.1 ANIMAL CARE SERVICES

SIC 0740,0750

**DESCRIPTION:** This group includes veterinaries and businesses that provide boarding services for animals such as horses, dogs and cats.

**MATERIALS USED AND WASTES GENERATED:** The primary sources of pollution include animal manures, waste products from animal treatment, and runoff from pastures where larger livestock are allowed to roam. These pastures may border streams and direct access to the stream may occur. Both surface water and/or ground water may be contaminated.

##### *Source Control BMPs*

- *Businesses bordering streams shall not allow the direct access of animals to the stream. This shall be achieved by fencing or the use of streamside vegetation which inhibits livestock entry. The fence should be set back at least 10 feet from the high-water line. The vegetation strip should be at least 25 feet wide and not accessible to animals. Greater setback widths are desired on steep-sloped properties. The vegetative buffer must consist of plant species that inhibit livestock entry.*
- *Pastures used by animals shall be located in an area with the minimum drainage impact possible and be maintained in a manner that avoids excessive erosion. This shall be achieved by the use of appropriate animal density and/or grazing activity (such as pasture rotation), proper fertilizer practices and reseeded as necessary. Portable electric fencing can be used to temporarily enclose portions of a pasture to allow time for reestablishment of vegetation.*
- *Barns and livestock buildings shall have roof drain systems. These systems shall discharge away from livestock holding areas thereby preventing the mixing of stormwater and manure.*
- *Drainage patterns from a pasture shall be controlled to prevent the direct entry of contaminated stormwater to public ditches, adjacent property or streams and lakes.*
- *Manures and manure contaminated wastes shall be collected on a regular basis and stored in a manner that prevents the entry of stormwater.*
- *Businesses should consult with the County Conservation District or Cooperative Extension Service for technical advice on fulfilling the above requirements.*

*See the Supplemental Guidelines for other large animal management BMPs.*

**Stormwater Treatment BMPs:** Concentrated flows of stormwater from animal roaming/grazing areas shall be treated with a biofilter as described in Chapter III-6, Volume III. Animal densities on pastures shall be such as to not result in overgrazing and excessive erosion. Runoff from parking lots shall be treated with applicable treatment BMPs from Volume III.

IV-2.4.2 COMMERCIAL CAR AND TRUCK WASHES

SIC: 7542

**DESCRIPTION:** Facilities include automatic systems found at individual businesses or at gas stations and 24-hour convenience stores, as well as self-service. There are three main types: tunnels, rollovers and hand-held wands. The tunnel wash, the largest, is housed in a long building through which the vehicle is pulled. At a rollover wash the vehicle remains stationary while the equipment passes over. Wands are used at self-serve car washes. Some car washing businesses also sell gasoline.

**MATERIALS USED AND WASTES GENERATED:** The main ingredients are water and detergents. Waxes may be present in the commercial operations. Wastewaters are discharged to sanitary sewers. In self-service operations a drain is located inside each car bay.

Although these businesses discharge the wastewater to the sanitary sewer, some washwater can find its way to the storm drain, particularly with the rollover and wand systems. Rollover systems often do not have air drying. Consequently, as it leaves the enclosure the car sheds water to the pavement. With the self-service system, wash water with detergents can spray outside the building and be lost to the storm drain. Users of self-serve operations may also clean engines and change oil, dumping the used oil into the drain.

**Source Control BMPs:** See BMP S1.10, Fueling Stations, if gas is sold on premises. Also see BMPs S1.20, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

The following BMPs also apply:

- With rollover systems that do not have air drying, a drain shall be located at the exit of the building to which extraneous wash water can drain. This drain shall be connected to the sanitary sewer.
- The solution preventing loss of water at self-service businesses is to construct an embayment of sufficient length. Observation of several such operations indicates the individual bay should be at least 30 feet in length.
- Vehicles should be washed in an area that is tied directly into the sanitary sewer per the guidelines of the local Sewer Authority. The detergents in wash water from vehicles which runs into the stormwater treatment systems will render oil/water separators useless otherwise.

**Regulatory Requirements:** See R.1 and R.10 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Downspouts from the wash building may be discharged downstream of any treatment BMP as long as the drainage control requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.3 EQUIPMENT REPAIR

SIC: 7353, 7600

**DESCRIPTION:** Includes several businesses that specialize in repairing different equipment including communications equipment, radio, TV, household appliances, and refrigeration systems. Also included are businesses that rent or lease heavy construction equipment (7353) as miscellaneous repair and maintenance may occur on site.

**MATERIALS USED AND WASTES GENERATED:** A survey of several of these businesses indicates they produce used oil and solvents.

**Source Control BMPs:** See BMP S1.10 if equipment fueling is done on-site. Also see BMPs S1.20, S1.30, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

**Regulatory Requirements:** See R.1, R.2, R.3, and R.10 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Businesses that repair, store, or resale used construction or other mobile industrial equipment such as fork lifts, log handling equipment, cranes, etc, shall treat stormwater from outside equipment and storage and maintenance areas with an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.4 LAUNDRIES AND OTHER CLEANING SERVICES

SIC: 7211 through 7217

**DESCRIPTION:** This category includes all types of cleaning services such as laundries, linen suppliers, diaper services, coin-operated laundries and dry cleaners, and carpet and upholstery services.

Materials used differ depending on whether wet or dry cleaning is used. Wet washing may involve the use of acids, bleaches and/or multiple organic solvents. Dry cleaners use an organic-based solvent, although small amounts of water and detergent are sometimes used. Solvents may be recovered and filtered for further use.

Carpet and upholstery cleaning may occur on location or at the plant. On-location is done with dry materials or by a hot water extraction process. In-plant processes usually use solvents followed by a detergent wash.

**MATERIALS USED AND WASTES GENERATED:** Wash liquids are discharged to sanitary sewers. Of concern is the loading and unloading of liquid materials, particularly at large commercial operations, and the disposal of spent solvents and solvent cans.

**Source Control BMPs:** See BMPs S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

*The following BMPs also apply:*

- *Mobile cleaning units shall not discharge the accumulated wash water to storm drains or to surface or ground water. Such water shall be discharged to the sanitary sewer according to local Sewer Authority requirements.*
- *A spill response plan must be developed for each facility. This plan should be implemented immediately upon the spill or release of any liquid.*
- *Spent solvent cans must be disposed of properly in an appropriate, covered container.*

*For more information on dry cleaning and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

**Regulatory Requirements:** See R.1, R.2, R.3, and R.10 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater from roof-tops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.5 MARINAS AND BOAT CLUBS

SIC: 7999

**DESCRIPTION:** Marinas and yacht clubs provide moorage for recreational boats. Marinas may also provide fueling and maintenance services. Other activities include cleaning and painting of boat surfaces, minor boat repair, and pumping of bilges and sanitary holding tanks. Not all marinas have a system to receive pumped bilge water.

The 1991 Puget Sound Water Quality Management Plan calls for modification of state regulations to require the treatment of stormwater runoff; development of a model ordinance for sewer hookups by boats using public and private marinas, to be adopted voluntarily by local jurisdictions; and the formation of a task force that will prepare a comprehensive program to control the adverse effects of marinas.

**MATERIALS USED AND WASTES GENERATED:** Both solid and liquid wastes are produced as well as stormwater runoff from the parking lot. Waste materials include sewage and bilge water. Maintenance by the tenants will produce used oils, oil filters, solvents, waste paints and varnishes, used batteries, and empty contaminated containers and soiled rags.

**Source Control BMPs:** See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

*The following BMPs also apply:*

*Marina/yacht club owners shall post the following BMPs in a prominent place, which are to be carried out by boat owners:*

*In marinas/yacht clubs where repair work is allowed:*

- *Preparation of the hull of the boat for resurfacing which occurs over water requires that a tarp be affixed to the hull in a manner that traps any debris. The debris shall be collected from the tarp before the tarp is removed and properly disposed of.*
- *Paint burning or the use of spray guns shall not be allowed on topsides or above decks.*

*Other BMPs:*

- *Sanitary sewage shall be disposed of by the use of pump-out stations, portable on-site pump-outs, or commercial mobile pump-out facilities.*
- *Tenants shall be encouraged to place oil-absorbing materials in the bilge. These should be removed at appropriate intervals and disposed of properly. A sign shall be posted indicating the nearest oil collection and hazardous waste collection facilities. Bilge water should not be discharged unless it does not possess a sheen.*
- *Vessels with automatic bilge pumps shall be maintained in a manner that will prevent waste material from being pumped automatically into the surface water. The use of oil absorbent materials in the bilges should help to prevent such a discharge.*
- *Any spillage onto the docks or boat is to be cleaned up immediately and disposed of properly.*

- *The marina owner is to be notified immediately of any spill. Also, in the event of an accidental discharge of oil or hazardous material into waters of the state or onto land with a potential for entry into state waters, the yard owner or manager and the Department of Ecology shall be notified immediately.*

*Locally, notify the regional Department of Ecology offices:*

*Northwest Region - Redmond (206) 867-7000 (24-hour)  
Southwest Region - Olympia (206) 753-2353 (24-hour)*

*Additionally, the National Response Center must be called; their number is 1-800-424-8802 (24-hour).*

*If the spill is within salt water, the U.S. Coast Guard must be called at (206) 286-5440.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, R.5, R.7, and R.10 in Chapter IV-5.*

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may discharge directly to the surface water as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.6 GOLF AND COUNTRY CLUBS, GOLF COURSES AND PARKS

SIC: 7992, 7997

**DESCRIPTION:** Establishments primarily engaged in the operation of golf courses open either to members and their guests or open to the general public on a contract or fee basis. Rather than separating public and private golf courses, they are combined here to prevent duplication of information. Public and private parks are also included here because of the similarity in uses and wastes produced.

**MATERIALS USED AND WASTES GENERATED:** Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algicides and/or mosquito larvicides.

The application process can lead to inadvertent contamination of nearby surface waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering of surface greens in golf courses may cause pesticides or fertilizers to migrate to surface and shallow ground water resources.

The application of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained. Maintenance shops where the equipment is maintained must comply with the BMPs specified under "Vehicle Maintenance Shops" (see Section IV-2.4.9). The BMPs outlined below focus on the use of fertilizers and pesticides.

*Source Control BMPs: The owner must comply with BMPS S1.90 AND S2.20 in Chapter IV-4 in the use of pesticides and herbicides.*

*Other BMPs:*

- *Establish an Integrated Pest Management (IPM) Program (see BMP S1.90 in Chapter IV-4). IPM can help to minimize the need for chemical pest control measures by providing optimum growing conditions for turf grasses.*

*Lawn Management*

- *Select the appropriate turfgrass mixture for your climate and soil type. Certain tall fescues and rye grasses resist insect attack because of symbiotic endophytic fungi found naturally in their tissues which repel or kill common leaf and stem-eating lawn insects. They do not, however, repel root-feeding lawn pests, and are toxic to ruminants such as cattle and sheep. The fungus causes no known adverse effects to the host plant or to humans. Endophytic grasses are commercially available and can be used in areas such as parks or golf courses where grazing does not occur. The local Cooperative Extension office can offer advice on which types of grass are best suited to the area and soil type.*
- *Lawns should be aerated regularly in areas of heavy use where the soil tends to become compacted. Aeration should be done while the grasses in the lawn are growing most vigorously.*
- *Thatching should generally be done when the layer of thatch becomes greater than  $\frac{1}{4}$ " deep.*
- *While grass clippings cannot be left on many parts of a golf course, they can be collected and dispersed in the rough or other undeveloped (but not buffer) areas adjacent to the golf course. Clippings are relatively high in N (4%) and are a good source of nutrients as they decompose.*



- *Mowing is a stress-creating activity for turfgrass. When grass is mowed too short its productivity is decreased and there is less growth of roots and rhizomes. The turf becomes less tolerant of environmental stresses, more disease prone and more reliant on outside means such as pesticides, fertilizers and irrigation to remain healthy. Set the mowing height at the highest acceptable level and mow at times and intervals designed to minimize stress on the turf. Increased mowing tends to increase shoot density and leaf succulence. Increased water use has been observed with increased mowing height, but this water use may be offset by increased mowing frequency.*

#### *Irrigation*

- *The depth from which a plant normally extracts water depends on the rooting depth of the plant. Appropriately irrigated lawn grasses normally root in the top 6 to 12 inches of soil; lawns irrigated on a daily basis often root only in the top 1 inch of soil. Improper irrigation can encourage pest problems, leach nutrients, and make a lawn completely dependent on artificial watering. The amount of water applied depends on the normal rooting depth of the turfgrass species used, the available water holding capacity of the soil and the efficiency of the irrigation system. Consult with either the local Soil Conservation office or Cooperative Extension office to help determine optimum irrigation practices.*

#### *Fertilizer Management*

- *Research suggests that turfgrass is most responsive to nitrogen fertilization, followed by potassium and phosphorus. Fertilization needs vary by site depending on plant, soil and climatic conditions. Evaluation of soil nutrient levels through regular testing ensures the best possible efficiency and economy of fertilization. For details on soils testing, contact the local Conservation District or Cooperative Extension Service.*
- *Fertilizers should be applied in the amounts appropriate to the vegetative requirements, and at the time of year that minimizes losses to surface and ground waters. Do not fertilize during a drought or when the soil is dry. Alternatively, do not apply fertilizers within three days prior to predicted rainfall. The longer the period between fertilizer application and either rainfall or irrigation, the less fertilizer runoff occurs. Use slow release fertilizers such as methylene urea, IDBU or resin coated fertilizers when appropriate, generally in the spring. Use of slow release fertilizers is especially important in areas with sandy or gravelly soils. Time the application to periods of maximum plant uptake. Research indicates that fall application of fertilizer nitrogen for the next growing season in cool moist climates should be discouraged.*
- *All fertilizer applications should be performed by properly trained persons. Fertilizers should not be applied to swales, filter strips, or buffer areas surrounding sensitive water bodies.*

#### *Use of Pesticides<sup>1</sup>*

- *Properly maintained and healthy turfgrass will tolerate the presence of low levels of pest populations without suffering permanent damage. Healthy turfgrass will also recover more rapidly from major pest or disease infestations. Chemical controls should only be used when other methods have not worked. Use the safest pesticide which can appropriately control the target pest. The pesticide should have low mobility, high adsorption and low*

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<sup>1</sup> The term "pesticide" here includes those substances commonly thought of as insecticides, fungicides, miticides, nematocides, herbicides and rodenticides.

*persistence.*

- *Regular visual inspections should be done and spot pesticide applications then performed.*
- *All mixing and application should be done under the direct supervision of a licensed pesticide applicator. Applications should be performed in strict accordance with the instructions on the pesticide label. Contact the Pesticide Management Division of the Washington State Department of Agriculture if any questions arise.*
- *Prior to application, ascertain that no significant precipitation events are predicted within the next three days.*
- *Handle and store all pesticides according to the BMPs found in S1.30, S1.40 and S1.50 in Chapter IV-4. An emergency spill control plan should also be developed (see BMP S1.80 in Chapter IV-4).*

*For more information on pesticide application and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

#### *Weed Suppression*

- *Set weed tolerance levels for various areas of the golf course or park. Determine which weed species are currently growing in the area and how aggressively they are growing or spreading. Determine how much damage they are likely to cause to other plants, structures or the overall aesthetics of the area. Direct suppression efforts should be focused on weed populations that threaten to exceed tolerance levels rather than on all weeds growing in the area.*
- *A healthy lawn mowed regularly at the proper height is one of the best ways to suppress weeds. Regular mowing encourages lawn growth and discourages the growth of such species as crabgrass.*

*Regulatory Requirements: See R.1, R.3, and R.10 in Chapter IV-5.*

*Stormwater Treatment BMPs: Stormwater from parking lots shall be treated by one of the methods presented in Volume III, Runoff Control.*

*Stormwater runoff from rooftops may discharge directly to the surface water as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).*

References

- (1) Olkowski, William, Sheila Daar and Helga Olkowski, Common-Sense Pest Control, The Taunton Press, May, 1991.
- (2) Fortunato, Philip D., Hydroseeding Specification Guide, Briargreen, Inc., January, 1992.
- (3) Gaunt, Cary, Pollution Prevention Opportunities at the Fort Eustis Golf Course, Draft, SAIC, March, 1992.
- (4) Spectrum Research, Inc., Environmental Issues Related to Golf Course Construction and Management: A Literature Search and Review. A final report submitted to the U.S. Golf Association: Green Section, August, 1990.
- (5) Shapiro and Associates, Inc., Environmental Monitoring Program for the Proposed Remington Golf Course, prepared for Covington Creek Associates, January, 1991.
- (6) Shapiro and Associates, Inc. and D.R. Strong Consulting Engineers, Inc., Site Management Manual for the Proposed Remington Golf Course, prepared for Covington Creek Associates, March, 1991.
- (7) Virginia Division of Soil and Water Conservation, Ecological Turf Tips to Protect the Chesapeake Bay, Nutrient Management for Golf Course Managers, ETT #2, undated.

IV-2.4.7 MISCELLANEOUS SERVICES

SIC: 4959, 7260, 7312, 7332, 7333, 7340, 7395, 7641, 7990, 8411

**DESCRIPTION:** Includes a mix of service businesses that generate Dangerous Wastes. Included here are photographic studios, commercial photography, funeral services, amusement parks, furniture and upholstery repair and pest control services.

**MATERIALS USED AND WASTES GENERATED:** Building maintenance businesses produce wash and rinse solutions, oils, and solvents. Pest control businesses produce rinsewater with residual pesticides from washing application equipment and empty containers.

Outdoor advertising businesses will produce photographic chemicals, inks, waste paints, organic paint sludges containing metals.

Funeral services are known to produce formalin, formaldehyde and ammonia, which is usually legally discharged to the sink.

Upholstery and furniture repair businesses produce oil, stripping compounds, wood preservatives and solvents.

*Source Control BMPs: See BMPs S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*For more information on photofinishing and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.4, and R.10 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.8 PROFESSIONAL SERVICES

SIC: 6000, 7000 and 8000, not listed elsewhere

**DESCRIPTION:** Included here are the remaining service businesses including theaters, hotels/motels, finance, banking, hospitals and medical services, nursing homes, schools and universities, and legal, financial and engineering services.

**MATERIALS USED AND WASTES GENERATED:** The primary concern is runoff from parking areas. Stormwater from parking lots will contain undesirable concentrations of oil and grease, suspended particulates, and metals such as lead, cadmium and zinc. It will also contain the organic by-products of engine combustion. Some also produce Dangerous Wastes, for example, hospitals, nursing homes and other medical services. These materials are stored within the building until disposal.

**Source Control BMPs:** See BMPs S1.20, S1.30, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

**Regulatory Requirements:** See R.1, R.2, R.3, and R.10 in Chapter IV-5.

**Stormwater Treatment BMPs:** Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.9 VEHICLE MAINTENANCE AND REPAIR

SIC: 4000\*\*, 7530

**DESCRIPTION:** Includes businesses that repair and maintain automobiles, trucks, and buses, excluding those businesses listed elsewhere in this manual. Businesses included here are lube and tune shops, auto and truck repair and painting shops; and battery, radiator, muffler, and tire shops. Excluded here are vehicle dealers and gasoline service stations that also repair vehicles.

**MATERIALS USED AND WASTES GENERATED:** Wastes generated are similar to those produced by general purpose gas stations, although businesses that provide specialized maintenance activities will not produce all the wastes listed below.

Materials include waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions with chromium, zinc, copper, lead and cadmium, brake fluid, soiled rags, oil filters, sulfuric acid and battery sludges, and machine chips with residual machining oil.

A large number of vehicles may be parked in and around the service buildings.

*Source Control BMPs: See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.70, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.*

*Additionally:*

- *Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.*

*For more information on automotive repair and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.*

*Regulatory Requirements: See R.1, R.2, R.3, R.7, R.10 and R.11 in Chapter IV-5.*

**Stormwater Treatment BMPs:** Stormwater from parking and maintenance areas where dripping oil or hydraulic fluids is likely to be occurring shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators.

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

IV-2.4.10 MULTI-FAMILY RESIDENCES

SIC: NA

**DESCRIPTION:** Multifamily residential buildings such as apartments and condominiums. The activities of concern are vehicle parking, vehicle washing and oil changing, and garbage containers.

**MATERIALS USED AND WASTES GENERATED:** Stormwater from parking lots will contain undesirable concentrations of oil and grease, suspended particulates, and metals such as lead, cadmium and zinc. It will also contain the organic by-products of engine combustion. These conditions will be exacerbated if car owners wash their cars and change their oil which they may dump down the nearest storm drain.

**Source Control BMPs:** See BMPs S1.20, S1.50, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

*Additionally,*

- *Signed and designated containers for used oil and antifreeze shall be provided for residents. The containers shall be covered and shielded from the weather. Used oil and antifreeze shall be recycled whenever possible.*

**Regulatory Requirements:** See R.1, and R.10 in Chapter IV-5.

**Stormwater Treatment BMPs:** Stormwater from parking lots shall be treated using one of the treatment systems described in Volume III, Runoff Control.

Stormwater from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

Stormwater from parking and maintenance areas where dripping oil or hydraulic fluids is likely to be occurring shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

IV-2.4.11 CONSTRUCTION BUSINESSES

SIC: 1500, 1600, 1700

**DESCRIPTION:** This section does not deal with construction sites, but rather the location of the businesses themselves. It includes builders of homes, commercial and industrial buildings. It also includes heavy equipment contractors who excavate, as well as construction specialties such as plumbing, painting and paper hanging, carpentry, electrical, roofing and sheet metal, wrecking and demolition, stonework and masonry.

Maintenance and repair of equipment can occur at the site of business owners. Heavy equipment contractors may park their equipment adjacent to their businesses. Repairs may occur in the parking area where contamination of the pavement or soil can occur. Demolition contractors may store reclaimed material before resale.

**MATERIALS USED AND WASTES GENERATED:** Although the vast majority of waste materials are generated at the construction site, they are also typically found in smaller quantities at the business sites where construction materials and equipment are temporarily stored. The storage yard may be located at the place of business or at a separate storage yard. Potential waste materials include solvents, paints, batteries, strong acid and alkaline wastes, paint and varnish removers. These are Dangerous Wastes. Used oil is also produced. Contractors frequently have their own fueling facilities for equipment.

The types of wastes generated by specialty contractors vary substantially. Painting contractors will generate paint and other finishing residues, spent thinners, paint containers, used oil, other lubricants and antifreeze from servicing their vehicles.

Roofing contractors generate residual tars and sealing compounds, spent solvents, kerosene, and soap cleaners, as well as non-hazardous waste roofing materials.

Sheet metal contractors produce small quantities of acids and solvent cleaners such as kerosene, metal shavings, adhesive residues and enamel coatings, and asbestos residues that have been removed from buildings.

Asphalt paving contractors are likely to store application equipment such as dump trucks, pavers, tack coat tankers and pavement rollers at their businesses. Stormwater passing through this equipment may be contaminated by the petroleum residuals. Maintenance of the equipment generates waste fluids and solvents.

**Source Control BMPs:** See BMPs S1.10 (if fueling is done on-site), S1.20, S1.30, S1.40, S1.50, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions. For additional information about managing work material at construction sites, refer to Chapter II-3 in Volume II.

**Additionally:**

- Drain oil filters while the oil is warm for as long as possible (24 hours) and at an angle. Collect the oil for recycling in a separate, labeled container. Drained filters should be kept in a suitable container or drum and sent to a scrap metal recycler or hazardous waste management facility. Don't put undrained filters in the dumpster, or put drained filters in the dumpster without first checking with your local health department.

**Regulatory Requirements:** See R.1, R.2, R.3, R.7, R.9, and R.10 in Chapter IV-5. Additionally, NPDES permits, while not required for business locations, will be required for construction sites larger than 5 acres in size. Please see Chapter IV-5 and Chapter II-2 in the Erosion Control Volume for more information.



Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside storage areas shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

Asphalt paving contractors and contractors that maintain heavy equipment or vehicles on-site shall have stormwater from outside equipment storage areas treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).



CHAPTER 3

PUBLIC AGENCIES AND REQUIRED BMPs

Activities of many local governments and state and federal agencies in the Puget Sound basin are similar to many of the business activities listed in Chapter IV-2. Government activities, as well as those of other businesses, also contribute significantly to non-point pollution.

Local governments whose actions can affect water quality include cities and counties, and also single-purpose entities such as fire, sewer and water districts. With few exceptions, all state and federal agencies have some facility or activity that can contribute to non-point pollution via stormwater runoff.

Currently, large municipalities (Seattle and King County, urbanized population >250,000) and medium municipalities (Pierce County, Snohomish County, Spokane and Tacoma, urbanized population between 100,000 to 250,000) are required to apply for NPDES permits. Additionally, the Washington State Department of Transportation is considered to be a municipality and must obtain NPDES permits for its highway system, maintenance facilities and ferry system. See R.11 in Chapter IV-5 for more information on NPDES permits.

IV-3.1 PUBLIC BUILDINGS AND STREETS

**DESCRIPTION:** The construction of public facilities is an opportunity to include BMPs to improve the quality of stormwater. Included in this group are public buildings not discussed elsewhere in Chapter IV-3. Also included are streets and roads.

**MATERIALS USED AND WASTES GENERATED:** Materials such as concrete, asphalt, sheetrock, rebar, glass, and lumber are commonly used in buildings. Asphalt or port and cement and aggregate are used on streets as well as paint for marking street crossings, etc.

Wastes generated include solvents, paints, acid and alkaline wastes and paint and varnish removers. Large amounts of scrap materials are also produced throughout the course of construction and street repair.

**Source Control BMPs:** See BMPs S1.10, S1.30, S1.50, S1.80, S1.90, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

*In addition, the following BMPs are required:*

- *Open vegetated ditches, instead of storm drains, should be used where feasible along roads, streets, and highways. Design ditches to serve the dual functions of drainage and stormwater treatment. See Chapters III-2 and III-6 in Volume III for the design of conveyance and biofiltration systems.*
- *Disposal of construction wastes and pollutants is covered in detail in Chapter II-3 in Volume II.*

**Regulatory Requirements:** See R.1, R.2, R.3, R.7, R.8, R.9, R.10 and R.11 in Chapter IV-5.

**Stormwater Treatment BMPs:** Stormwater from parking lots and roads shall be treated using one of the systems described in Volume III, Runoff Control. Treatment BMPs shall be installed on new roads, and existing roads undergoing significant upgrading. Treatment BMPs shall be installed whenever an existing road is modified from open ditches to curbs and storm sewers.

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see BMPs RI.15 and RI.16 in Chapter III-3 of the Runoff Control Volume).

#### IV-3.2 VEHICLE AND EQUIPMENT MAINTENANCE SHOPS

**DESCRIPTION:** Government maintenance shops are a potential source of non-point pollution since they are similar to general service gas stations or vehicle repair service shops. Maintenance shops may be owned and operated by city or county governments, state or federal agencies, as well as schools, colleges and universities.

In addition to engine and body maintenance, government maintenance shops are likely to wash and fuel the vehicles on-site. Washing may take place in enclosed and fully automated systems similar to commercial vehicle washers, or by hand in the parking area. Engines and engine parts are commonly steam cleaned. Retired vehicles may be kept on-site to be stripped for parts, or sold at auction to the public. Vehicles and equipment may be painted.

**MATERIALS USED AND WASTES GENERATED:** Solid and liquid wastes are produced, as well as stormwater runoff from paved surfaces. Wastes produced include: used oils, oil filters, antifreeze, solvents, brake fluid, batteries, sulfuric acid, battery acid sludges, empty contaminated containers and soiled rags. Gasoline and diesel fuels are spilled from pumps and during transfer from tanker trucks to underground storage tanks. Leaking underground storage tanks can cause ground water contamination and in addition, they are a safety hazard.

Stormwater can be contaminated by: spilled fuels and oil; solid and liquid wastes (noted above) that are not properly stored while awaiting disposal or recycling; dirt, oils and greases from steam cleaning and vehicle washing that occurs outside; and dripping of these same materials from parked vehicles. Stormwater contaminated by fuels may contain significant concentrations of dissolved organics that cannot be removed by an oil/water separator. Water is produced from vehicle and parts washing and steam cleaning.

Research by Municipality of Metropolitan Seattle (Metro) of its bus bases indicates that mean concentrations of oil and grease typically range from 10 to 20 mg/l with individual samples commonly exceeding 50 mg/l, exceeding the Ecology guideline.

Deliberate disposal of materials to the storm drain may commonly occur, in particular used oils and brake fluid, used antifreeze and radiator flush. It is common practice to temporarily store used oils, brake fluid, and solvent in underground tanks although the latter is more frequently stored in steel drums.

**Source Control BMPs:** See BMPs S1.10, S1.20, S1.30, S1.40, S1.50, S1.60, S1.80, S2.00 and S2.20 in Chapter IV-4 to determine appropriate actions.

- *In addition, any retired vehicles kept on-site for scrap parts shall be emptied of all gas, transmission and hydraulic fluids and coolant. Vehicles being held for resale should be periodically checked for leakage. Fluids should be recycled or otherwise properly disposed of.*

**Regulatory Requirements:** See R.1, R.2, R.3, R.6, R.7, R.10 and R.11 in Chapter IV-5.

**Stormwater Treatment BMPs:** Stormwater from parking and maintenance areas where

dripping fluids are likely to occur shall be treated by an API or CPS-type oil/water separator (Chapter III-7 in Volume III, Runoff Control).

Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators or equivalent (see Volume III).

Stormwater runoff from rooftops may be discharged to the storm drain below the treatment system as long as the drainage requirements of the local Public Works Department are met. If there is no stormwater drainage system (storm sewer) to discharge to, runoff from rooftops should be disposed of through the use of an infiltration facility wherever possible (see Chapter III-3 of the Runoff Control Volume).

#### IV-3.3 MAINTENANCE OF OPEN SPACE AREAS

**DESCRIPTION:** The maintenance of large open spaces that are covered by expanses of grass and landscaped vegetation. Examples are zoos and public cemeteries. Golf courses and parks are covered in Section IV-2.4.6.

**MATERIALS USED AND WASTES GENERATED:** Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algicides and/or mosquito larvicides.

The application process can lead to inadvertent contamination of nearby surface waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering, of surface greens in golf courses, may cause pesticides or fertilizers to migrate to surface and shallow ground water resources.

The application of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained. Maintenance shops where the equipment is maintained must comply with the BMPs specified under "Vehicle Maintenance Shops" (see Section IV-2.4.8).

*Source Control BMPs: The owner must comply with BMP S1.90 in Chapter IV-4 in the use of pesticides and herbicides.*

*BMPs covering lawn maintenance, fertilizer and pesticide application and irrigation are covered in Section IV-2.4.6.*

*Regulatory Requirements: See R.1, R.3, and R.10 in Chapter IV-5.*

Stormwater Treatment BMPs: Stormwater from parking lots shall be treated by one of the methods presented in Volume III, Runoff Control.

#### IV-3.4 MAINTENANCE OF PUBLIC STORMWATER FACILITIES

**DESCRIPTION:** Proper maintenance is the key to insuring that stormwater facilities will continue to perform their intended function. Polluted water and sediments that are removed during the cleaning operation must be properly disposed of.

Facilities include roadside catchbasins on arterials and within residential areas, conveyance pipes, detention facilities such as ponds and vaults, and all other types of stormwater treatment systems presented in Volume III, Runoff Control.

Research has shown that roadside catchbasins can remove from 5 to 15 percent of the pollutants present in stormwater. However, to be effective they must be cleaned. Research has indicated that once catchbasins are about 60 percent full of sediment, they cease removing sediments. Generally in urban areas, catchbasins become 60 percent full within 6 to 12 months, and therefore they must be cleaned at this frequency.

Water and solids produced during the cleaning of stormwater systems can adversely affect both surface and ground water quality if disposed of improperly. Ecology has documented water quality violations and fish kills due to improper disposal of decant water and catchbasin sediments from maintenance activities.

Historically, decant water from trucks has been placed back in the storm drain. Solids have been disposed of in permitted landfills and in unpermitted vacant land including wetlands. Research has shown that these residuals contain pollutants at concentrations that may exceed water quality criteria.

For example, limited sampling by King County and the Washington Department of Transportation of sediments removed from catchbasins in residential and commercial areas has found the petroleum hydrocarbons to frequently exceed 200 mg/gram. Above this concentration, regulations require disposal at a lined landfill.

General requirements are listed below. Specific requirements for each type of hydraulic control and treatment facilities are presented in Volume III, Runoff Control, Chapters III-2 through III-8.

*Source Control BMPs: The public agency is required to comply with BMPS S2.00 and S2.20 in Chapter IV-4.*

- *An interim policy for the disposal of catchbasin sediments will be developed within the next one to two years.*

Stormwater Treatment BMPs: See Volume III, Runoff Control for the maintenance requirements of specific systems. These requirements are listed at the end of the description of each BMP.

#### IV-3.5 MAINTENANCE OF ROADSIDE VEGETATION AND DITCHES

**DESCRIPTION:** Effective maintenance of vegetation in road rights-of-way can significantly improve the quality of stormwater from these areas. A good vegetative cover will reduce if not eliminate the erosion of slopes and drainage ditches that can be significant sources of sediment. The vegetation present in properly designed ditches and median swales can remove pollutants such as metals that are carried in particulate form in stormwater runoff.

*Source Control BMPs: To minimize non-point pollution the following BMPs shall be employed.*

- *Develop a written policy with maintenance procedures to minimize bare or thinly vegetated ground surfaces within the right-of-way particularly on potentially erosive slopes and in drainage ditches.*
- *Maintenance of roadside ditches will be carried out in a manner that insures the vegetation will be reestablished by the next wet season thereby minimizing erosion of the ditch as well as making the ditch effective as a biofilter.*
- *In the area between the edge of pavement and the bottom of the ditch, commonly known as the "bare earth zone", use grass vegetation wherever possible; if not from the edge of pavement, at least from the top of the slope of the ditch.*

- *Maintain any diversion ditches constructed on top of cut slopes to prevent slope erosion by the interception of surface drainage (see BMP E2.55 in Volume II).*
- *Examine culverts on a regular basis for scour around the inlet and outlet, and repair as necessary. Give priority to those culverts carrying perennial and/or salmonid-bearing streams, and culverts near streams in areas of high sediment load, such as those near subdivisions during construction.*
- *When using pesticides, comply with Ch. 17.21 RCW and Ch. 16-228 WAC (R.8 in Chapter IV-5), and additional stipulations presented in BMP S1.90 in Chapter IV-4.*

Stormwater Treatment BMPs: No stormwater treatment BMPs are required. See "Public Buildings and Streets" (Section IV-3.1) and "Maintenance of Public Stormwater Facilities" (Section IV-3.4).

#### IV-3.6 MAINTENANCE OF PUBLIC UTILITY CORRIDORS

**DESCRIPTION:** The BMPs described herein are for the maintenance practices employed in large public utility corridors for the transmission of electrical power, gas and water from remote supply sources and less frequently for easements for major gravity and force main lines for sewage.

**MATERIALS USED AND WASTES GENERATED:** Two potential sources of non-point pollution include pesticides used for pest or vegetation management, and the erosion and loss of soils from improperly maintained right-of-way access roads and drainage.

**Source Control BMPs:** See BMPs S1.50, S1.90 and S2.00 in Chapter IV-4 to determine appropriate actions. Additionally, these BMPs shall be employed to minimize non-point pollution:

- *Develop a written policy with maintenance procedures and an implementation schedule that provide for a vegetative cover program which minimizes bare or thinly vegetated ground surfaces within the corridor, where erosion might result in the entry of sediments into adjacent surface waters. A grassed or gravel access road is preferred to bare dirt.*
- *Develop a written policy with maintenance procedures that insure erosion of the access road is minimized, particularly in the vicinity of surface waters. This policy shall satisfy the Erosion and Sediment Control Requirements (Minimum Requirement #1) in Volume I.*
- *Maintenance practices shall insure that stormwater does not accumulate and drain across and/or onto roadways, but is conveyed through roadside ditches and culverts. The road shall be crowned, outsloped, water barred or otherwise left in a condition not conducive to accelerated erosion. Grass-lining and appropriately maintaining a roadside ditch discharging to a surface water is an effective way of removing some pollutants associated with sediments carried by stormwater.*
- *Ditches and culverts shall be maintained at the appropriate frequency to insure that plugging and flooding across the roadbed, with attendant erosion, does not occur.*
- *When applying pesticides, comply with Ch. 17.21 RCW and Ch. 16-228 WAC (R.8 in Chapter IV-5), and BMP S1.90 in Chapter IV-4.*
- *Do not temporarily store waste materials around unstaffed pump stations and electric substations.*

- *Electric utilities should use power poles constructed with a material other than wood, or use poles that have been preserved with chemicals less toxic than creosote or penta, such as inorganic arsenicals and copper naphthenate.*
- *Remove all litter produced when cutting or replacing wires, etc.*
- *Water and sediments removed from electric transformer vaults should first be analyzed for the presence of Dangerous Wastes. Water removed shall only be disposed to a sanitary sewer consistent with BMP S2.00 in Chapter IV-4 and the requirements of the local Sewer Authority (R.1 in Chapter IV-5) if these wastes are uncontaminated by PCBs or other materials. If contamination is found, the water and sediments shall be treated as Dangerous Waste and disposed of appropriately.*

Stormwater Treatment BMPs: No stormwater-treatment BMPs are required.

#### IV-3.7 WATER AND SEWER DISTRICTS AND DEPARTMENTS

**DESCRIPTION:** The maintenance of water and sewer systems can produce residual materials which, if not properly handled, can cause short-term environmental impacts in adjacent surface and/or ground waters. Maintenance operations of concern include the cleaning of sewer and water lines, and water reservoirs, general activities around treatment plants, disposal of sludges, and the temporary shutdown of pump stations for either normal maintenance or emergencies.

Draining of large reservoirs, tanks or pipelines can involve large quantities of water. Depending upon allowable discharge rates they can require many hours or days to drain.

Larger water and sewer districts or departments may service their own vehicles. See "Vehicle and Equipment Maintenance Shops" (Section IV-2.4.9) for the required BMPs.

Easement corridors through which major transmission lines pass usually require ongoing maintenance. The reader is referred to "Maintenance of Public Utility Corridors" (Section IV-3.6) for the required BMPs.

With the exception of a few simple processes, both water and sewage treatment produce residual sludges that must be properly disposed of. However, this activity is controlled by other Ecology regulatory programs and is not discussed in this manual.

**MATERIALS USED AND WASTES GENERATED:** During the maintenance of water transmission lines and reservoirs, water district/departments must dispose of waste water, both when the line or reservoir is initially emptied, as well as when it is cleaned and then sanitized. Sanitization requires chlorine concentrations of 25 to 100 ppm, considerably above the normal concentration used to chlorinate drinking water.

These waters are discharged to sanitary sewers where available. However, transmission lines from remote water supply sources often pass through both rural and urban-fringe areas where sanitary sewers are not available. In these areas, chlorinated water may have to be discharged to a nearby stream, particularly since the emptying of a pipe section occurs at low points that frequently exist at stream crossings. Although prior to disposal the water is dechlorinated using sodium thiosulfate or a comparable chemical, malfunctioning of the dechlorination system can severely impact stream fisheries.

The drain lines from reservoirs located in unsewered areas discharge to the stormwater drainage system. Sometimes after sanitary service is provided to the area, the drain line is not connected to the nearest sanitary sewer but remains



connected to the storm drains.

The cleaning of sewer lines and manholes generates sediments. These sediments contain both inorganic and organic materials, are odorous and contaminated with microorganisms and heavy metals. Activities around sewage treatment plants can be a source of non-point pollution. Besides the normal runoff of stormwater from paved surfaces, grit removed from the headworks of the plant is stored temporarily in dumpsters that may be exposed to the elements. Normal maintenance may produce waste paints, used oil, cleaning solvents, and soiled rags.

*Source Control BMPs:* Water purveyors shall examine each reservoir located where sanitary sewers are available to determine if the discharge line for wash water is connected via air gap to the sanitary sewer and to make such connection if it is not. Also see BMPs S1.50 and S2.00 in Chapter IV-4.

The following BMPs are also required:

- An understanding with the local sewer district is important so that sewer capacities are not exceeded. Special care should be taken to intercept heavy sediment before it enters the sewer system.
- Where sanitary sewers are not available for either reservoirs or major transmission lines when they are cleaned, the water purveyor should prepare a plan indicating the locations of discharge points. The plan should include a conceptual design and implementation schedule for the installation of a system, either permanent or portable, to be installed at each point that will provide delay time between the point of dechlorination and the entry point to an adjacent receiving water.
- Where the discharge point for wash water is not adjacent to any receiving water, nearby ditches or fields may be suitable.
- Waste water from the cleaning of reservoirs, if contaminated by bottom sediments, shall be discharged to a sanitary sewer or trucked to an appropriate disposal point as dictated by the local Sewer Authority. Sediments shall be intercepted and trapped to prevent their entry to the sewer.
- In sewage treatment plants, the storm drain leading from an open area in which wet grit is stored prior to final disposal shall discharge to the treatment plant.

*Regulatory Requirements:* See R.1, R.2, and R.3 in Chapter IV-5.

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators.

In lieu of separate stormwater treatment, owners of public sewage treatment facilities may choose to use the sewage treatment plant to treat the stormwater, partially or totally.

The agency may choose to discharge stormwater without treatment via the plant outfall. If this approach is selected, the allowable concentrations and loadings for the entire discharge (sewage plus stormwater) shall not exceed what would have been allowed had a stormwater treatment system been installed. In effect, the allowable discharge from the sewage treatment plant must be reduced to compensate for the lack of treatment of the stormwater. Ecology regulations and permit

conditions must be met prior to the use of this type of discharge.

Stormwater runoff from rooftops may be discharged to the storm drain below the stormwater treatment system as long as the drainage requirements of the local Public Works Department are met.

#### IV-3.8 PORT DISTRICTS

**DESCRIPTION:** Some port districts are very small and have only a few activities such as a marina and boat launches, while others are very large and are responsible for activities as varied as a city or town. For many ports, the majority of activities are carried out by private businesses who are leasing port facilities. Port officials need to list the various types of businesses and then refer to the appropriate pages in Chapter IV-2 to identify the required BMPs.

Types of business activities include: recreational boat marinas and launch ramps; boat maintenance and repair; airfields; container transshipment, bulk material import/export such as farm products, lumber, logs, alumina, and cement; break-bulk (piece) material such as machinery, equipment, and scrap metals. Ports provide warehouses, on or away from the shoreline for client use.

Port districts frequently have tenants whose activities are not marine-dependent. Therefore, the potential exists for the presence of any type of manufacturing or commercial business.

**MATERIALS USED AND WASTES GENERATED:** The types of materials used and wastes generated are very specific to the industrial activity. Marine terminals require extensive use of mobile equipment that may drip fluids. This equipment is usually maintained on site. Consequently, all of the waste materials associated with vehicle maintenance may be generated at a marine terminal. Cargo containers are frequently repaired and cleaned on port property.

A significant amount of debris can accumulate on loading/unloading or open storage areas, providing a source of stormwater contamination. Wooden debris from the crating of piece cargo crushed by passing mobile loading equipment leaches soluble pollutants when allowed to sit in pooled stormwater. Log sorting yards produce large quantities of bark that can be a source of fine suspended solids and leached soluble pollutants.

The types of activities, and potential waste materials generated at airfields are discussed in Chapter IV-2.

*Source Control BMPs: Having identified the specific types of businesses and activities, port officials can refer to Chapter IV-2 to identify the required BMPs.*

*There are some aspects that are unique to ports that require additional specification:*

- *Mobile cranes, like those used in construction, are frequently used to load barges. Although mobile, these cranes may sit for an extended period on a pad or wharf, adjacent to or over water. Drip pans shall be placed under these cranes.*
- *All steam cleaning or pressure washing of equipment or containers shall occur either in building or in a designated area that drains to a sanitary sewer. See BMP S1.20 in Chapter IV-4.*
- *All maintenance of mobile equipment shall occur in a building, except for refrigerated trailers and very large equipment. The maintenance of refrigeration engines in refrigerated trailers may occur in the parking area*

with due caution to avoid the spillage of engine or refrigeration fluids. Refrigerator coolants may be recyclable.

- Larger mobile equipment shall receive maintenance in a designated area. Mobile equipment may be idle for extensive periods of time. This equipment shall be parked in a designated paved area.
- The designated areas for maintenance and storage shall be curbed to prevent the runoff of stormwater from outside the designated area. The stormwater within the designated area shall pass through an API or CPS-type oil/water separator (see Chapter III-7 in Volume III, Runoff Control). If the area is not too large, the drain shall connect to a sanitary sewer as long as it complies with the requirements of the local Sewer Authority (R.1 in Chapter IV-5).
- The designated areas shall be paved with Portland cement concrete rather than asphalt.
- Loading/unloading areas shall be paved and sloped to prevent the pooling of water. The use of catchbasins and drain lines within the interior of the paved area shall be minimized as they will frequently be covered by material, or they should be placed in designated "alleyways" that are not covered by material, containers or equipment. To the maximum extent possible, perimeter drain systems should be used.
- Large loading areas frequently are not curbed along the shoreline. As a result, stormwater passes directly off the paved surface into the surface water. Curbs shall be placed along the edge, or the edge shall be sloped such that the stormwater can flow to an internal storm drain system that leads to treatment.
- As noted above, a significant amount of debris can accumulate on loading/unloading areas. These surfaces shall be swept frequently to remove material that could otherwise be washed off by stormwater. An area may be covered for a period of time by containers, logs, or other material. As a particular area is cleared, it shall be swept; catchbasins shall be inspected regularly and cleaned if more than half full of sediment.

Stormwater Treatment BMPs: Source control BMPs such as good housekeeping should always be used to control stormwater pollution. Stormwater from parking lots and outside areas where manufacturing processes occur shall be treated using infiltration and/or detention as detailed in Volume III, Runoff Control. Those practices shall be used in combination with other appropriate pre-treatment and treatment BMPs such as biofiltration, pre-settling basins and oil/water separators.

Stormwater runoff from rooftops may be discharged to the storm drain below the stormwater treatment system as long as the drainage requirements of the local Public Works Department are met.

The above requirements are limited to surfaces over firm ground. Staging areas located over open water are not required to have stormwater treatment systems as Ecology has not at this time identified a practical way in which such a system can be installed.

Stormwater runoff from rooftops may be discharged to the storm drain below the stormwater treatment system as long as the drainage requirements of the local Public Works Department are met.

The above requirements are limited to surfaces over firm ground. Staging areas located over open water are not required to have stormwater treatment systems as Ecology has not at this time identified a practical way in which such a system can be installed.

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## CHAPTER IV-4

## SOURCE CONTROL BMPs

## INTRODUCTION

Source control BMPs are organized by the activities found on the checklist in Chapter IV-1. Each of these BMPs include several different ways to improve runoff quality. Specific recommendations for each business are not made since the activities for each vary widely. The local government will make the final decision on appropriate BMPs for each business.

If possible, a pollution-creating activity should be altered to one which does not cause pollution. If the activity cannot be changed, then it should be enclosed. If it is too expensive to enclose the entire area, then perhaps the activity can be covered with just a frame and a roof. This area should also be provided with an impervious surface and drained to the sanitary sewer, process treatment or to a dead-end sump according to either local Sewer Authority or other permit requirements.

## IV-4.1 BMP S1.10 FUELING STATIONS

In addition to general service gas stations, fueling may also occur at 24-hour convenience stores, construction firms, warehouses, car washes, and businesses with fleet vehicles. Fueling also occurs at port facilities and industrial complexes where mobile equipment is used. Fuels contain organic compounds and metals that adversely affect aquatic life.

IF FUELING IS DONE ON-SITE, WHETHER AT A GAS STATION OR OTHER FUELING AREA, THE FOLLOWING BMPs ARE REQUIRED

1. The fueling facility shall be built in compliance with the Uniform Fire Code and the National Electric Code.
2. The fuel island shall be paved using Portland cement concrete, not asphalt and be designed to contain fuel spills. The fuel island shall be designed as a spill containment pad and sized to prevent the runoff of spilled fuel and the runoff of stormwater from surrounding pavement. Parking lot stormwater shall be discharged to the stormwater drainage system, not the sanitary sewer.
3. Liquids spilled on the fuel island shall be collected in drains; either trench drains or catchbasins. The pad shall be sloped towards the drains. The drain(s) shall be connected to the sanitary sewer, process treatment or a dead-end sump. To comply with the requirements of the local Sewer Authority and the Uniform Fire Code (R.1 and R.2 in Chapter IV-5) the drain shall have a valve to allow shutoff in the event of a large fuel spill.
4. The fuel island shall be covered to prevent the direct entry of precipitation onto the spill containment pad (see Figure IV-4.1). The roof/canopy shall, at a minimum, cover the spill containment pad and preferably extend several additional feet to prevent windblown rain from entering.
5. Spills should be prevented whenever possible. The owner or operator shall develop an emergency spill cleanup plan (per BMP S1.80) and have responsible designated person(s) available either on site or on call at all times. Suitable cleanup materials shall be kept on site to allow prompt cleanup should a spill occur.
5. Educate employees and customers on the proper use of fuel dispensers. Post signs in accordance with the Uniform Fire Code. Post "No Topping Off" signs;

topping off gas tanks causes spillage and vents gas fumes to the air. Make sure that the automatic shutoff on the gas nozzle works.

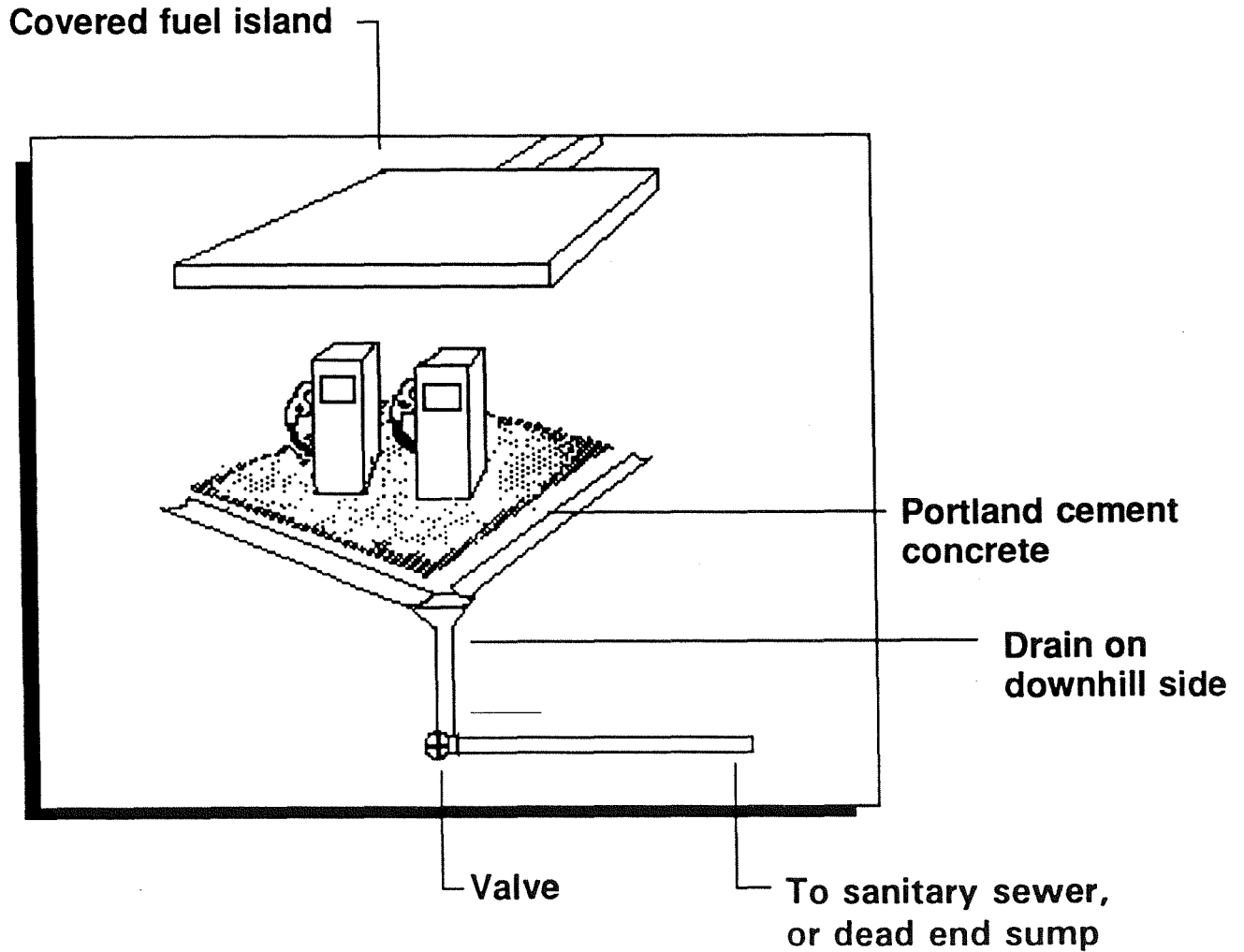
6. Temporary fuel tanks used to fuel vehicles in the field shall be placed in a bermed, impervious (using heavy mil plastic or portland cement) area. The bermed area shall be large enough to contain the greater of: 10% of the total enclosed combined tank volume or 110 percent of the largest tank's volume.

Exceptions

In industrial complexes or port facilities where very large mobile equipment is used such as log loaders, the fuel island need not be covered. However, the pad must be designed in a manner that prevents the run-on of stormwater from adjacent areas. The pad must also be designed in a manner that allows the collection of all rain that falls on the pad.

See BMP S1.30 for information on the transfer of fuels from a tanker to the fuel storage tanks and BMP S1.40 regarding the installation of the tanks.

IV-4.1 Details of Fuel Island



**IV-4.2 BMP S1.20 VEHICLE/EQUIPMENT WASHING AND STEAM CLEANING**

If vehicle and/or equipment washing or steam cleaning is done on premises, the following measures are required.

Washing of highway vehicles, equipment and parts such as construction equipment, shall occur in a building or in a designated area such as that described below. This requirement refers to all methods of washing in which water is used including low-pressure water, high-pressure water and steam.

Wash water from cleaning activities contains significant quantities of oil and grease, suspended solids, heavy metals, and organics, as well as pollutants from the detergents.

Oil/water separators tend to be ineffective because the surfactants in detergents chemically stabilize free and dispersed oil.

**GENERAL REQUIREMENTS**

Wash water from vehicle and equipment cleaning shall be discharged to the sanitary sewer. All requirements of the local Sewer Authority and/or other permit requirements must be met prior to discharge. The owner shall conduct washing in one of the following locations in order of preference:

1. At a commercial washing business in which the washing occurs in an enclosure (see Chapter IV-2, "Car and Truck Washes") and drains to the sanitary sewer or;
2. Inside the owner's vehicle or equipment building which is plumbed to drain to the sanitary sewer or;
3. In a building the owner has constructed specifically for washing of vehicles and equipment which is plumbed to drain to the sanitary sewer or;
4. In an outside area without walls and/or roof designated by the vehicle owner as a wash area, meeting the requirements outlined below.

The use of mobile wash services is not allowed unless the wash water can be contained and discharged to a sanitary sewer per the requirements of the local Sewer Authority or discharged into and be treated by a closed-loop recycling system. Exceptions to these General Requirements are noted below.

**REQUIREMENTS FOR UNCOVERED WASH AREAS**

A wash area without walls and/or roof is the least desirable option. Building roofs and walls prevent entry of precipitation, and walls contain wash water. These standards are designed to prevent release of petroleum compounds and metals into the environment and minimize the discharge of precipitation to the sanitary sewer. If the owner chooses to conduct washing operations in an outside area the owner shall establish a designated wash area with the following features:

1. Paved, preferably with portland cement, and constructed as a spill containment pad to prevent the run-on of stormwater from adjacent pavement areas. The spill containment area shall be graded so that all water is collected in a containment pad drain system. The drain system may be perimeter drains, trench drains or catchment drains. The containment pad shall be sized to extend out a minimum of four feet on all sides of the vehicles and/or equipment being washed.



2. All wash water shall discharge to the sanitary sewer, process treatment or a dead-end sump. All requirements of the local Sewer Authority and/or other permit requirements must be met prior to discharge;
3. The discharge shall be treated by one of the following methods:
  - Pass through an SC-type (spill control) oil/water separator (or an API or CPS oil/water separator as directed by the local Sewer Authority) and shall comply with the pre-treatment requirements of the local Sewer Authority (R.1 in Chapter IV-5). Although the detergents in the wash water will tend to disperse the oil, a well-maintained SC-type oil/water separator will protect against deliberate dumping. A positive control valve is required (see #4 below).
  - Discharge to a containment sump with a positive control valve (see #4 below), live containment volume and overflow with oil/water separation. The minimum live storage volume shall be sized for the 6-month, 24-hour storm for the area of the containment pad.
4. The discharge pipe shall have a positive control valve that is shut when washing is not occurring, thereby preventing the entry of stormwater. This valve may be manually operated but a pneumatic or electric valve system is preferable. Signs shall be posted to inform people of the operation and purpose of the valve. The valve may be on a timer circuit; where it is opened upon completion of a wash cycle. The timer would then close the valve after the sump or separator is drained. The recommended time period for the timer would be the time required to drain the sump live storage at the design oil/water separator inflow rate from the sump.
5. In areas where the wash water cannot be discharged to a sanitary sewer, wash water should be collected in a dead-end sump, tank, or other device and transported to the nearest sanitary facility for proper disposal.
6. A portland cement spill containment pad is recommended for steam cleaning.
7. The wash area shall be well marked at gas stations, multi-family residences and any other business where vehicles may be washed by non-employees. Included in the posting will be a statement forbidding the changing of oil in the wash area. The location of the nearest oil recycling facility should be posted. See Figure IV-4.2 for an illustration of these requirements.

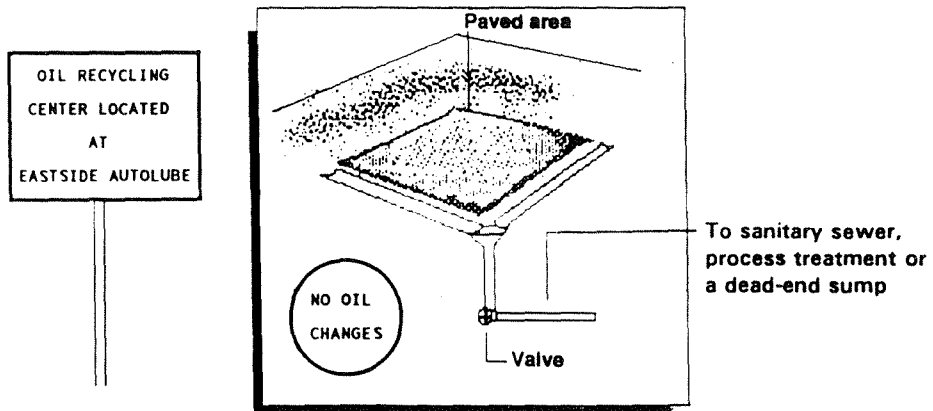
#### EXCEPTIONS

1. At existing gas stations where it is not possible to have the designated area discharge to a sanitary sewer, the station can, whenever extensive vehicle washing is occurring (such as washing cars to raise charity funds), place a temporary plug in the storm drain and pump the accumulated water to the nearest sanitary sewer.

Local governments can help this solution by making the equipment available and obtaining the approval of the local Sewer Authority if the sewers are not owned by the local government responsible for the public storm drains.
2. Dealerships of new and used automobiles or trucks may wash the vehicles in the parking stalls as long as only water is used. Soaps, detergents and cleaners shall not be used. Soaps, detergents and cleaners are all "biodegradable" to a certain extent, but the word "biodegradable" has no legal definition in this state. As a result, manufacturers can make claims which in some cases may be misleading. The dealership can also use the temporary plug system outlined above for gas stations.

3. Truck washes at industrial sites which are used to prevent the tracking of dirt, sediment and floatable materials such as wood, onto public streets can discharge to the storm drain. However, the wash water shall pass through a catchbasin and oil/water separator. Soaps and other cleaners shall not be used if the wash water is discharged to the storm drain.

Figure IV-4.2 Requirements for an Uncovered Wash Area



**IV-4.3 BMP S1.30 LOADING AND UNLOADING LIQUID MATERIALS**

If loading or unloading occurs of liquids in containers or direct liquid transfer occurs, then the following BMPs apply.

Consistent with Uniform Fire Code requirements (R.2 in Chapter IV-5) and to the extent possible, unloading or loading of liquids should occur in the manufacturing building so that any spills that are not completely retained can be discharged to the sanitary sewer, process treatment or a dead-end sump consistent with local Sewer Authority and permit requirements.

Practices are described below for areas where loading is done outside and loss to storm drains could occur.

**CONTAINED LIQUIDS AT LOADING AND UNLOADING DOCKS**

1. Loading/unloading docks shall have overhangs or door skirts that enclose the trailer end (see Figures IV-4.3 and IV-4.4).
2. The loading/unloading area is to be designed to prevent run-on of stormwater.
3. The owner shall retain on site the necessary materials for rapid cleanup of spills (see BMP S1.80).

**RAIL TRANSFER TO ABOVE/BELOW-GROUND STORAGE TANKS**

1. To minimize the risk of accidental spillage, the owner shall have a written "operations plan" that describes procedures for loading and/or unloading. Employees shall be trained in its execution and it shall be posted or otherwise made easily available to employees.
2. As a part of the operations plan, or as a separate document, the owner shall have an Emergency Spill Cleanup Plan (BMP S1.80).
3. Drip pans shall be placed at locations where spillage may occur such as hose connections, hose reels and filler nozzles. Drip pans shall always be used when making and breaking connections (see Figure IV-4.5).
4. A drip pan system as illustrated shall be installed within the rails to collect spillage from tank cars (see Figure IV-4.6).
5. An employee trained in spill containment and cleanup shall be present during loading/unloading.

Figure IV-4.3 Dock With Door Skirt

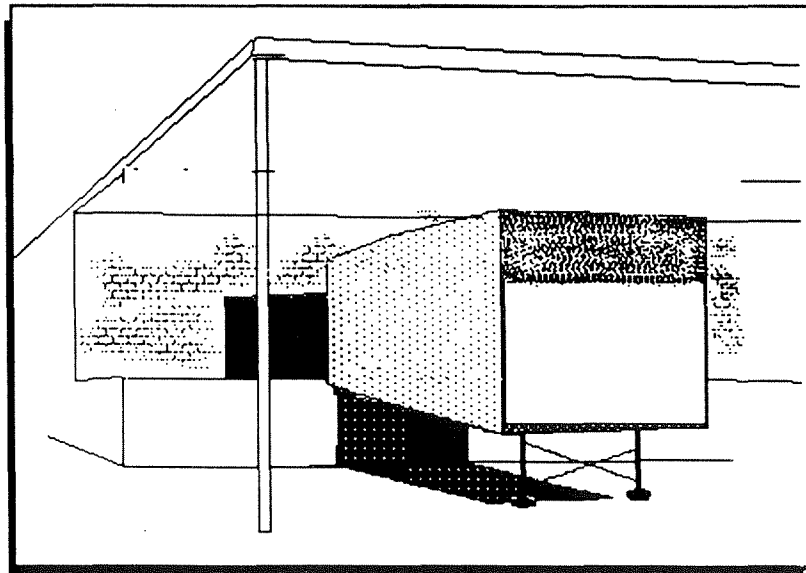
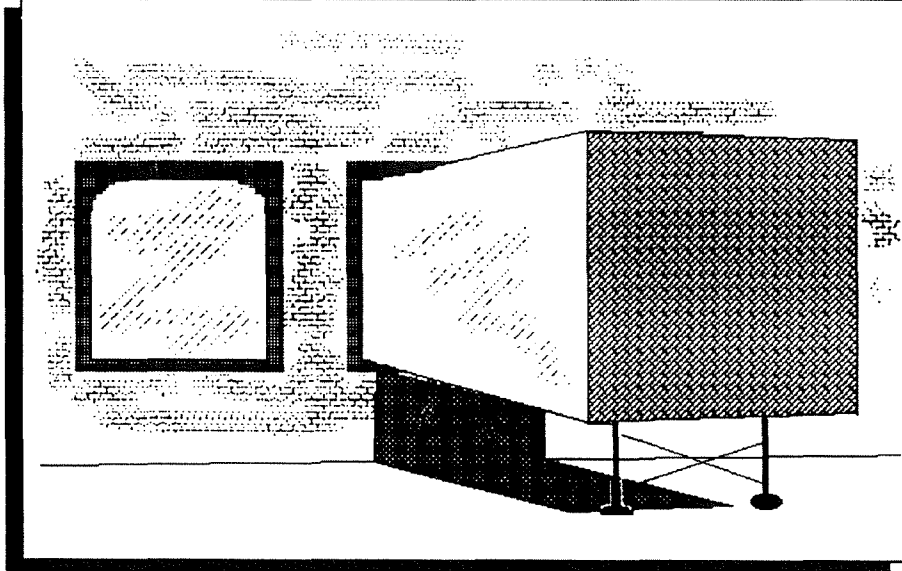


Figure IV-4.4 Dock With Overhang

Figure IV-4.5

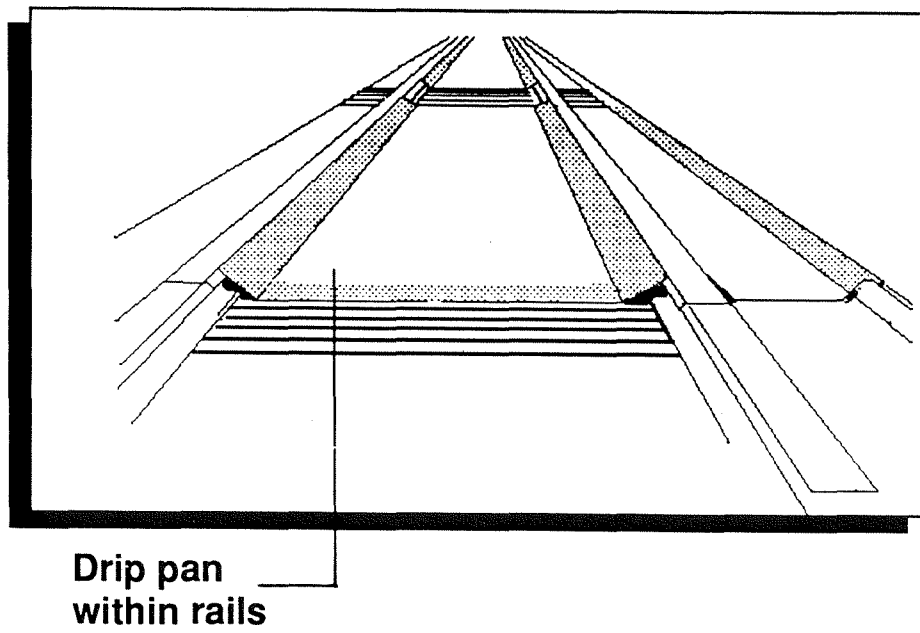
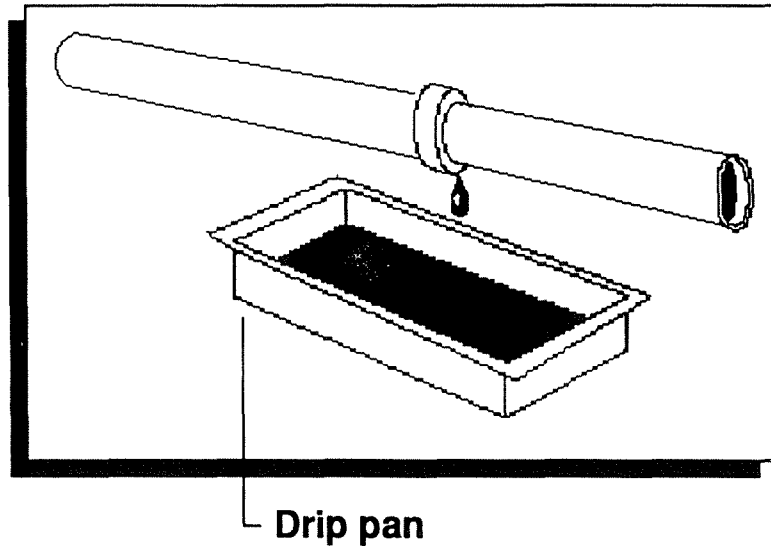


Figure IV-4.6

TANKER TRUCK TO ABOVE/BELOW-GROUND STORAGE TANKS

1. To reduce the risk of spills, the owner shall have a written "operations plan" describing procedures for loading and/or unloading. Employees shall be trained in its execution.
2. The operations plan will include an emergency spill cleanup plan. (BMP S1.80). Cleanup materials shall be readily available and employees will be trained in their use.
3. The area on which the transfer takes place shall be paved. If the liquid is reactive with asphalt (for example, gasoline) Portland cement concrete shall be used to pave the area.
4. The transfer area shall be designed to prevent the run-on of stormwater from adjacent areas. This may be achieved by sloping the pad and surrounding area in a appropriate manner, or with a small, flattened curb (like a small speed bump) around the "uphill" side of the transfer area;
5. The transfer area shall be designed to prevent the runoff of any spilled liquids from the area. This can be accomplished by sloping the area to a drain. The drain shall be connected to a dead-end sump or to the sanitary sewer subject to the requirements of the local Sewer Authority. For the latter two situations, a positive control valve shall be installed.
6. If the transfer area is connected to the sanitary sewer, a spill containment sump should be installed between the spill containment pad and the sewer connection. The sump should be large enough to include 50 gallons of storage space, grit sedimentation volume and a manual drain shut-off valve. Instructions in its use should be prominently posted. Alternatively, an API or CPS oil/water separator sized for a 15 minute retention time at the greater flow rate of the: greatest fuel dispenser nozzle through-put rate of the peak flow rate of the 6-month, 24-hour storm event over the surface of the containment pad.
7. Drip pans shall be placed at locations where spillage may occur such as hose connections, hose reels and filler nozzles. Drip pans shall always be used when making and breaking connections (see Figure IV-4.5).

LOADING AND UNLOADING FROM OR TO MARINE VESSELS

Facilities and procedures for the loading or unloading of petroleum products must comply with Coast Guard requirements (R.5 in Chapter IV-5).

TRANSFER OF SMALL QUANTITIES FROM TANKS AND CONTAINERS

See BMPs S1.40 and S1.50 for requirements on the transfer of small quantities from tanks and containers, respectively.

**IV-4.4 BMP S1.40 LIQUID STORAGE IN ABOVE-GROUND TANKS**

Any business which stores liquids in above-ground tanks shall comply with the following practices.

Storage of reactive, ignitable, or flammable liquids must comply with the Uniform Fire Code (R.2 in Chapter IV-5). The following practices are to complement, not conflict with the Uniform Fire Code. Below-ground tanks shall comply with Ecology requirements (R.6 in Chapter IV-5).

**PERMANENT TANK STORAGE**

1. The tank shall include an overfill protection system to minimize the risk of spillage during loading.
2. Permanently installed tanks shall be surrounded by dikes as illustrated in Figure IV-4.7. The dike shall be of sufficient height to provide a volume that is the greater of either 10% of the total enclosed tank volume or 110% of the volume contained in the largest tank.
3. The dikes and the surface within the dike area shall be sufficiently impervious to prevent loss of the stored material in the event of spillage.
4. Outlets from the tank area shall have positive control to prevent uncontrolled discharge from the tank area of spilled chemicals or petroleum products.
5. The outlet shall have a dead-end sump for the collection of small spills. It shall be cleaned weekly to minimize the potential for contamination of stormwater and/or ground water.
6. During the wet season, accumulated stormwater shall be released frequently.
7. For petroleum tank farms, the stormwater shall pass through an API or CPI-type oil/water separator (BMP RD.35, Volume III, Runoff Control).
8. If a tank is to be located in an area where firearms may be discharged, concrete encapsulation (or equivalent) should be used to protect the inner tank.
9. Tanks should be guarded against vehicles through the use of bollards or traffic barriers.
10. All installations shall be done per the Uniform Fire Code and the National Electric Code.
11. Double walled tanks do not need containment systems. All double-walled tanks should be UL approved.

**SMALL PORTABLE TANK STORAGE**

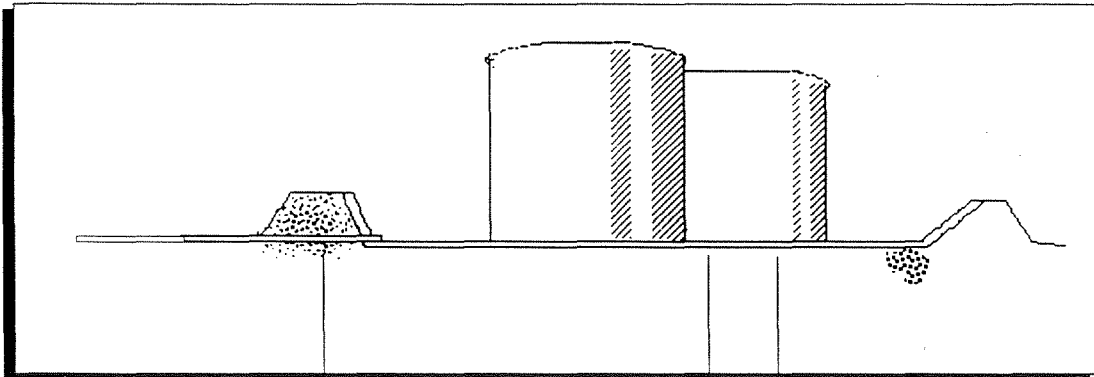
Where portable, double-hulled tanks are used to contain fuels for servicing vehicles, a diking system as described above need not be used.

1. A secondary containment system (or equivalent) similar to that shown shall be used whenever liquids are temporarily stored in a portable tank (see Figure IV-4.8).
2. The containment system should be a bermed impervious area (using either heavy mil plastic or portland cement). The minimum storage volume shall be 100% of the total tank volume.

3. If a tank is to be located in an area where firearms may be discharged, concrete encapsulation (or equivalent) should be used to protect the inner tank.
4. Tanks should be guarded against vehicles through the use of bollards or traffic barriers.
5. All tank installations should be per the Uniform Fire Code and the National Electric Code.



Figure IV-4.7 Above-Ground Tank Storage

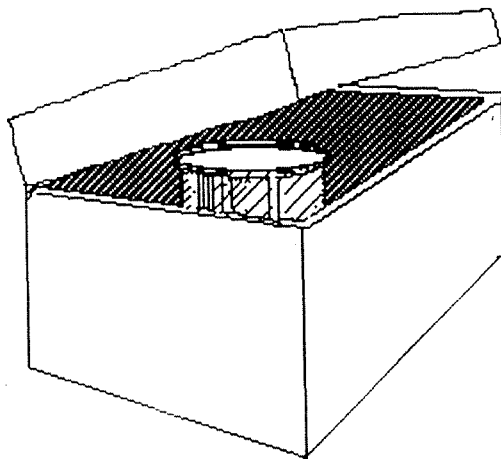


The dike shall provide a volume that is the greater of either 10% of the total enclosed tank volume or 110% of the volume contained in the largest tank.

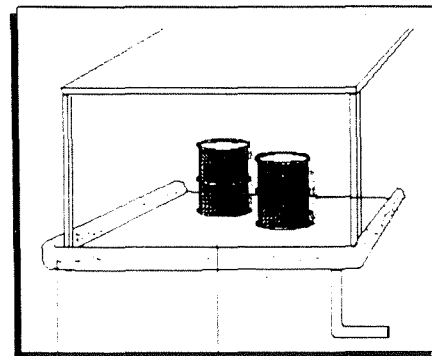
Impervious surface

Permanently installed tanks surrounded by dike system

Figure IV-4.8 Secondary Containment System



Container completely encloses storage tank



The dike shall provide a volume that is the greater of either 10% of the total enclosed tank volume or 110% of the volume contained in the largest tank.

Covered, designated area

Figure IV-4.9 Covered and Bermed Containment Area

## IV-4.5 BMP S1.50

CONTAINER STORAGE OF LIQUIDS, FOOD WASTES  
OR DANGEROUS WASTES

A container is any portable device in which material is stored. These practices apply to container(s) located outside a building used to temporarily store accumulated food wastes, vegetable or animal grease, used oil, liquid feedstock or cleaning chemical, or Dangerous Wastes (liquid or solid) unless the business is permitted by Ecology to store the wastes (R.4 in Chapter IV-5).

- Containers used to store Dangerous Waste, food waste, or other liquids shall be kept inside a building unless this is impracticable due to site constraints or Uniform Fire Code requirements. If the containers are placed outside, the requirements of this BMP must be met.
- Dumpsters used to store items awaiting transfer to a landfill (such as used oil filters) shall be placed in a lean-to structure. Dumpsters shall be in good condition without corrosion or leaky seams. See below for the exact requirements.
- If waste container drums are stored above ground, they shall be kept in an area such as a service bay. If drums are kept outside, they must be stored in a lean-to type structure to keep rainfall from reaching the drums. See below for the exact requirements.
- Garbage dumpsters shall be replaced if they are deteriorating to the point where leakage is occurring. They shall be kept under cover to prevent the entry of stormwater (see below).

Storage of reactive, ignitable, or flammable liquids must comply with the Uniform Fire Code (R.2 in Chapter IV-5). The following practices shall complement, not conflict, with current Uniform Fire Code requirements.

1. Containers shall be located in a designated area.
2. The designated area shall be paved, free of cracks and gaps and impervious in order to contain leaks and spills.
3. For liquid wastes, tanks shall be surrounded by dikes as illustrated in Figure IV-4.9. The dike shall be of sufficient height to provide a volume that is the greater of either 10% of the total enclosed tank volume or 110% of the volume contained in the largest tank.
4. The designated area shall be covered (see Figure IV-4.9).
5. The area inside the curb shall slope to a drain. If the material being stored is controlled by the Uniform Fire Code, or is used oil or Dangerous Waste a dead-end sump shall be installed.

For all other liquids the drain shall be tied to the sanitary sewer if available. Otherwise, process treatment or a dead-end sump shall be used subject to local Sewer Authority or permit requirements. The drain must have positive control (for example, a locked drainage valve or plug) to prevent release of contaminated liquids.

6. If the business is using roll-containers (for example, dumpsters) that are picked up directly by the collection truck, a filet can be placed on both sides of the curb to facilitate moving the dumpster.
7. Businesses accumulating Dangerous Wastes that do not contain free liquids need not carry out items #3 through #5 above if the designated area is sloped and

the containers are elevated or otherwise protected from storm water run-on.

8. Where material is temporarily stored in drums, a containment system can be used as illustrated, in lieu of the above system (see Figure IV-4.10). If a tank is to be located in an area where firearms may be discharged, concrete encapsulation (or equivalent) should be used to protect the inner tank.
9. Containers mounted for direct removal of a liquid chemical for use by employees must be placed inside a containment area as described above. A drip pan shall be used at all times (see Figure IV-4.11).
10. Drums stored in an area where unauthorized persons may gain access must be secured in a manner that prevents accidental spillage, pilferage or any unauthorized use (see Figure IV-4.12).
11. If the material is a Dangerous Waste, the business owner shall comply with any additional Ecology requirements (See R.3 in Chapter IV-5) not presented above.
12. If a storage area is to be used on-site for less than 30 days, a portable secondary system like that shown in Figure IV-4.10 can be used in lieu of a permanent system as described above.
13. An employee trained in emergency spill cleanup procedures shall be present when Dangerous Wastes, liquid chemicals or other wastes are loaded or unloaded (see BMP S1.80).

Figure IV-4.10  
Temporary Drum Containment  
System

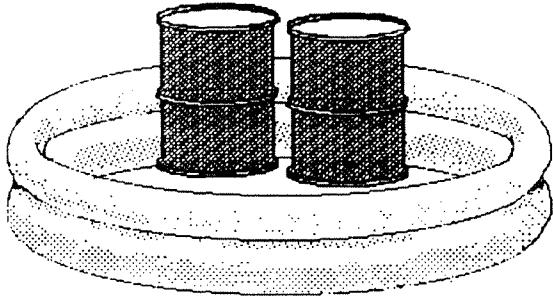
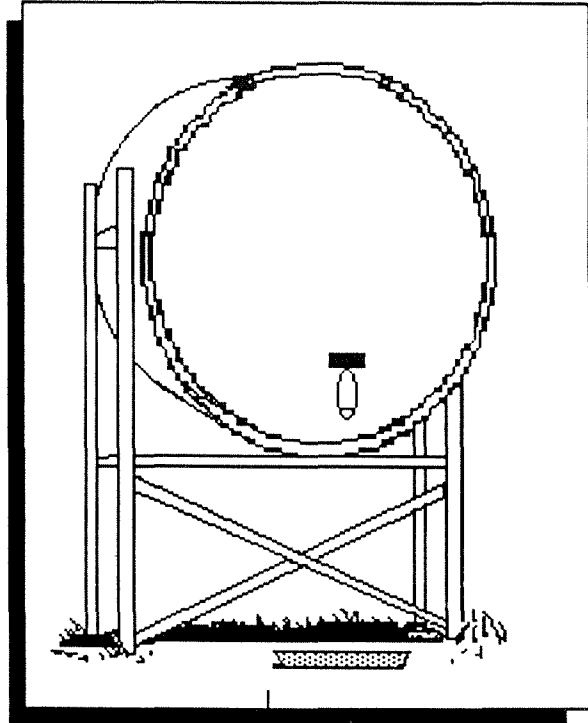


Figure IV-4.11  
Mounted Container With  
Drip Pan



Mounted  
container  
with drip pan

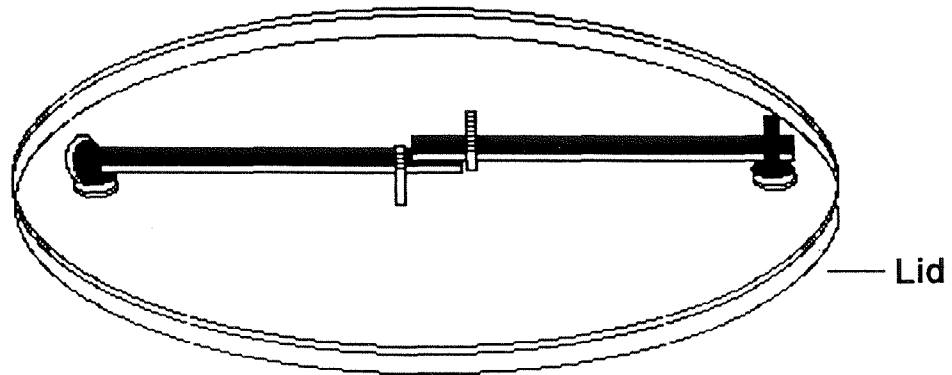


Figure IV-4.12  
Locking System for Drum Lid

**IV-4.6 BMP B1.60 OUTSIDE STORAGE OF RAW MATERIALS, BY-PRODUCTS  
OR FINISHED PRODUCTS**

If the raw material, by-product or product is a liquid see the previous BMP. This section covers solid material.

This BMP is for:

1. Material such as gravel, sand, topsoil, compost, logs, sawdust, wood chips;
2. Lumber and other building materials;
3. Concrete and metal products.

The business shall select one of the following practices appropriate to the type of material:

1. Build a covered area as shown in Figure IV-4.13. The area upon which the materials is stored shall be paved or;
2. Place temporary plastic sheeting over the material as illustrated (see Figure IV-4.14) or;
3. Pave the area and install a drainage system. Stormwater from the area shall be treated using one of the treatment systems presented in Volume III, Runoff Control. This is the preferred option for log storage.

With Option #3, the paved area shall be sloped in a manner that minimizes the pooling of water on the site, particularly with materials that may leach pollutants into stormwater and/or ground water such as compost, logs and wood chips. A minimum slope of 1.5 percent is recommended. Curbing shall be placed along the perimeter of the area to prevent the run-on of uncontaminated stormwater from adjacent areas as well as runoff of stormwater from the stockpile area.

The storm drainage system shall be designed to minimize the use of catchbasins in the interior of the area, as they tend to rapidly fill with the manufacturing material. Rather, the area should be sloped to drain stormwater to the perimeter where it can be collected, or to internal drainage "alleyways" where material is not stockpiled.

Figure IV-4.13 Covered Storage Area for Raw Materials

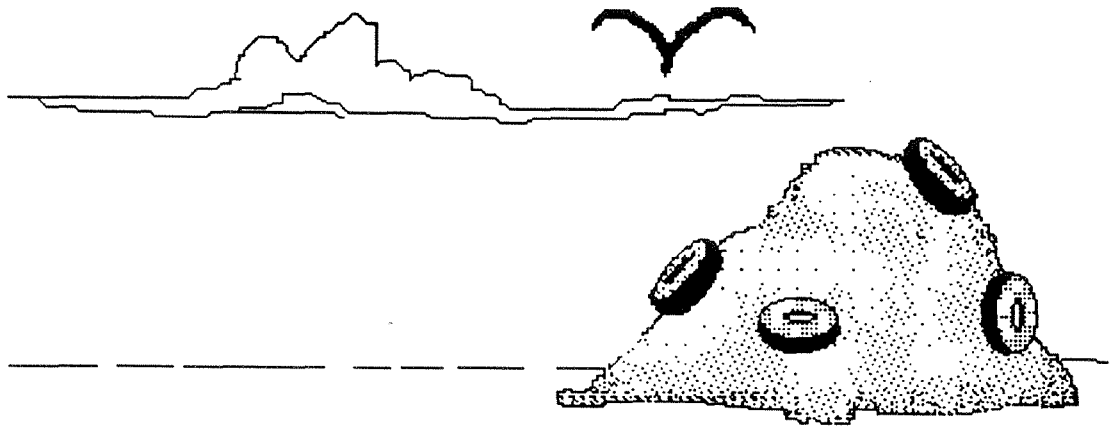
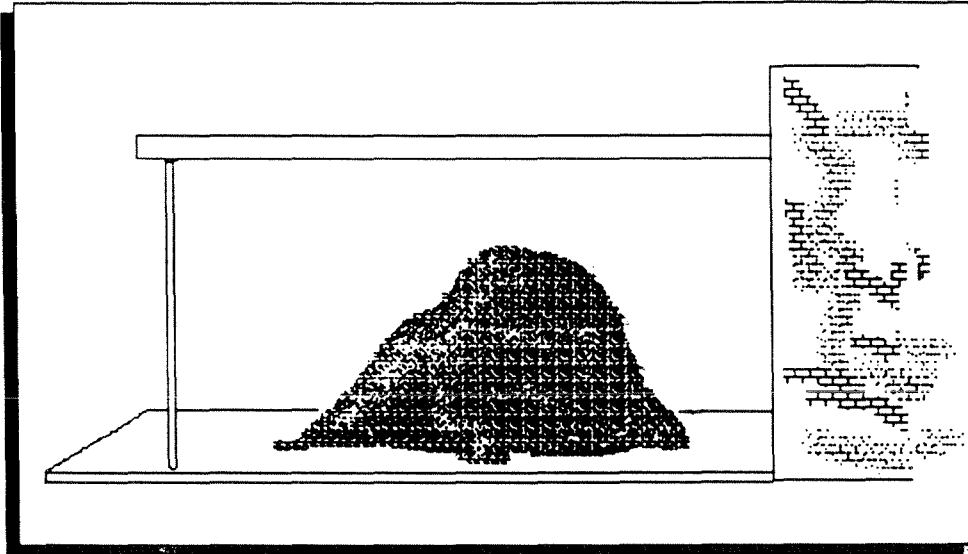


Figure IV-4.14 Material Covered with Plastic Sheeting

#### IV-4.7 BMP S1.70 OUTSIDE MANUFACTURING ACTIVITIES

These practices should be used by those businesses identified in Chapter IV-2 that carry out manufacturing activities in an area exposed to precipitation.

##### ALTER THE ACTIVITY

The preferred option is to alter the activity so that pollutants are no longer discharged. If altering the practice will not significantly reduce the concentration of the pollutants, further actions as described below must be taken.

##### ENCLOSE THE ACTIVITY (see Figure IV-4.14)

If possible, the manufacturing activity should be completely enclosed in a building and the floor drains connected to the sanitary sewer. The allowable concentration of pollutants is then specified by the local Sewer Authority (R.1 in Chapter IV-5). The area used may be so great as to make enclosure prohibitively expensive.

Costs of this BMP may be increased if the building code of the local jurisdiction requires a certain number of parking spaces be provided with a building even though its construction will not alter the nature of the manufacturing activity and therefore the number of employees.

##### COVER THE ACTIVITY (see Figure IV-4.15)

The cost of a building can be significantly reduced by not covering the sides, thus eliminating the need for ventilating and lighting systems. Floor drains shall be connected to the sanitary sewer.

If rejected asphalt is temporarily stored on-site before disposal, it shall be covered.

##### SEGREGATE THE ACTIVITY

Certain parts of the activity may be the worst source of pollutants. Those parts can be segregated and enclosed or covered. Their drains can then be hooked to the sanitary sewer, process treatment or a dead-end sump depending upon available methods and applicable permit requirements.

A method commonly used in large industrial complexes where much of the process equipment is exposed is to place curbing around the immediate boundary of the individual processes. The storm drains from these interior areas discharge to the process wastewater treatment system.

##### DISCHARGE OF HIGH FREQUENCY STORMS TO THE PUBLIC SANITARY SEWER

Businesses that utilize the public sanitary sewer system for their process or sanitary discharges may be able to utilize the public sewer for stormwater treatment under the following conditions.

If the segregated area is very small (less than a hundred or so square feet), the local Sewer Authority may be willing to allow the area to remain uncovered with the drain connected to the sanitary sewer (R.1 in Chapter IV-5).

It may be possible under unusual circumstances to connect a much larger area to the sanitary sewer if the rate of stormwater discharge is matched to the capacity of the sewer. This approach will be limited to a small number of industries with outside activities that produce pollutants of particular concern.

Figure IV-4.15 Enclose the Activity

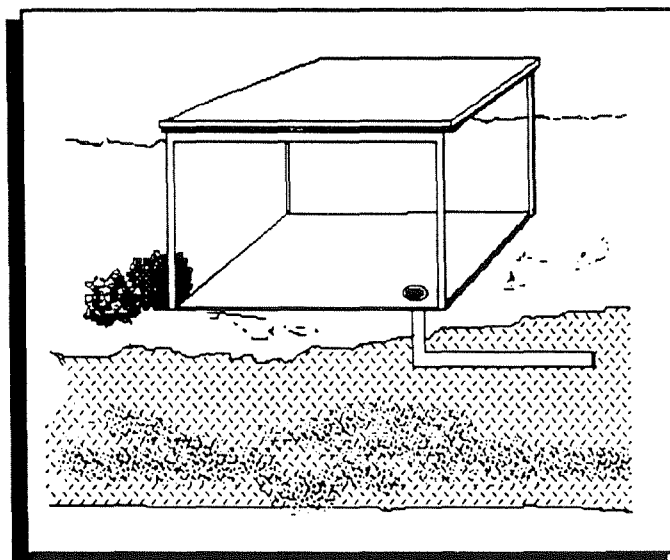
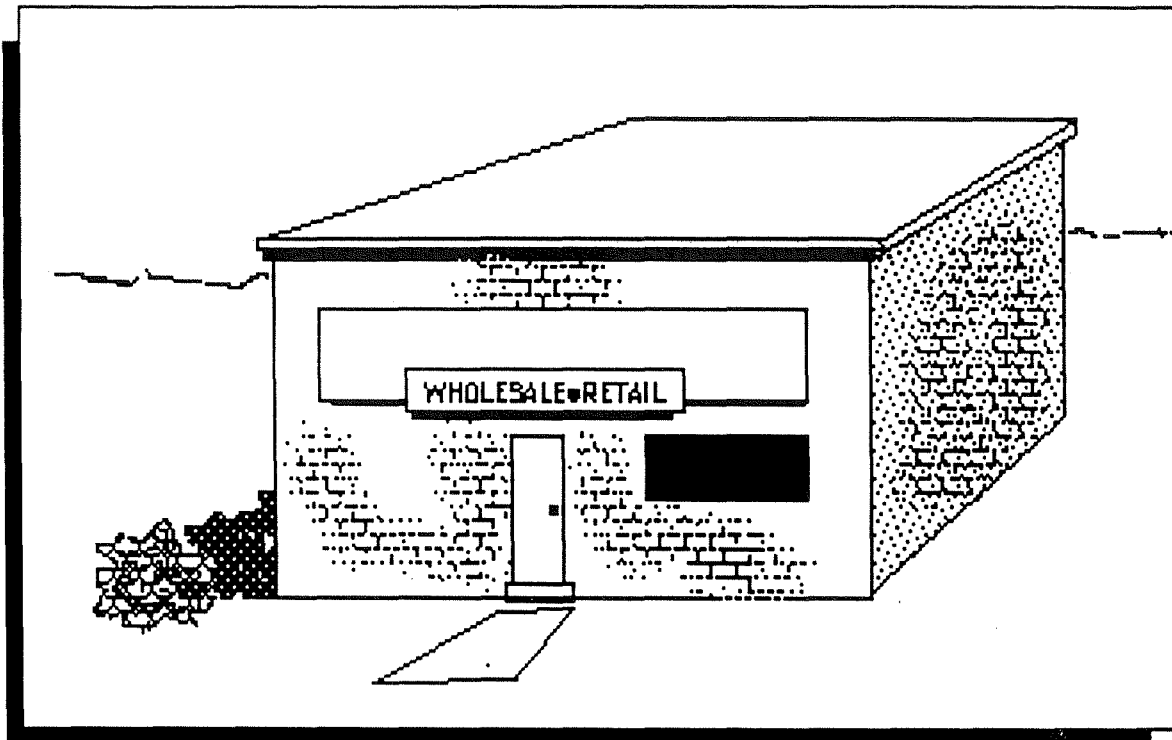


Figure IV-4.16 Cover the Activity



Since the majority of the pollutants in stormwater are discharged over time by the small, high frequency storms, the excess runoff from the infrequent large storms can be bypassed to the storm drain. To comply with the goals of this manual the sanitary sewer must have sufficient capacity to take a peak stormwater flow equivalent to the runoff of the water quality design storm (the 6-month, 24-hour storm - See Appendix AI-2.1 in Volume I). Stormwater discharge rates in excess of this value are bypassed to the storm drain.

If the sewer does not have the capacity to handle the 6-month storm peak-rate, a detention facility can be installed with a volume sufficient to reduce the peak rate to the capacity of the sewer (Volume III, Runoff Control).

Any discharge to a public sanitary sewer must meet the requirements of the local Sewer Authority (R.1 in Chapter IV-5).

To implement this BMP a hydraulic evaluation of the "downstream" sewer system shall occur in consultation with the local Sewer Authority.

#### DISCHARGE TO THE BUSINESSES' PROCESS WASTEWATER TREATMENT SYSTEM

Industries that generate large volumes of process wastewater typically have their own wastewater treatment system that discharges directly to the nearest receiving water. These industries shall have the discretion to use their own wastewater treatment system to treat stormwater within the constraints of their NPDES permit requirements for process treatment.

The industry may also choose to discharge the stormwater directly to its effluent outfall without treatment as long as the total loading of the discharge process water and stormwater does not exceed the loading had a stormwater treatment device been used. In effect, the allowable discharge of pollutants from the process wastewater treatment system is reduced. This option would be subject to permit constraints and, potentially, regular monitoring.

#### STORMWATER TREATMENT

If none of the above BMPs can be implemented then one of the treatment methods presented in the Runoff Control Volume shall be installed.

**IV-4.8 BMP S1.80 EMERGENCY SPILL CLEANUP PLANS**

Owners of facilities engaged in storing, processing, or refining oil and/or oil products are required by Federal Law to have a Spill Prevention and Control Plan (SPCC). Owners of businesses that produce Dangerous Wastes are required by State Law to have a spill cleanup plan. These businesses should also refer to R.7 in Chapter IV-5.

The businesses and public agencies identified in Chapters IV-2 and IV-3 of this manual that are required to have an Emergency Spill Cleanup Plan shall follow these general guidelines in its preparation.

1. The first part of the plan shall contain a description of the facility including the owner's name and address, the nature of the facility activity and the general types of chemicals used in the facility.
2. The plan shall contain a site plan showing the location of storage areas for chemicals, the locations of storm drains, and the direction of slopes towards those drains, and the location and description of any devices to stop spills from leaving the site such as positive control valves.
3. The plan shall describe notification procedures to be used in the event of a spill, such as key personnel, and agencies such as Ecology and the local Sewer Authority.
4. The plan shall provide instructions regarding cleanup procedures.
5. The owner shall have a designated person with overall spill response cleanup responsibility.
6. Key personnel shall be trained in the use of this plan. All employees should have basic knowledge of spill control procedures.
7. A summary of the plan shall be written and posted at appropriate points in the building, identifying the spill cleanup coordinators, location of cleanup kits, and phone numbers of regulatory agencies to be contacted in the event of a spill.
8. Cleanup of spills shall begin immediately. No emulsifier or dispersant shall be used.
9. In fueling areas: absorbent should be packaged in small bags for easy use and small drums should be available for storage of absorbent and/or used absorbent.
10. Absorbent material shall not be washed down the floor drain or storm sewer.
11. Emergency spill containment and cleanup kit(s) shall be located at the facility site. The contents of the kit shall be appropriate to the type and quantities of chemical liquids stored at the facility. The kit might contain appropriately lined drums, absorbent pads, and granular or powdered materials for neutralizing acids or alkaline liquids. Kits should be deployed in a manner that allows rapid access and use by employees. This plan shall be updated regularly.
12. Ecology and the local Sewer Authority shall be notified immediately if the spill may reach sanitary or storm sewers, or surface water.

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**IV-4.9 BMP S1.90 VEGETATION MANAGEMENT/INTEGRATED PEST<sup>1</sup> MANAGEMENT**

Two very different types of vegetation management are used by businesses. The first type of management is necessary for businesses such as public and private utilities. Their need is to minimize the growth of vegetation in undesirable locations such as utility corridors. Other businesses, such as public and private golf courses and parks need to manage desirable vegetation for luxuriant growth and beauty. Many businesses have at least a minimal amount of landscaping around their building that they wish to maintain.

In short, one type of business wants to minimize the presence of vegetation where the other wishes to maximize it. Both types of businesses, whether using herbicides to be rid of undesirable vegetation, pesticides to reduce pest infestations or fertilizers to promote vegetative growth need to implement these practices in an intelligent, environmentally sound fashion.

**PRACTICES FOR BUSINESSES WISHING TO PROMOTE PLANT GROWTH****Seeding and Planting BMPs**

Businesses who wish to use temporary or permanent seeding, or who intend to plant vegetation should refer to the following BMPs found in Volume II, Erosion and Sediment Control:

BMP E1.10 Temporary Seeding

BMP E1.15 Mulching and Matting

BMP E1.20 Clear Plastic Covering

BMP E1.35 Permanent Seeding and Planting

BMP E1.40 Sodding

These BMPs provide information on grass mixtures, temporary and permanent seeding, maintenance of a recently planted area and fertilizer application rates.

**INTEGRATED PEST MANAGEMENT**

Integrated Pest Management (IPM) is a long-term, ecologically based systems approach to controlling pest populations that utilizes a needs assessment based on decision-making criteria. IPM maximizes reliance on natural pest controls. IPM has two fundamental aims. The first is to steer pesticide<sup>2</sup> use away from prophylactic, broad spectrum use towards optimized selective use, using the various IPM components to guide decision-making and achieve an economically justifiable income. The second is to recognize that the non-economic consequences of pest control (and not just pesticide use) may be harmful to the environment, and so pesticide inputs should be reduced and natural controls maximized in order to minimize the environmental side effects (1).

Integrated control is a pest management system that utilizes all suitable techniques either to reduce pest populations and maintain them at levels below those causing economic injury, or to so manipulate the populations that they are prevented from causing such injury.

<sup>1</sup> As used in this BMP, pest is defined to mean any agent, whether insect, fungal, bacterial or vegetation which causes damage or as in the case of weeds, is in the wrong place at the wrong time.

<sup>2</sup> As used here, the term pesticide includes those chemicals commonly known as pesticides, rodenticides, fungicides, nematicides and herbicides unless otherwise specifically indicated.

Integrated control achieves this ideal by harmonizing techniques in an organized way, by making the techniques compatible and blending them into a multifaceted, flexible system (2).

The major components of IPM are:

- Initial information gathering: The pest and/or problem needs to be identified. Information should be collected on the biology of the pest and its management, and previous methods used to manage the pest in the area. Records should be kept in some manner of on-going activities.
- Monitoring: Observe the plants or the site for potential pest problems at regular intervals. Each monitoring system needs to be tailored to the particular situation, and the level of effort should be appropriate to the amount of damage caused by the pest, the time available, and the skill level of the person making the inspections.
- Establishing injury levels: an injury or tolerance level is used to determine if the problem is serious enough to justify some kind of treatment. A trade-off needs to be made between the amount of damage done versus the cost of control. An injury level should be determined for each potential pest, and that level should be compared with field samples or observations before any action is taken.
- Record-keeping: Records should be kept of what is seen, decisions made, actions taken, and results. Records are the memory of the systems. When personnel leave, their experience is lost if there are no records.
- Least-toxic treatments: Treatment strategies should be chosen that are the least disruptive of natural controls, least hazardous to human or non-target organisms health, least damaging to the general environment, the most likely to produce a permanent reduction in the environment's ability to support that pest, and the most cost-effective in the short and long term. The most energy and cost-effective pest management strategy in the long term is to redesign the system to eliminate the life support systems required by the pests.
- Evaluation and adjustment: Inspect after the treatment action has been taken. Has the treatment been worthwhile? How can the whole process be improved to achieve the overall objectives of the program? (3)

Pesticides are used only where other techniques are not adequate or possible to use. Prevention is a major component of IPM and can be best addressed at the program design stage. (4).

Scouting can regularly be done by work and road crews for insect and weed infestations so that some sort of early action can be taken. Prompt action against a pest before it becomes established means that less toxic methods of control such as hand weeding can be used instead of an herbicide or pesticide.

#### BMPS FOR THE USE OF PESTICIDES

1. A pesticide-use plan should be formulated and shall include at a minimum: a list of selected pesticides and their specific uses; brands, formulations, application methods and quantities to be used; equipment use and maintenance procedures; safety, storage, and disposal methods; monitoring and record keeping procedures and public notice procedures. All procedures shall conform to the requirements of Ch. 17.21 RCW and Ch. 16-228 WAC (see R.8 in Chapter IV-5).

2. Any control used should be done at the life stage when the pest is most vulnerable. For example, if it is necessary to use a Bacillus thuringiensis application to control tent caterpillars, it must be applied before the caterpillars cocoon or it will be ineffective. Any method used should be site-specific and not used wholesale over a wide area. Once an application is made, its effectiveness should be evaluated so that future treatment can be more finely tuned.
3. The pesticide chosen shall be the least toxic pesticide available that is capable of reducing the infestation to acceptable levels. The pesticide should readily degrade in the environment and/or have properties that strongly bind it to soil particles.
4. Documented evidence shall be provided showing the inapplicability of available alternatives.
5. An annual evaluation procedure should be developed and include a review of the effectiveness of treatments, buffers and sensitive areas, public concerns and complaints, and recent toxicological information on pesticides used or proposed for use.
6. Pesticides shall not be sprayed within 100 feet of open waters including wetlands, ponds, streams, sloughs and any drainage ditch or channel that leads to open water.
7. If required or recommended by the local government, public posting of the area to be sprayed shall be done prior to the application. All sensitive areas including wells, creeks and wetlands shall be flagged prior to spraying and a buffer strip of approximately 100 feet shall be used.
8. Spray application shall not occur during weather conditions indicated in the applicable WACs.
9. Spreader/stickers used shall be the least toxic and/or most target specific available.
10. Apply the pesticide according to label directions. Pesticides should be mixed, and equipment cleaned, in an area where accidental spills will not enter surface or ground waters, and will not contaminate the soil. Rinseate from equipment cleaning and/or triple-rinsing of pesticide containers should be used as product.
11. The application equipment used should be capable of immediate shutoff in the event of an emergency.

#### RESOURCES

Persons interested in finding out more information on IPM can contact the Bio-Integral Resource Center (BIRC), P.O. Box 7414, Berkeley, CA. 94707. They publish a number of reports and a periodical, "IPM Practitioner".

The Department of Ecology publishes "Hazardous Waste Pesticides" (#89-41) which can help to determine if a particular pesticide is a dangerous waste, and includes information on pesticide waste reduction.

EPA publishes "Suspended, Canceled and Restricted Pesticides" which lists all restricted pesticides and the specific uses which are allowed.

IV-4.10 BMP S2.00 MAINTENANCE OF STORM DRAINAGE FACILITIES

Proper maintenance of public and private stormwater facilities is necessary to insure they serve their intended function. In a study recently completed by the King County Conservation District (3), almost one-half the BMPs installed on large construction sites were not maintained. Without adequate maintenance, sediment and other debris can quickly clog facilities, making them useless. Rehabilitation of such facilities is expensive, and in the case of infiltration systems may be impossible. Polluted water and sediments removed during the cleaning operation must be properly disposed of.

MAINTENANCE STANDARDS

Local governments shall develop standards for the maintenance of public and private stormwater facilities. These standards shall include but need not be limited to the following:

1. Catchbasins, stormwater detention and treatment systems shall be inspected at least annually. A representative of the local government shall also inspect private facilities at least annually to insure compliance by the owner of the following maintenance requirements.
2. Any deterioration threatening the structural integrity of the facilities shall be immediately repaired. These include such things as replacement of clean-out gates, catchbasin lids, and rock in emergency spillways.
3. A catchbasin shall be cleaned if the depth of deposits are equal to or greater than 1/3 the depth from the basin to the invert of the lowest pipe into or out of the basin. If a catchbasin is found during the annual inspections to significantly exceed this standard, it shall be cleaned every 6 months. If woody debris is likely to accumulate in a catchbasin, it should be cleaned on a weekly basis.
4. Warning signs (e.g. "Dump No Waste - Drains to Ground Water", "Streams", "Lakes" etc.) shall be painted or embossed on or adjacent to all storm drain inlets. They shall be repainted as needed.
5. Debris shall be regularly removed from surface basins used for either peak-rate control or stormwater treatment.
6. Stormwater treatment facilities shall be maintained according to criteria or procedures presented in Volume III. (Maintenance requirements are detailed at the end of each BMP description).
7. Parking lots shall be swept when necessary to remove debris.

FINAL DISPOSAL OF CONTAMINATED WATER

(Ecology policy regarding disposal is under development by the Urban Non-Point Management Unit and is not available at this time.)

FINAL DISPOSAL OF CONTAMINATED SEDIMENTS

(Ecology policy regarding disposal is under development by the Urban Non-Point Management Unit and is not available at this time.)

**IV-4.11 BMP S2.10 LOCATING ILLICIT CONNECTIONS TO STORM DRAINS**

Illicit connections are sanitary or process wastewater drains located in a building that discharge to the storm drain, rather than to the sanitary sewer. An allowable exception is noncontact cooling water which may be discharged to a storm drain.

Experience has shown that illicit connections are very common, even in buildings constructed as late as the 1960's. Building owners are seldom aware that their drain lines are improperly connected since their sewer bills are tied to water use.

The following are general guidelines to assist local governments in establishing their programs.

1. Prioritize areas by age of structures. Give priority to buildings whose internal activities may cause water pollution if the drains are improperly connected.
2. Prepare a map of each area as it is to be surveyed. Show on the map the known location of storm drains and sanitary sewers. Aerial photos may be useful. Check records to identify known side sewer connections and show these on the map.
3. Conduct a field survey of the buildings to locate observable storm drains from buildings and paved surfaces. Note where these join the public storm drain.
4. Perform TV inspection of the storm drains and record with video tape that notes footage as the TV passes through the line.
5. Compare the observed locations of connections with the information on the map. Note suspect connections that are inconsistent with the field survey.
6. Remove significant accumulations of sediment from the storm drain system. Test the sediment before disposal (BMP R2.00, Section IV-5.10). Ask private property owners to clean their catchbasins and lines at the same time.
7. Determine whether each suspect connection is a storm drain or internal drain by inspection of the building and dye testing as necessary.
8. Inform private owners who have illicit connections of their obligation to connect to the sanitary sewer.

EPA is developing a "Draft Manual of Practice Identification of Illicit Connections", prepared by The Cadmus Group, Inc. and Triad Engineering, Inc. for Kevin Weiss at the USEPA Permits Division (EN-336), 401 M St. S.W., Washington D.C. 10460. The most current draft is dated September 7, 1990.

This USEPA manual covers outfall mapping, evaluation and analysis, identification of potential industrial sources, on-site investigation and field survey techniques in great detail.

## IV-4.12 BMP S2.20 STREET SWEEPING

Application: Street sweeping should be implemented for sites with high impervious cover. It should be implemented for programs designed to improve runoff quality from existing development sites. Sites which exhibit high levels of sediment on impervious surfaces should also implement aggressive source control measures to prevent accumulation of such sediments.

Street sweeping is a common maintenance method in most urban areas, but is seldom thought of as a means to control pollutants. Street sweeping refers to the removal of accumulated dust, dirt and debris from impervious streets surfaces with the use of mechanical cleaners. Street sweeping may be an effective method of pollutant control in highly urbanized areas where space is at a premium and retrofitting is difficult.

While traditional street sweeping has shown limited effectiveness at improving water quality there is evidence that it can be effective when better equipment and operating procedures are used. The City of Austin, Texas, (1) documented statistically significant improvements in water quality at a shopping mall located in a ground water recharge zone after implementation of an intensive sweeping program. Monitoring conducted before and after startup of the sweeping program documented that event mean concentrations dropped from 50 to 84 percent for particulate-type pollutants. The City concluded that pollutant concentrations from high-density development could be dropped with better maintenance and frequent parking lot sweeping.

Silverman and Stenstrom (3) argue that street sweeping could potentially be effective at removing oil and grease. They state that sweeping efforts would need to concentrate on locations which receive heavy deposits (e.g., curbs) and that innovative street sweeping technology needs to be developed.

The results of street sweeping in the Puget Sound basin seem to be less certain. The low intensity rains which occur in the Puget Sound basin rarely clear streets of all dirt and debris. Pitt and Bissonnette (2) found that in Bellevue, from 50 to 100 grams per curb-meter of street surface particulates remain on the streets after storms of about 6 mm or greater. Loading values would be much higher in areas with streets in poor condition. On the surface, it seems that sweepers used in this area would have a better opportunity to clean streets of all particulate pollutants.

However, Pitt and Bissonnette also concluded that street sweeping had little effect on water quality. A possible reason for this is that most pollutants adsorb on to silt and clay-size particles, which are the ones most likely to be removed by rainfall.

In order to remove these particles, the most efficient types of sweepers, such as regenerative air cleaners or vacuum sweepers must be used. No current conventional sweeper is effective in removing oil and grease (3).

## METHODS TO MAXIMIZE SWEEPING EFFICIENCY (4)

## 1. Number of passes and frequency:

- Increase the frequency of sweeping streets with high pollutant loadings, particularly in industrial areas
- Generally speaking, one pass can remove 50% of available solids, two passes provides 75% removal.
- Streets cleaned weekly will provide more removal efficiency; less frequent sweeping will accomplish little.



2. Equipment type and operation:

- As new sweepers are purchased, consider vacuum or regenerative air sweepers as these types are the most effective in removing the small particles most associated with pollutants.
- Train operators to attain maximum sweeper performance such that sweeper speed, brush adjustment and rotation rate, sweeping pattern, maneuvering around parked vehicles, interim storage and disposal methods result in optimal pollutant removal.

3. Pollutant loading/source reduction on street surfaces:

- Establish programs for prompt sweeping and removal of debris from special problem areas (special events, high litter or erosion zones).
- Develop, implement and enforce regulations for alternate side parking during cleaning operations, litter control, trash and refuse storage and disposal (especially yard debris, waste oil, etc.).
- Enforce construction site erosion controls.

4. Street maintenance:

- Include water quality benefits in cost analysis for street repair, particularly in high traffic zones in order to reduce the amount of particulates shaken from vehicles travelling over rough roads, and the amount of particulates generated from the deteriorating street surface itself.
- Consider improving street conditions in order to increase the effective of street sweeping.

5. Public awareness and support:

- Educate citizens and public officials about the multiple benefits available from an improved street sweeping program.
- Educate citizens about street pollutant source reduction by eliminating yard debris, oil and other wastes in street gutters.

References

- (1) Austin, City of, Stormwater Pollutant Loading Characteristics for Various Land Uses in the Austin Area, July, 1989.
- (2) Pitt, Robert and Pam Bissonnette, Bellevue Urban Runoff Program Summary Report, City of Bellevue, August, 1984.
- (3) Silverman, Gary S. and Michael K. Stenstrom, "Source Control of Oil and Grease in an Urban Area", in Design of Urban Runoff Quality Controls, ASCE, 1988.
- (4) Austin, City of, Inventory of Urban Nonpoint Source Pollution Control Practices: Application and Feasibility for Urban Watersheds Abatement Measures, Department of Environmental Protection, June, 1988.

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- (1) Burns, A.J., T.H. Coaker and P.C. Jepson, editors, Integrated Pest Management, Academic Press-Harcourt Brace Jovanovich, 1987.
- (2) Smith, Ray F. and Robert van den Bosch, "Integrated Control" in Pest Control - Biological, Physical and Selected Chemical Methods, Kilgore, Wendell W. and Richard L. Doult, editors, Academic Press, New York, 1967.
- (3) Olkowski, William, Helga Olkowski and Sheila Daar, "What is IPM?", in Common Sense Pest Control, Volume 3, Summer 1988.
- (4) Huffaker, C.B., "Fundamentals of Biological Weed Control", in Biological Control of Insect Pests and Weeds, DeBach, Paul, editor, Reinhold Publishing Corp., New York, 1964.
- (5) Letter to Stormwater Unit, Department of Ecology, from Washington Toxics Coalition dated January 31, 1990.

CHAPTER IV-5 OTHER REGULATORY REQUIREMENTS

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**IV-5.1 R.1 STORMWATER DISCHARGES TO PUBLIC SANITARY SEWERS,  
SEPTIC SYSTEMS, SUMPS AND PROCESS TREATMENT**

Discharging stormwater to a public sanitary sewer (BMP S1.70, Section IV-4.7) requires approval of the local Sewer Authority if Ecology has delegated the authority to set pretreatment requirements. If it has not yet received such authority, the business or public agency that wishes to discharge stormwater to the sanitary sewer must obtain the approval of the Pretreatment Program administrator at the regional Ecology office.

In setting pretreatment requirements, the local Sewer Authority or Ecology must operate within State Regulations Ch. 173-216 WAC (State Waste Water Discharge Permit Program) which in turn must comply with Federal Regulations 40 CFR Part 403.5 (National Pretreatment). Specific prohibitions include materials which:

1. Pass through the municipal treatment plant untreated or interfere with its operation;
2. Create a fire or explosion hazard, create a public nuisance or hazard to life, prevent entry into the sewer for maintenance and repair or is injurious in any other way to the operation of the system or the operating personnel;
3. Have a pH less than 5.0 or greater than 11.0 or have any corrosive property capable of causing damage or hazard to the system, equipment, or personnel;
4. Will cause obstruction to flows;
5. Will cause the sewage temperature to exceed 40°C or will in any case interfere with the biological activity in the municipal treatment plant.

Stormwater cannot be discharged to the sanitary sewer system except under extraordinary circumstances which are defined as the condition under which treatment by all known and available technology will not meet Ecology standards for discharge to receiving waters or will cause unreasonable financial burden. This can only be determined in consultation with Ecology.

The rate of stormwater entering the sanitary sewer cannot exceed the hydraulic capacity of the collection system or the treatment plant by the combined flow of sanitary sewage and stormwater.

The allowable concentrations of particular materials such as metals and grease may vary with the particular sewer system, since the responsibility of setting such limits rests with the local Sewer Authority, if delegated that authority by Ecology, or by Ecology where that delegation has not occurred.

To give some indication of typical limiting concentrations so they may be compared to a particular stormwater discharge of interest, the Municipality of Metropolitan Seattle (Metro) concentration limits are summarized below.

1. The concentration of fats, oils and greases of animal or vegetable origin, petroleum oil, non-biodegradable cutting oil or mineral oils shall not exceed 100 mg/l; (Note: the Ecology effluent guideline for oil and grease is 10 mg/l.)
2. Arsenic, 1 mg/l; cadmium, 3 mg/l; chromium, 6 mg/l; copper, 3 mg/l; lead, 3 mg/l; mercury, 0.1 mg/l; nickel, 6 mg/l; silver, 1 mg/l; zinc, 5 mg/l; cyanide, 2 mg/l.

3. Prohibited substances include gasoline, kerosene, naphtha, benzene, toluene, xylene, ethers, alcohols, ketones, aldehydes, peroxides, chlorates, perchlorates, bromates, carbides, hydrides and sulfides.

#### PROCESS TREATMENT

Process treatment may be used to dispose of polluted stormwater depending on the NPDES permit constraints of the particular business. The total loading of discharged process treatment water and stormwater cannot exceed the loading had a stormwater treatment device been used.

#### USE OF DEAD-END SUMPS

Substances which cause a violation of water quality standards must not be discharged to a septic system, surface or ground water. Where either sewage systems or process wastewater treatment are not available, an alternative is the use of a dead-end sump. Sumps are tanks with drains which can be periodically pumped and disposed of by an appropriate waste disposal operator. Depending on the composition of the waste, it may or may not be considered Dangerous Waste.

For more information on disposal requirements for sumps, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.

IV-5.2 R.2 UNIFORM FIRE CODE REQUIREMENTS

Storage of flammable, ignitable and reactive chemicals and materials must comply with the stricter of: local zoning codes, local fire codes, the Uniform Fire Code, Uniform Fire Code standards or the National Electric Code.

References:

Uniform Fire Code, International Conference of Building Officials and the Western Fire Chiefs Association, ISSN 0896-9736.

Uniform Fire Code Standards, National Fire Protection Association.

National Electric Code, National Fire Protection Association.

NFPA 30A Automotive and Marine Service Station Code, American National Standard Institute and the National Fire Protection Association.

IV-5.3 R.3 ECOLOGY REQUIREMENTS FOR GENERATORS OF DANGEROUS WASTES

The State's Dangerous Waste Regulations (Chapter 173-303 WAC) cover accumulation, storage, transportation, treatment and disposal of Dangerous Wastes. Of interest to this manual are those businesses or public agencies that accumulate the waste at their building until taken from the site by a contract hauler. Consequently, only those aspects of the regulations that apply to waste generators and accumulation are considered here.

State regulations require generators of Dangerous Wastes to obtain an Ecology Identification Number if they generate more than 220 pounds per month (2.2 pounds if the waste is defined as Extremely Hazardous). In addition, under certain circumstances as described below the generator must obtain a permit to store Dangerous Wastes. Where storage permits are required Ecology has the responsibility of ensuring that technical requirements are met.

Local governments must be concerned about situations where an Ecology storage permit is not required (less than 220 pounds per month). Although these generators still fall under Ecology regulations, the technical requirements are general. The first opportunity for local government to enforce the regulations is when a generator requests a building permit.

A storage permit is **not** required by Ecology under the following circumstances:

1. If the business generates more than 2,200 pounds per month of Dangerous Waste but intends to store the accumulated material less than 90 days;
2. If the business generates between 220 and 2,200 pounds per month of Dangerous Waste but intends to store less than 180 days; or,
3. If the business produces less than 220 pounds per month regardless of the length of storage.

Generators that produce more than 220 pounds per month (See 1 and 2 above) and avoid the need for a permit must still fulfill these general regulations with regard to temporary storage:

IF PLACED IN CONTAINERS

1. If the container is not in good condition (e.g severe rusting, apparent structural defects) or if it begins to leak, the owner must replace the container.
2. The container must be labeled as to its contents.
3. The container must be lined with a material that does not react with the waste.
4. The container must always be closed except when adding or removing waste.
5. The container must not be opened, handled, or stored in a manner which may cause a rupture or leak.
6. Examine the containers for leakage at least weekly.
7. Containers storing reactive or ignitable waste must meet requirements of the Uniform Fire Code.

8. Incompatible wastes must be stored separately.
9. Ecology may require secondary containment of the storage area. Specifically, the storage area must:
  - a. Be capable of collecting and holding spills and leaks;
  - b. If uncovered, be capable of handling a 25-year storm;
  - c. Have a base which is free of cracks or gaps and is sufficiently impervious to leaks, spills and rainfall;
  - d. Be sloped or designed such that liquids can drain to a point for removal;
  - e. Have positive drainage control (e.g. a valve) to insure containment until any liquid is removed. Removal must occur in a timely manner;
  - f. Have a holding capacity equal to 10 percent of the volume of all containers or 100 percent of the volume of the largest container whichever is greater;
  - g. Not allow runoff of rainfall from areas adjacent to the storage area.

If the waste does not contain free liquids the above requirements need not be met provided that the area is sloped or the containers are elevated.

#### IF PLACED IN TANKS

1. The tank must be lined with a material that does not react with the waste.
2. The tank, tank area and its ancillary equipment must be inspected regularly according to a posted schedule.
3. If retired, the tank is be cleaned of all contents. Any wash waters should be disposed of in a manner similar to the disposal of the actual wastes.
4. Tanks storing reactive or ignitable waste must meet the Uniform Fire Code requirements. Incompatible wastes must be stored separately.

The above generators must also have a designated employee on site or on call with the responsibility for coordinating all emergency response measures. Any spills are to be contained and cleaned up as soon as practicable.

If the business produces less than 220<sup>1</sup> pounds per month it need not comply with the above regulations. It need only dispose of the waste in a manner acceptable to the local Health Department which is (generally):

1. Dispose of the waste to a permitted facility; or,
2. Dispose of the material to a recycling facility; or,
3. Dispose of the waste to a permitted municipal or industrial landfill.
4. Put the waste to a beneficial use, such as the use of sludge as fertilizer.

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<sup>1</sup>Some wastes are designated "Extremely Hazardous" in which case the above controls are imposed if more than 2.2 pounds are produced per month.



For more information on disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.

**IV-5.4 R.4 MINIMUM FUNCTIONAL STANDARDS FOR CONTAINERS**

The local health department or district establishes standards on the use and integrity of solid waste containers. These local regulations must meet or exceed the State Minimum Functional Standards, WAC 173-304-200, which state:

"Reusable containers, except for detachable containers, shall be: rigid and durable; corrosion resistant; nonabsorbent and water tight; rodent-proof and easily cleanable; equipped with a close fitting cover; suitable for handling with no sharp edges or other hazardous conditions ...".

Detachable containers are reusable containers that are mechanically loaded or handled such as a dumpster or drop box.

"Detachable containers shall be durable, corrosion-resistant, nonabsorbent, nonleaking and having either a solid cover or screen cover to prevent littering."

Other relevant requirements include:

"All persons collecting or transporting solid wastes shall avoid littering, or the creation of other nuisances at the loading point..."

" ... solid waste shall be moved in such a manner that the contents will not fall, leak in quantities to cause a nuisance, or spill therefrom. Where such spillage or leakage does occur, the waste shall be picked up immediately ..."

**IV-5.5 R.5 COAST GUARD REQUIREMENTS FOR MARINE TRANSFER OF PETROLEUM PRODUCTS**

Federal regulations 33 CFR Parts 153, 154 and 155 cover, respectively, general requirements on spill response, spill prevention at marine transfer facilities, and spill prevention for vessels.

These regulations specify technical requirements for transfer hoses, loading arms, closure and monitoring devices. The regulations also cover small discharge containment: they require the use of "fixed catchments, curbing, and other fixed means" at each hose handling and loading arm area, and each hose connection manifold area. Portable containment means can be used in exceptional situations where fixed means are not feasible.

The capacity of the containment area varies from the volume of 1 to 4 barrels depending on the size of the transfer hoses.

The regulations also require an operations plan and specifies its general contents. The plan shall describe the responsibilities of personnel, nature of the facility, hours of operation, sizes and numbers of vessels using the facility, nature of the cargo, procedures if spills occur, and petroleum transfer procedures. The plan must also include a description and location of equipment for monitoring, containment, and fire fighting.

See also, NFPA 30A Automotive and Marine Service Station Code, American National Standard Institute and the National Fire Protection Association.

IV-5.6 R.6 USEPA REQUIREMENTS FOR UNDERGROUND TANK STORAGE

EXEMPT TANKS

Regulations are for underground tanks (tank systems having 10 percent or more of their volume underground) containing petroleum or listed hazardous substances. It covers all tanks except:

1. Farm and residential tanks holding 1,100 gallons or less of motor fuel;
2. Tanks storing heating oil used on premises;
3. Tanks on or above the floor of underground areas;
4. Septic tanks;
5. Tanks holding 110 gallons or less;
6. Emergency spill and overflow tanks.

NEW REQUIREMENTS FOR TANKS (INSTALLED AFTER DECEMBER 1988)

1. Certify that the tank and piping are installed properly according to industry codes;
2. Equip with devices that prevent spills and overfills;
3. Protect tank and piping from corrosion;
4. Equip the tank and piping with leak detection.

REQUIREMENTS FOR EXISTING TANKS (INSTALLED BEFORE DECEMBER 1988)

1. Equip with leak detection by these dates:

If tank was installed	Leak detection by
Before 1965	1989
1965-1969	1990
1970-1974	1991
1975-1979	1992
1980 to December 1988	1993

2. Implement tank filling procedures that will prevent spills and overfills.
3. By December 1998, tanks and piping shall be equipped with corrosion prevention; if the tank does not have corrosion protection or an internal lining and devices to prevent spills and overfill, a monthly inventory with tightness testing is required until December 1998.
4. By December 1998, equip to prevent spills and overfills.
5. Leak detection in piping shall be installed by December 1990.

Pressure piping: devices to automatically shut off or restrict flow or have an alarm that indicates leak. Conduct annual tightness testing or use monthly monitoring methods for tanks.

Suction piping: Monthly monitoring or tightness testing shall be done every 3 years on the same schedule as leak detection. If suction piping is sloped to draw back to storage tank when suction is released and only one check valve is included in each suction line directly below the suction pump then leak detection is not required.

6. If the existing tank has been upgraded with corrosion protection and a device to prevent spills and overfills, then a monthly inventory control and tank tightness test must be performed every 5 years. If the tank has not been upgraded, a monthly inventory control and tank tightness test must be performed every year.

#### REPORTING REQUIREMENTS

1. Notification of installation of tank and/or any suspected releases.
2. Confirmed release/corrective action.
3. Notification 30 days before permanent closure.

#### REPORTING OF SUSPECTED RELEASES

Owners/operators must report the leak within 24 hours, and follow the procedures outlined in the regulations for any of the following:

1. Discovery of release at the tank site or the surrounding area.
2. Unusual operating conditions such as sudden loss of product, equipment behavior, unexplained water in tank.
3. Monitoring results indicating a release may have occurred unless the monitoring device was found to be defective or, in the case of inventory control, if the second month does not confirm initial data.

#### RECORD KEEPING REQUIREMENTS

1. Records of leak detection performance and maintenance; previous year monitoring results and most recent tightness test results, including:
  - a. leak detection manufacturing performance claims;
  - b. records of maintenance, repair; and,
  - c. calibration of leak detection.
2. Records of the last two corrosion protection system inspections.
3. Expert analysis of corrosion potential if corrosion protection equipment is not used.
4. Records of site assessment results are required when permanent closure occurs. Records shall be kept a minimum of 3 years after closure.
5. Records for repaired or upgraded tanks.
6. Check local regulatory requirements.

IV-5.7 R.7 USEPA/ECOLOGY EMERGENCY SPILL CLEANUP REQUIREMENTS

USEPA - SPCC PLANS (40 CFR Part 112)

Federal Regulations require that owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, or consuming oil and oil products are required to have a Spill Prevention and Control Plan (SPCC), provided that the facility is non-transportation related; and, that the above-ground storage of a single container is in excess of 660 gallons, or an aggregate capacity greater than 1,320 gallons, or a total below-ground capacity in excess of 42,000 gallons.

The Plan must:

1. Be well thought out in accordance with good engineering;
2. Achieve three objectives - prevent spills, contain a spill that occurs, and clean up the spill;
3. Identify the name, location, owner, and type of facility;
4. Include the date of initial operation and oil spill history;
5. Name the designated person responsible;
6. Show evidence of approval and certification by the person in authority;
7. Contain a facility analysis.

ECOLOGY DANGEROUS WASTES (WAC 173-303-350)

Generators must have a Contingency Plan which must include:

1. Actions to be taken in the event of spill;
2. Descriptions of arrangements with local agencies;
3. The name of the owner's Emergency Coordinator;
4. A list of emergency equipment available;
5. An evaluation plan for business personnel.

For more information on disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.

IV-5.8 R.8 WSDA PESTICIDE REGULATIONS

Washington State pesticide laws are administered by the Department of Agriculture (WSDA), under the Washington Pesticide Control Act (Ch. 15.58 RCW), Washington Pesticide Application Act (Ch. 17.21 RCW), and regulations under Ch. 16-228 WAC. The requirements relevant to water quality protection are:

1. Persons who apply pesticides are required to be licensed except:
  - a. people who use general-use pesticides on their own or their employer's property;
  - b. grounds maintenance people using only general-use pesticides on an occasional basis not amounting to a regular occupation;
  - c. governmental employees who apply general-use pesticides without utilizing any kind of motorized or pressurized apparatus;
  - d. employees of a commercial applicator or a government agency who are under direct on-site supervision by a licensed applicator.
2. Licensed applicators must undergo 40 hours of continuing education to keep their license.
3. No person shall pollute streams, lakes, or other water supplies while loading, mixing or applying pesticides.
4. No person shall transport, handle, store, load, apply, or dispose of any pesticide, pesticide container, or apparatus in such a manner as to pollute water supplies or waterways, or cause damage or injury to land, including humans, desirable plants and animals.

For more information on pesticide application and disposal requirements for solid and hazardous wastes, see Step By Step: Fact Sheets for Hazardous Waste Generators, publication 91-12, available from Ecology's Regional Offices.

Another useful publication is Hazardous Waste Pesticides: A Guide for Growers, Applicators, Consultants and Dealers, publication #89-41, dated August, 1989. This brochure is available from Ecology's publications department, (206) 438-7472.

EPA also publishes a brochure, Suspended, Canceled and Restricted Pesticides, which is available from the EPA Region 10 Office in Seattle.

IV-5.9 R.9 AIR QUALITY REGULATIONS

The Puget Sound region is under the jurisdiction of regional air quality authorities who in turn must function under Washington State and Federal air quality regulations.

The Northwest Air Pollution Agency covers Whatcom, Island and San Juan counties. The Puget Sound Air Pollution Control Agency covers Snohomish, King and Pierce counties. The Olympic Air Pollution Control Authority covers Clallam, Jefferson, Mason and Thurston counties.

Of direct interest to persons using this manual are air authority policies on fugitive dust and outside painting.

All three air authorities require that reasonable precautions be taken to prevent fugitive particulate material from becoming airborne when handling, loading, transporting or storing particulate material.

The Puget Sound Air Pollution Control Authority (PSAPCA) takes the above policy one step further by defining what reasonable precautions are such as: the paving of parking lots and storage areas; housekeeping measures (for example, sweeping) minimization of the accumulation of mud and dust and preventing its tracking onto public roads; and stabilization of storage piles with water spray, chemical stabilizers, tarps, or enclosures.

PSAPCA requires that abrasive blasting and spray painting operations be performed inside a booth designed to capture the blast grit and overspray. Outdoor blasting or painting of structures or items too large to be handled indoors are to be enclosed with tarps.

PSAPCA requires that reasonable precautions be taken to prevent the tracking of material onto public roads. One precaution is wheel-washing of trucks.



IV-5.10 R.10 ECOLOGY WASTE REDUCTION PROGRAMS

Reducing the amount of wastes generated by a business or public agency also reduces the opportunity for their introduction to stormwater. The Washington Legislature established an Office of Waste Reduction and Recycling to "encourage voluntary reduction of solid wastes, hazardous wastes, hazardous substances, air and water pollutants by citizens, businesses and government agencies".

Local governments have been required since the early 1970's to prepare solid waste management plans. Now, cities and counties are required to include in those plans elements that address waste reduction.

Ecology conducts an annual survey to track progress and also conducts studies to identify waste reduction opportunities in specific industries. Example studies include wood treatment, paint manufacturing and metal plating.

Every business and public agency should conduct a waste reduction audit of its facilities and activities. Ecology has publications available from its Office of Waste Reduction and Recycling which detail the benefits and recommended procedures for conducting audits. Here is a brief summary:

**Management initiative:** the beginning point is commitment by management that waste reduction and recycling are important business or agency goals.

**Use of an audit team:** Creating a team representing various departments and all levels of seniority will result in many good ideas and commitment to the program. It is the role of the audit team to carry out the remaining planning steps.

**Goal setting:** Qualitative goals ("We would like to increase our use of recycled paper."), commensurate with the overall goals of the business or agency, should be established at the outset of the team's work. These can be modified as the plan is developed. They also may be modified to quantifiable goals ("We will increase our usage of recycled paper to 50% by the end of the year.") by the end of the process.

**Review of operations:** Next, a review "on (recycled) paper" of the various activities of the organization should be done as there are opportunities in every department to reduce waste. This includes purchasing, receiving, delivery, inventory, personnel, and manufacturing/ processing.

When the team is evaluating the processing area it should consider source reduction, scheduling procedures, waste segregation, and preventive maintenance. For example, preventive maintenance helps reduce leaks and wastes caused by unanticipated equipment breakdowns.

**Conduct audit:** Having identified general areas of opportunity, the team should conduct a physical audit of organization, with particular emphasis on processing.

**Generate and evaluate list of reduction options:** The next step is to generate a list of reduction options or alternatives. Do an evaluation to set priorities.

**Implementation:** Implement the options according to a realistic and agreed-upon schedule.

**Followup evaluation:** Management and the audit team should meet several times throughout the implementation period to evaluate progress.

**Employee training:** Employees should be trained in the various phases of the waste reduction program. New employees should be trained soon after they are hired. All

important points of the program should be summarized and easily available to all employees.

IMEX - The Industrial Materials Exchange is issued by the Seattle-King County Department of Public Health. The publication contains lists of materials offered for recycling and manufacturers looking for specific products. This is a free service. To obtain a copy, call (206) 296-4899 or write: Industrial Materials Exchange, 172-20th Ave., Seattle, WA 98122.

## IV-5.11 R.11 NPDES STORMWATER PERMITS

## SUMMARY

EPA's National Pollutant Discharge Elimination System Permit (NPDES) regulations for stormwater (40 CFR Parts 122, 123 and 124) became effective on November 16, 1990. Washington is a NPDES delegated state which requires Ecology to administer NPDES permits for designated industries and municipalities. Cities and counties with a population of 100,000 and greater that have separate storm sewer systems, most industries that discharge stormwater associated with industrial activities or storage of raw materials, and construction sites 5 acres in area and greater (including those parcels which are smaller than 5 acres but part of a development greater than 5 acres in size) are required to apply for NPDES permits. Stormwater from industrial uses that does not come in contact with industrial activities or storage of raw materials or products, such as runoff from roofs and parking lots, generally does not require a NPDES permit.

The goals of these new storm water NPDES regulations are to:

- > Stop the illegal discharge of waste waters and other pollutants into storm sewers, which should be used only for storm water run-off;
- > Reduce the amount of pollutants in storm water
- > Establish a permit system for storm water discharged by municipalities over 100,000 in population;
- > Establish a permit system for storm water discharged from industrial sites.

The Stormwater Management Program that Ecology and the Puget Sound Water Quality Authority are preparing for the Puget Sound Basin will be as consistent as possible with NPDES requirements. The thrust of the Stormwater Program is to direct the 112 cities and counties in the Basin to adopt and implement programs to prevent water pollution and enhance water quality for themselves and privately owned facilities in their jurisdiction. NPDES is a statewide permit program that Ecology will administer directly to cities, counties and regulated industrial facilities.

## MUNICIPAL PERMITS

Large municipalities (Seattle and King County) are defined as having an urbanized population of 250,000 or more. Both named municipalities submitted Part 1 of the application by November 18, 1991. Part 2 is due November 16, 1992. Medium municipalities (Pierce County, Snohomish County, Spokane and Tacoma) are defined as having an urbanized population of at least 100,000 but less than 250,000 and are required to submit Part 1 of the application by May 18, 1992 with Part 2 due by May 17, 1993. For NPDES purposes, the Washington State Department of Transportation (WSDOT) is considered a medium municipality and will apply for a municipal stormwater NPDES permit for its 7,000 miles of highway throughout the state.

According to 1991 population estimates, additional counties (Clark, Kitsap and Spokane) may have more than 100,000 urbanized population in unincorporated areas. The city of Spokane is expected to be redesignated as a medium municipality. These local governments will not be considered medium municipalities until the final federal 1990 census is published and the NPDES regulation is amended to include them. The deadlines for submission of Part 1 and Part 2 of these NPDES applications are expected to be 18 months and 30 months, respectively, from the date of the NPDES amendment. Detailed information on municipal stormwater NPDES permits can be found

in the Stormwater Management Program Implementation Guidance, which is a separate document from this technical manual.

On October 1, 1992, EPA is scheduled to extend the regulation to additional stormwater discharges. No information is currently available about the contents of these regulations.

**MUNICIPAL DEADLINES**

November 18, 1991	King County and Seattle submitted Part 1 applications to Ecology
February 14 1992	Ecology completed review of King County and Seattle,s Part applications.
April/May 1992	EPA to amend stormwater NPDES regulations to include new medium municipalities <sup>2</sup> added by the 1990 census.
May 18, 1992	Tacoma, WSDOT, Pierce and Snohomish Counties to submit Part 1 applications to Ecology.
August 16, 1992	Ecology to complete review of Tacoma, WSDOT, Pierce and Snohomish Counties' Part 1 applications.
October 1, 1992 <sup>3</sup>	EPA to issue NPDES regulations which designate additional stormwater discharges to be regulated.
November 16, 1992	Deadline for King County and Seattle's Part 2 applications to be submitted to Ecology.
No specific date	Ecology to review completeness of King County and Seattle's Part 2 applications.
May 17, 1993	Deadline for Tacoma, WSDOT, Snohomish and Pierce Counties' Part 2 applications to be submitted to Ecology.
No specific date	Ecology to review completeness of Tacoma, WSDOT, Pierce and Snohomish Counties' Part 2 applications.
October/November 1993 <sup>4</sup>	Medium municipalities added by 1990 census to submit municipal Part 1 applications to Ecology.
November 16, 1993	King County and Seattle's municipal permits issued by Ecology.
January/February 1994 <sup>5</sup>	Ecology to complete review of added medium municipality Part 1 applications.

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2 New medium municipalities expected to be designated are Clark, Kitsap and Spokane Counties and the city of Spokane which will be redesignated.

3 EPA may not comply with this deadline.

4 Assumed 18 months after EPA designation.

5 Date approximate; 90 days after Part 1 application due.

- May 17, 1994 Tacoma, WSDOT, Pierce and Snohomish Counties' municipal permits issued by Ecology.
- October/November 1994<sup>6</sup> Added medium municipalities' Part 2 applications to be submitted to Ecology.
- October/November 1995<sup>7</sup> Added medium municipality permits issued by Ecology.

#### INDUSTRIAL PERMITS

Ecology intends to cover all storm water discharges associated with industrial activities with one "baseline" permit

The Washington Department of Ecology (Ecology) is responsible for implementing EPA requirements for storm water permits in Washington State. Ecology plans to write one permit which will cover most of the thousands of industries required to have a storm water permit. We refer to this permit as the Baseline General Permit for Industrial Storm Water, or more simply, the baseline permit.

In writing this baseline permit, Ecology plans to obtain input from advisory committees, and to conduct public workshops and public hearings. After completing the baseline permit, Ecology will decide which types of industries need more specific requirements for storm water control. We will write "industry-specific" general permits for those industry types. Industries for which an "industry-specific" permit is written, will no longer be covered under the baseline permit.

#### WHICH INDUSTRIAL ACTIVITIES NEED TO HAVE A STORM WATER NPDES PERMIT?

EPA regulations list those industrial activities which may need to have a storm water discharge permit (see page IV-5-22). During the development of the baseline permit, Ecology will consider requiring additional industries to have a permit.

The federal regulation applies only to "point source" storm water discharges to surface waters or municipal storm sewers. A "point source" discharge is defined in state regulations as "any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container,.....from which pollutants are or may be discharged."

For the industries identified in categories (1) through (10), a permit is necessary if there is a point source storm water discharge to a surface water or a municipal storm sewer from any of the following areas:

- industrial plant yards,
- immediate access roads and rail lines used or traveled by carriers of raw materials, manufactured products, waste material, or by-products used or created by the facility,
- material handling sites,
- refuse sites,
- sites used for the application or disposal of process waste waters (as defined at 40 CFR part 401),
- sites used for the storage and maintenance of material handling equipment,
- sites used for residual treatment, storage, or disposal,
- shipping and receiving areas,

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<sup>6</sup> Date approximate; assumed 30 months after designation.

<sup>7</sup> Date approximate; assumed 42 months after designation.

- manufacturing buildings,
- storage areas (including tank farms) for raw materials, and intermediate and finished products,
- areas where industrial activity has taken place in the past and significant materials remain and are exposed to storm water.

For the industries identified in category (11), a permit is required for point source discharges from any of the areas that are listed above (except access roads and rail lines of category 11 industries), only if material handling equipment or activities, raw materials, intermediate products, final products, waste materials, by-products, or industrial machinery are exposed to storm water.

SOME INDUSTRIES DO NOT HAVE TO APPLY FOR A STORM WATER PERMIT.

\* Industries which have storm water management and treatment requirements in an existing NPDES permit do not have to apply for a storm water permit.

\* Industries which discharge their storm water only to a municipal combined sewer or sanitary sewer do not have to apply. Cities which have combined sewers in a portion of their geographic area include:

Anacortes	Bellingham	Bremerton
Everett	Mount Vernon	Olympia
Port Angeles	Seattle	Snohomish
Spokane		

Industries located in these cities will need to determine if their storm water discharges to a combined sewer or a storm sewer.

\* Industries which only have storm water discharges from office buildings and accompanying parking lots do not have to apply.

\* For industries which must have a storm water permit for their industrial activities, permit requirements do not apply to storm water from office buildings and accompanying parking lots, as long as the storm water from these areas does not mix with storm water from the industrial area.

#### HOW AND WHEN DO I APPLY FOR A PERMIT?

Three types of permits are possible. Each has a different application process.

##### **Baseline Permit:**

Applications for coverage under the baseline permit should be submitted after Ecology adopts the permit (targeted for June 30, 1992), but before the current federal deadline of October 1, 1992. Applications will consist of filing a **NOTICE OF INTENT**. Ecology has not yet decided on the information requirements for a **NOTICE OF INTENT**. Proposed requirements for a Notice of Intent will be discussed at public workshops and hearings.

##### **Individual Permit:**

Industries which are required to have a storm water permit may apply for an individual permit. An individual permit is a permit which is written for and issued to a specific facility. EPA regulations require that industries not covered under a general (baseline) permit, or part of a group application to EPA (see below), must apply for an individual storm water permit by October 1, 1992. Individual permit applications for discharges composed entirely of storm water, must comply with 40 CFR 122.21, and complete EPA forms 1 and 2F.

Ecology is prepared to issue individual permits for facilities not already under permit only for exceptional circumstances. As previously stated, Ecology plans to cover all facilities initially under the baseline permit. Facilities which Ecology determines need individual permits, will be addressed at a later date.

Therefore, facilities that file applications for an individual permit may not have their application acted on. All facilities are encouraged to participate in receiving coverage under the baseline permit by submitting a **NOTICE OF INTENT**.

**Industry-Specific General Permits:**

Ecology will consider development of several industry-specific general permits after the baseline general permit program is underway. An industry-specific permit is a permit which can apply to all industries of a similar type. Ecology will choose which industries will receive increased attention under industry-specific permits. Industries for which an industry-specific permit is written will no longer be covered under the baseline permit. Industry-specific permits may not be written for industries which have made a group application to EPA.

Some industrial facilities have jointly submitted group applications to EPA for coverage under a general permit to be developed specifically for their group. Except for industries owned or operated by municipalities under 100,000 in population, the deadline for formation of groups has passed. Those groups which have received approval from EPA for Part 1 of their application may choose to proceed with Part 2 of their application. However, group applicants should understand that Ecology is not required to issue group-specific general permits. Ecology intends to cover the industries in these groups, at least initially, under the baseline permit. During development of the baseline permit, we will consider group monitoring alternatives to reduce monitoring costs to dischargers.

**MUNICIPALITIES WHICH OWN OR OPERATE INDUSTRIAL ACTIVITIES MAY HAVE TO APPLY FOR A STORM WATER PERMIT**

Some municipalities own or operate an industrial activity listed in the addendum. If that industrial activity has a storm water discharge from one of the areas described above, the municipality should apply for a storm water permit, **UNLESS** the industrial activity is in category 11 and the area is not exposed to storm water.

Industrial activities by municipalities which may require a storm water permit include:

- \* Sand and gravel mining,
- \* Crushed and broken stone operations, and rip rap mining and quarrying,
- \* Landfills, land application sites, and open dumps that receive or have received industrial waste,
- \* Transportation services which have vehicle maintenance shops, equipment cleaning operations, or airport de-icing operations,
- \* Sewage treatment plants with a design flow above one million gallons per day,
- \* Construction activities, including clearing, grading, or excavating sites, which disturb five acres or more.

Recently, federal legislation extended the individual and "group" permit application deadlines for municipalities with industrial activities. In spite of these extensions, Ecology encourages all municipalities, including those which are part of a group application to EPA, to submit a **NOTICE OF INTENT** by October 1, 1992, for coverage under the baseline permit.

WHAT WILL THE BASELINE PERMIT REQUIRE INDUSTRIES TO DO?

Ecology has not yet decided on the requirements of the baseline permit. EPA regulations include the following requirements which Ecology will consider putting in the permit:

- Compliance with surface water, ground water, and receiving water sediment standards;
- Monitoring of pollutants discharged;
- Prohibiting the discharge of anything but storm water to storm sewers;
- Submission of a **NOTICE OF INTENT** by October 1, 1992;
- Development of a **POLLUTION PREVENTION PLAN** within 180 days after Ecology adopts the permit;
- Implementation of the **POLLUTION PREVENTION PLAN** within one year after Ecology adopts the permit

The development of a **POLLUTION PREVENTION PLAN** by each industry is a key EPA requirement. Under a **POLLUTION PREVENTION PLAN**, an industry could be required to:

- > Identify potential sources of pollution which may affect storm water quality;
- > Describe how they will reduce the pollutants in their storm water and comply with their permit.

WILL I HAVE TO PAY A FEE TO ECOLOGY FOR A STORM WATER PERMIT?

Ecology charges a fee for permits as allowed under State regulation, Chapter 173-224 WAC. That regulation does not identify a fee for facilities which will be covered under the baseline permit for storm water. Ecology plans to seek an increased legislative appropriation for the next biennium (July 1, 1993-June 30, 1995) to administer storm water permits. Fees would be set by amending the fee rule. There will be opportunities for public comment on the fee proposals. Subject to the appropriation and adoption of the amended fee regulation, fees for storm water permits would become effective after July 1, 1993.

DO I NEED TO APPLY IF I DON'T HAVE A DISCHARGE TO SURFACE WATER?

EPA's storm water regulations apply only to discharges to surface water. In developing the state storm water permit program, Ecology will consider including industrial activities which have a point source discharge to seepage ponds, seepage pits, dry wells, injection wells and any other on-site disposal which could pollute ground water. Ecology does not encourage diversion of surface water discharges to on-site disposal systems because of the potential for ground water contamination.

INDUSTRIAL STORM WATER DEADLINES & TARGET DATES

- 5/15/91 Industrial facilities which discharge storm water to separate storm sewer systems operated by King Co., Seattle, Snohomish Co., Pierce Co., or Tacoma, must notify that local government.
- 5/18/92 Current deadline for submission of Part 2 group applications to EPA
- 6/30/92 Target date for Ecology to adopt baseline general permit. The permit is effective 30 days later.



- After  
7/31/92      **New industries** must submit a NOTICE OF INTENT (to Ecology), and develop a pollution prevention plan (to be retained by the industry), before commencement of construction of a storm water discharge. EPA has proposed that these be completed at least 30 days prior to commencement.
- 10/1/92      Deadline for industries with an **existing** storm water discharge to submit a Notice of Intent (NOI) to Ecology for coverage under the baseline general permit; or to submit an individual permit application to Ecology.
- 10/1/92      Proposed deadline for submission of most Part 2 group applications to EPA.

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**ECOLOGY WILL HOLD PUBLIC WORKSHOPS AND HEARINGS CONCERNING THE BASELINE GENERAL PERMIT**

We will hold **PUBLIC WORKSHOPS** to explain the issues surrounding the baseline general permit, and to provide opportunity for public comment. The **PUBLIC WORKSHOPS** will probably be held in the first part of May. Subsequently, we will hold **PUBLIC HEARINGS** on the permit.

**FOR FURTHER INFORMATION**

**ECOLOGY CONTACTS:**

Linda Matlock    (206) 438-7614    INDUSTRIAL STORM WATER GENERAL PERMITS

Peter Birch      (206) 438-7076    MUNICIPAL STORM WATER PERMITS

USEPA REGION X CONTACT: Steve Bubnick: (206) 553-8399

NATIONAL STORM WATER HOTLINE: (703) 821-4823

**INDUSTRIES SUBJECT TO FEDERAL REGULATION:**

(Reference: 40 CFR 122.26(b)(14))

The following categories (1 through 10) of facilities are considered to be engaging in "industrial activity." They are required by USEPA to have a storm water NPDES permit if they have a storm water discharge to surface water.

- 1) Facilities subject to storm water effluent limitations guidelines, new source performance standards, or toxic pollutant effluent standards under 40 CFR subchapter N (except facilities with toxic pollutant effluent standards under category 11 below).
- 2) Facilities classified by the Standard Industrial Classification (SIC) system as:
  - 24 - Lumber and Wood Products Except Furniture (except 2434-Wood Kitchen Cabinets). PLEASE SEE FOOTNOTE.
  - 26 - Paper and Allied Products (except 265-Paperboard Containers and Boxes; and except 267-Converted Paper and Paperboard Products except Containers and Boxes)
  - 28 - Chemicals and Allied Products (except 283-Drugs; and 285- Paints, Varnishes, Lacquers, Enamels, and Allied Products)
  - 29 - Petroleum Refining and Related Industries

- 311- Leather Tanning and Finishing
- 32 - Stone, Clay, Glass and Concrete Products (except 323-Glass Products, made of Purchased Glass)
- 33 - Primary Metal Industries
- 3441 Fabricated Structural Metal Products
- 373- Ship and Boat Building and Repair

3) Facilities classified by the Standard Industrial Classification (SIC) system as:

- 10 - Metal Mining
- 12 - Coal Mining
- 13 - Oil and Gas Extraction
- 14 - Mining and Quarrying of Nonmetallic Minerals, except Fuels

(Includes active or inactive mining operations (except for areas of coal mining operations no longer meeting the definition of a reclamation area under 40 CFR 434.11(1)...or except for areas of non-coal mining operations which have been released from applicable state or federal reclamation requirements by December 17, 1990) and oil and gas exploration, production, processing or treatment operations, or transmission facilities that discharge storm water that has come into contact with any overburden, raw material, intermediate products, finished products, byproducts or waste products located on the site of such operation....)

- 4) Hazardous waste treatment, storage, or disposal facilities, including those that are operated under interim status or a permit under subtitle C of RCRA.
- 5) Landfills, land application sites and open dumps that receive or have received any industrial wastes (waste that is received from any of the facilities described under this subsection) including those that are subject to regulation under subtitle D of RCRA.
- 6) Facilities involved in the recycling of materials including metal scrap yards, battery reclaimers, salvage yards and automobile junkyards, including but not limited to those classified as SIC 5015-Wholesale Trade Activities of Motor Vehicle Parts, Used; and SIC 5093-Scrap and Waste Materials.
- 7) Steam electric power generating facilities, including coal handling sites.
- 8) Transportation facilities classified under the following SIC codes, which have vehicle maintenance shops, equipment cleaning operations, airport deicing operations. (Only those portions of the facility involved in the above activities, or which are otherwise identified in one of the other 10 categories.)
  - 40 - Railroad Transportation
  - 41 - Local and Suburban Transit and Interurban Highway Passenger Transportation
  - 42 - Motor Freight Transportation and Warehousing (except 4221- Farm Product Warehousing and Storage, 4222-Refrigerated Warehousing and Storage, and 4225-General Warehousing and Storage)
  - 43 - United States Postal Service
  - 44 - Water Transportation
  - 45 - Transportation by Air
  - 5171- Petroleum Bulk Stations and Terminals
- 9) Treatment works treating domestic sewage or any other sewage sludge or wastewater treatment device or system, used in the storage treatment,

recycling, and reclamation of municipal or domestic sewage, including land dedicated to the disposal of sewage sludge that are located within the confines of the facility, with a design flow of 1.0 mgd or more, or required to have an approved pretreatment program under 40 CFR part 403.

Not included are farm lands, domestic gardens or lands used for sludge management where sludge is beneficially reused and which are not physically located in the confines of the facility, or areas that are in compliance with section 405 of the Clean Water Act.

- 10) Construction activity including clearing, grading and excavation activities except: operations that result in the disturbance of less than five acres of total land area which are not part of a larger common plan of development or sale.
- 11) Facilities under the following SIC classifications need to apply for a storm water NPDES permit **only if they are engaged in an "industrial activity" which is exposed to storm water and they have a point source storm water discharge to surface water.**
  - 20 - Food and Kindred Products
  - 21 - Tobacco Products
  - 22 - Textile Mill Products
  - 23 - Apparel and Other Finished Products Made From Fabrics and Similar Materials
  - 2434 Wood Kitchen Cabinets
  - 25 - Furniture and Fixtures
  - 265- Paperboard Containers and Boxes
  - 267- Converted Paper and Paperboard Products, Except Containers and Boxes
  - 27 - Printing, Publishing and Allied Industries
  - 283- Drugs
  - 285- Paints, Varnishes, Lacquers, Enamels, and Allied Products
  - 30 - Rubber and Miscellaneous Plastic Products
  - 31 - Leather and Leather Products (except 311, Leather Tanning and Finishing)
  - 323- Glass Products made of Purchased Glass
  - 34 - Fabricated Metal Products, Except Machinery and Transportation Equipment (except 3441, Fabricated Structural Metal Products)
  - 35 - Industrial and Commercial Machinery and Computer Equipment
  - 36 - Electronic and Other Electrical Equipment and Components, Except Computer Equipment
  - 37 - Transportation Equipment (except 373, Ship and Boat Building and Repair)
  - 38 - Measuring, Analyzing, and Controlling Instruments, Photographic, Medical and Optical Goods, Watches and Clocks
  - 39 - Miscellaneous Manufacturing Industries
  - 4221 Farm Product Warehousing and Storage
  - 4222 Refrigerated Warehousing and Storage
  - 4225 General Warehousing and Storage

IV-5.12 R.12 WASHINGTON STATE GROUND WATER QUALITY STANDARDS

In December, 1990, the state of Washington adopted a set of ground water standards to prevent ground water pollution. The public and private agencies, groups and people who developed and reviewed the standards intend them to protect ground water quality rather than react to ground water pollution.

The standards incorporate an existing part of state water quality law: the antidegradation policy. This policy strictly forbids degradation which would harm existing or beneficial use of ground water. Beneficial uses of ground water include drinking water, irrigation, and support of wildlife habitat.

During the next year or two, the Department of Ecology will develop guidance for implementing the standards, both for point sources and non-point sources of water pollution.

Implementing the Ground Water Standards

The standards provide numeric values which must not be exceeded to protect the beneficial use of drinking water. These values are called criteria. For example, the criterion for nitrate-nitrogen is 10 mg/l. The criteria are generally derived from health-based drinking water standards. The rule also provides for developing enforcement limits and early warning values that will allow preventative action or enforcement to be taken so that criteria will not be exceeded.

Washington law requires that all activities with the potential to contaminate water implement practices known as AKART -- short for "all known available and reasonable methods of prevention, control and treatment". AKART must be used regardless of the quality of the receiving waters. In other words, discharges must be as clean as it is possible to make them using AKART. As technology and preventive controls are refined to better protect water quality, AKART is also redefined. In individual cases where AKART fails to protect water quality, the activity must apply additional controls.

These standards apply to both point source and non-point source activities. Both federal and state law require point sources to operate under permits that set conditions for discharges. Guidance for permit development will describe how industry must conduct its activities in order to protect ground water quality. Each industry will be required to implement AKART specific to that industry.

Non-point source activities are diffuse in nature, and often consist of many small sources of pollution that have a cumulative effect. Some non-point sources, such as on-site septic systems, will be managed through the development of siting and design standards. In other cases, general permits will establish standards for management. General permits apply to all operators of a particular type of activity, such as stormwater management or confined animal feeding operations.

The standards apply to all underground waters in the saturated zone (generally at or below the water table), with few exceptions. One of these exceptions provides that the standards do not apply in the root zone of saturated soils where agricultural pesticides or nutrients have been applied at agronomic rates for agricultural purposes. The standards do apply below the crop's root zone. State approved BMPs may be considered one type of AKART for agriculture, and other point and non-point sources.

Contact Nancy Winters, (206) 438-7066, for more information about the standards.

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