# Highway Runoff Manual

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Environmental and Engineering Service Center

# Foreword

This manual has been prepared as a guide for our engineering and maintenance personnel to provide policies, procedures, and methods for developing and documenting the design and maintenance of improvements to the transportation system in Washington State.

This manual is a guide for the design and operation of transportation facilities that are related to or affect stormwater runoff. This manual is intended to provide uniform procedures for implementing design and maintenance decisions regarding highway runoff facilities to ensure a continuity of quality of these facilities throughout the state. It is recognized that not all conceivable situations will be included in the manual and as a result, sound judgment by knowledgeable personnel will be required for successful implementation. It is also recognized that the practices suggested in this manual may be inappropriate for some projects.

Updating this manual is a continuing process and revisions are issued periodically. Questions or suggestions for modifications are invited and should be directed to the Olympia Service Center Hydraulics Section. Orders for manuals should be addressed to the Publications Support Branch, WSDOT, P.O. Box 47400, Olympia, WA 98504-7400 or telephone (360) 705-7430.

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# Chapter 1 Introduction

## 1-1 Basis of Manual Development

The *Highway Runoff Manual* was developed to direct stormwater management for existing and new state highways, rest areas, park and ride lots, and ferry terminals. The manual was written by staff of the Washington State Department of Transportation (WSDOT) with input from an advisory committee made up of representatives of cities, counties, Indian tribes, and other state agencies.

The primary users of this manual will be the following WSDOT personnel: design engineers developing Stormwater Site Plans in design project offices, project inspectors in construction project offices responsible for inspection and maintenance of Temporary Erosion and Sediment Control Plans, and maintenance staff responsible for developing Roadside Management Plans and roadway maintenance practices. The department has developed the *Highway Runoff Manual* to establish minimum requirements and provide technical, uniform guidance for the avoidance and mitigation of water resource impacts of the highway system. The manual will be updated periodically to reflect advances in the management of stormwater, roadside vegetation, and roadway maintenance. The Olympia Service Center Hydraulics Section and Water Quality Unit will jointly be responsible for manual revisions and implementation oversight. The design criteria and procedures presented in this manual shall supersede conflicting information presented in other WSDOT manuals published prior to the date of this manual.

Initially, this manual will be applied in the Puget Sound basin. The Puget Sound basin includes the waters of 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 land draining into these waters. The Puget Sound Water Quality Management Plan and the Puget Sound Highway Runoff Program (Chapter 173-270 WAC) require the development and use of the manual. However, problems associated with stormwater, and the need to manage it properly under such programs as the National Pollutant Discharge Elimination System (NPDES), are not restricted to the Puget Sound basin. Therefore, WSDOT will apply the *Highway Runoff Manual* to certain projects statewide. There are a number of issues that need to be resolved before statewide application can occur, not the least of which is the applicability of certain design elements to the drier climates of eastern Washington. Statewide application of the manual is dependent upon local climatic, geologic, and hydrologic conditions. The Department of Ecology will be expanding its *Stormwater Management Manual for the Puget Sound Basin* (SMMPSB) to be applicable for areas outside of Puget Sound. The *Highway Runoff Manual* will be revised to be consistent with changes to the SMMPSB.

While statewide application of this manual is not currently required, projects outside the Puget Sound basin should follow the guidelines presented whenever there are space and funds available. For projects outside of the Puget Sound basin that are required by local jurisdictions to follow stormwater treatment guidelines, staff can use this manual to design the stormwater facilities. This is done to keep design procedures consistent statewide and should be acceptable to local agencies since ultimately the result is the same as long as an engineeringly sound design is used. The exception would be in the case of locally adopted basin or watershed plans, NPDES Stormwater Requirements, or sensitive area ordinances, pursuant to Minimum Requirement 8 in Chapter 2. Through interaction with the advisory committee, it has been the intent of WSDOT to develop a set of stormwater design standards that are consistent with state and local jurisdiction requirements such that these standards would be applicable to most WSDOT and local agency roadway department projects.

## 1-2 Problems Associated With Stormwater

Development can have a dramatic impact on the hydrologic cycle. In western Washington, land cover that once consisted primarily of mature forest has been replaced in many areas with impervious surfaces, such as buildings, parking areas, and roadways. The creation of impervious surfaces has two main impacts on the hydrologic cycle, increased runoff, and prevention of infiltration. Reducing land cover, mainly by tree removal, can also significantly increase runoff even though pervious surfaces remain.

The creation of impervious surfaces increases both the volumes of surface runoff and the peak rate of flow resulting from a storm event. The higher velocity and larger quantity of flow may cause stream bank erosion and general habitat destruction. Sediment from cleared areas and eroded and unstable stream banks is deposited downstream, filling ponds, stream beds, and stormwater facilities. Construction projects that include exposed and nonstabilized soils, especially on slopes, can be a source of such pollution.

Runoff functions as the transport mechanism for nonpoint sources of pollution, those sources being dispersed throughout the watershed resulting from a variety of land uses. The increase in the introduction of these pollutants from human habitation and activity can result in measurable degradation of receiving waters. Runoff from roadways and associated facilities may contain oil and grease (hydrocarbons), heavy metals such as lead and zinc, and in some cases, volatile organic compounds.

Aquatic life can be affected by development in a watershed. Habitats are altered when a stream changes its configuration and deposits its sediment load in response to significant urbanization. Natural structures of the stream channel, riffles, pools, gravel bars, and other areas, are altered and sometimes destroyed. Spawning areas, consisting mainly of clean gravels, can become imbedded with silt and unusable by fish. Urbanization may also cause an increase in water temperature when vegetation, which shades the water, is removed. Increase in water temperature coupled with nutrients from some land uses may cause algal blooms and reduction of dissolved oxygen (DO). Low DO can cause fish and other organisms to die, and allow undesirable species to establish residence.

A more subtle impact of development on the hydrologic cycle is the reduction of infiltration. Infiltration recharges ground water and produces interflow, the subsurface flow particularly common in the soils of the Puget Sound lowlands. Ground water is the source that produces summer base flows in streams and sustains water levels in some wetlands. Reduction in infiltration can dry up small streams and wetlands in the summer and in turn render aquatic systems useless during these times.

## 1-3 Solutions to Stormwater Problems

The best solution to problems created by stormwater runoff is the application of some type of Best Management Practice (BMP). BMPs are defined as physical, structural, and managerial practices that, when used individually or in combination, prevent or reduce pollution of water and attenuate peak flows and volumes. In order to address the types of problems discussed above, BMPs are grouped into three types: source control, water quality, and water quantity BMPs.

Source control BMPs are designed to prevent the introduction of pollutants into runoff. Examples would be mulches and cover over bare soil, and putting roofs over outside storage areas. Water quality BMPs include facilities that remove pollutants from runoff by simple gravity settling of particulate matter, filtration, biological uptake, and soil adsorption. Examples include wet ponds and vegetated swales. Water quantity BMPs protect stream ecosystems from excessive erosion by reducing the peak rate of runoff during a storm event by storing the flow and releasing it at a lower rate. Typical examples are dry ponds and dry vaults.

When BMPs are correctly applied to a project site, the impacts of the change of land use is minimized. There are several types of BMPs that are included within each of the three main groups. The selection of the proper BMP for a project is dependent on characteristics of the project site, and often any one of a number of BMPs could be utilized to accomplish the same result. Some project sites may require a combination of BMPs. When selecting a BMP for the project, the designer should first consider the ability of the BMP to treat highway runoff, then select the most cost effective, safe, and aesthetically pleasing of the available options.

Stormwater problems can be grouped into two separate categories. The first category being problems from existing impervious areas and the other being problems that will occur from new impervious areas if no stormwater controls are used. New projects that must comply with this manual are required to provide stormwater treatment for the new portions of the roadway. The existing highway sections will eventually be retrofitted with stormwater treatment facilities pursuant to the WSDOT retrofit program, which will include a project priority ranking. As a minimum, stormwater treatment facilities must be sized for the flows that they service and overall water quality must not be degraded as a result of the project.

The designers of new projects should keep in mind that the ultimate goal is to provide practicable stormwater treatment for the entire roadway. If it is cost effective to size a BMP for the entire roadway, even though only a lane is being added, then the BMP should treat the entire roadway, thus saving the cost of retrofitting in the future. If runoff from all of the roadway cannot be cost effectively treated then the selected BMPs should be sized to treat just the new roadway and placed in a location that will allow for future expansion when the site is retrofitted. When determining whether or not it is cost effective to provide stormwater treatment for the entire roadway, the design engineer must determine the benefits that will be derived from the additional treatment. Information relating to benefits derived from water quality improvements can be obtained from the Environmental Section, the Department of Fish and Wildlife, the Department of Ecology, and many local agencies.

When the requirements of this manual can not be met, the designer must contact the Hydraulics and Environmental Sections. The Hydraulics and Environmental Sections will coordinate with the Department of Fish and Wildlife, the Department of Ecology, and any affected local agency to determine the practicable amount of stormwater treatment that can be included in the project.

## 1-4 Background of Stormwater Management

Water pollution control has been a federal program since the first Water Pollution Control Act was passed by Congress in the 1960s. For many years, the emphasis was on the control of point source pollution, typically outfalls from industrial factories and municipal sewage treatment plants. Since the early 1980s, interest has been shifting to nonpoint source pollution. Nonpoint source pollution is pollution that originates from diffuse, diverse activities and land uses on the watershed, and enters a water body through nondiscernible, unconfined and indistinct conveyances. Stormwater is unique in that it originates as nonpoint source pollution, but it typically is collected, conveyed, and discharged as a point source.

Major amendments to the Federal Water Pollution Control Act (which has become known as the Clean Water Act) in 1987 addressed stormwater, by extending the NPDES permit program to include stormwater. Also in 1987, the Puget Sound Water Quality Management Plan was issued. This plan called for a Highway Runoff Program, which was subsequently developed in detail by the Department of Ecology and codified in Chapter 173-270 of the Washington Administrative Code. As a result of these federal and state initiatives, new requirements have been placed on the construction of highway projects.

Activities for both federal and state stormwater regulations are progressing concurrently. It is the intent of WSDOT to develop a highway runoff program that utilizes sound engineering principles and satisfies all federal and state requirements. This manual is based on the best engineering practices currently available and will satisfy all existing federal and state requirements.

## 1-5 Manual Organization

This manual is divided into eight different sections, each corresponding to a chapter. The first chapter is used as an overview to the stormwater problems associated with highways. It is intended to inform the designer which areas will require stormwater treatment and why stormwater treatment is required.

Chapter 2 lists the minimum requirements for stormwater treatment. There are nine minimum requirements listed that shall be checked for every project that is required to follow this manual. Each minimum requirement describes its function and when it should be applied.

Chapter 3 is a description of the methodology that must be used to design the BMPs for the project. The methodology is slightly different than the methodology previously used for WSDOT projects. Because of this, it is explained in detail using examples to show how it would be applied to a project.

Chapter 4 guides the project designer through the BMP selection process. It includes an easy to follow process for BMP selection. The result of this process are the recommended BMPs for both temporary (construction phase) use and permanent use.

Chapter 5 describes what should be included in a Stormwater Site Plan (SSP). The SSP is a required document for all projects that must follow the guidelines of this manual. The SSP will be the document used to review the selection and design process for the BMPs to be used in the project.

Chapter 6 deals with vegetation management. Different methods for managing vegetation along roadways are described. Using this chapter design engineers and maintenance personnel will be able to develop a plan for managing vegetation at the BMPs installed with the project and along the remaining right of way included in the project.

Chapter 7 contains information for design and maintenance personnel on the impact and mitigation of various roadway maintenance practices, including waste disposal, use of traction materials and deicers, and the maintenance of certain BMPs. A special section on bridge painting water quality impacts is included in this chapter for staff involved in these projects.

Chapter 8 is a complete listing of all WSDOT preferred BMPs. Each BMP is in a complete and stand-alone format. After reading Chapters 2 and 3 and following the process in Chapter 4 to select a BMP, this chapter will show the designer the complete set of design steps that must be used for the specific BMP.

## 1-6 Additional Information

Most projects lend themselves to easily installing one or more of the different BMPs. However, there are times when the site does not provide for easy installation of any of the BMPs or when the available BMPs in Chapter 8 are not well suited for the site. When these types of problems arise, the following staff should be contacted for assistance:

- BMP Selection: regional hydraulics staff, then Olympia Service Center Hydraulics Section.
- Outfall Inventory/Field Screening Results, Retrofit Priorities, NPDES Municipal Stormwater Permit, and Sampling: Olympia Service Center Water Quality Unit.
- Temporary Erosion and Sediment Control Plans and control of pollutants other sediment: regional environmental staff, then Olympia Service Center Water Quality Unit.
- Vegetation Management: regional and Olympia Service Center landscape architects, then Olympia Service Center Maintenance Office.
- Roadway Maintenance Practices: regional maintenance staff, then Olympia Service Center Operations Division Environmental Compliance Branch.

For some projects, it may be necessary to use BMPs that are considered experimental in nature. They must be approved by the Olympia Service Center Hydraulics Section in advance, prior to submittal to the Department of Ecology for review and approval.

The designer should contact the regional Hydraulics Section or the Olympia Service Center Hydraulics Section when selecting BMPs for projects outside of the Puget Sound basin that will implement stormwater treatment. For western Washington, this is mainly to verify the usefulness of the treatment. For eastern Washington, this is also necessary to select a suitable BMP, due to the climate specific requirements of some of the BMPs.

The Stormwater Management Manual for the Puget Sound Basin (SMMPSB) contains in-depth explanations of many of the parameters used to develop the *Highway Runoff Manual*. The SMMPSB should be used as the main reference whenever a designer seeks additional information about treatment of stormwater runoff. When using the SMMPSB as a reference, the designer must realize that it deals with many different type of projects, unlike the *Highway Runoff Manual* which primarily deals with roadway projects. As a result, some of the BMPs presented in the SMMPSB would not be applicable to a highway project.

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## 2-1 Introduction

All project designs that include clearing and grubbing, embankment work, or other earth work will include a Temporary Erosion and Sediment Control (TESC) Plan. The TESC will show which Best Management Practices (BMPs) will be used to meet Minimum Requirement 1.

Additionally, all state projects adding at least 5,000 square feet (465 square meters) of impervious surface will comply with Minimum Requirements 2 through 9. The designers will apply BMPs to the maximum extent practicable for each project. In the case where it is not practicable to fully implement the required BMPs, the procedure explained in Minimum Requirement 9 and Chapter 5 shall be followed to show what mitigation has been done and why further mitigation is not practicable for the project.

## 2-2 Minimum Requirement 1 — Erosion and Sediment Control

Projects will be designed and managed to prevent erosion and sediment from leaving the site. The designers will design the project to protect adjacent properties from sediment deposition and increased flows. Any temporary conveyance systems will be designed to handle flow from the 2-year design storm for the developed conditions. The configuration of the project stormwater management design and the temporary BMPs used during construction will be shown on the Stormwater Site Plan (SSP) (Minimum Requirement 9).

## 2-3 Minimum Requirement 2 — Preservation of the Natural Drainage System

Natural drainage patterns shall be maintained, and discharges from the site shall occur at the natural locations.

## 2-4 Minimum Requirement 3 — Source Control of Pollutants

The project will be designed to prevent stormwater from coming in contact with pollutants. This shall include, but not be limited to:

- Minimize natural vegetation removal.
- Vegetation restoration after construction.
- Maintain vegetative buffers around water bodies.
- Proper storage and handling of potential pollutants.
- Establishing vegetation management plans.
- Street sweeping on a regular basis.

While source control is the preferred method of eliminating pollutants, there are few opportunities to practice source control on typical highway projects. The exception being during the construction phase of all projects and for the permanent phase of park and ride, regional offices, area maintenance offices, storage facilities, and and rest area projects. Chapter 4 provides a more detailed description of sources control BMPs.

## 2-5 Minimum Requirement 4 — Water Quality Treatment

All projects shall provide water quality treatment of stormwater runoff from the newly created impervious surface. The practicality of providing water quality treatment for runoff from any existing impervious area shall be investigated. The associated costs for treating new and existing impervious areas shall be recorded in the project's Hydraulics Report. BMPs for existing impervious runoff will be implemented whenever the investigation demonstrates that it would more feasible to construct the BMPs during the current project instead of waiting until a future date to fully retrofit the entire roadway section. BMPs for existing impervious runoff will also be installed whenever the benefit derived from immediately retrofitting the roadway can be shown to outweigh the cost of installing the BMPs. The treatment is to be designed to reduce pollutant loads and concentrations in stormwater using physical, biological, and chemical removal mechanisms. Water quality treatment BMPs will be designed to treat the 6-month 24-hour design storm. The volume of the 6-month design storm is equal to 64 percent of the volume of the 2-year design storm.

## 2-6 Minimum Requirement 5 — Water Quantity Treatment

All projects that do not meet one of the exemptions listed below shall provide water quantity treatment of stormwater runoff from the newly created impervious surface. The practicality of providing water quantity treatment for runoff from any existing impervious area shall be investigated. The associated costs for treating new and existing impervious areas shall be recorded in the project's Hydraulics Report. BMPs for existing impervious runoff will be implemented whenever the investigation demonstrates that it would be more feasible to construct the BMPs during the current project instead of waiting until a future date to fully retrofit the entire roadway section. BMPs for existing impervious runoff will also be installed whenever the benefit derived from immediately retrofitting the roadway can be shown to outweigh the cost of installing the BMPs.

Infiltration is the preferred method of reducing the quantity of stormwater runoff. If infiltration cannot be used at the project site, then the peak rate of runoff from the treated area after project completion shall be no greater during the 2-year design storm than 50 percent of the existing conditions 2-year peak runoff. The peak rate of runoff after project completion shall be no greater during the 10-year and 100-year design storms than the existing condition 10-year peak runoff and 100-year peak runoff respectively.

Projects do not have to include water quantity treatment if any one of the following apply:

- The discharge is directly to a body of salt water.
- The discharge is directly to one of the major rivers listed in Figure 2-6.1.
- The discharge is directly to a lake with a surface area greater than 300 acres.

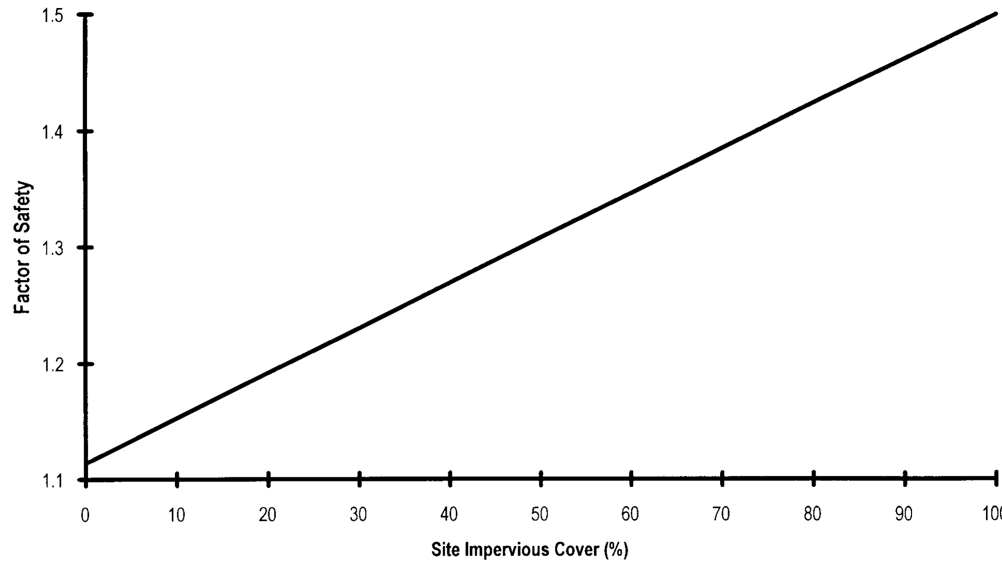
There are other situations when providing no water quantity treatment for a project may be preferable. For instance, if the project is located in a rural basin and an analysis shows that sheet flow from the roadway will fully infiltrate prior to reaching the nearest receiving water body, then it may be beneficial to allow this to occur instead of collecting the runoff and discharging it as surface flow to the receiving body. Anytime the designer believes that water quantity treatment should not be included but the project does not meet one of the three exemptions listed in the previous paragraph, he/she must contact the Hydraulics Section as early in the project as possible. The Hydraulics Section will aid the designer in properly analyzing the effects of the project's runoff. The Hydraulics and Environmental Sections will also coordinate with the appropriate state, local, and federal agencies to ensure adequate protection of all natural resources.

Whenever the project utilizes a detention BMP (RD.11 Dry Pond or RD.20 Dry Vault/Tank) a factor of safety must be applied to the BMP volume. The factor of safety is dependent on the percentage of total area that is impervious which is contributing flow to the BMP. The factor of safety is obtained from Figure 2-6.2. The factor of safety will be applied by first designing the BMP using the Santa Barbara Urban Hydrograph Method (see Chapter 3) and then multiplying the initial design volume by the factor of safety to obtain the final volume. The BMP's volume must be increased from the initial design volume to the final volume without increasing the average depth.

| River | Upstream Point for Exemption |
|---|---|
| Bogachiel | Bear Creek |
| Calawah | Sitkum River |
| Chehalis | Bunker Creek |
| Columbia | Canada Border |
| Cowlitz | Skate Creek |
| Elwha | Lake Mills |
| Grande Ronde | Oregon Border |
| Hoh | South Fork Hoh River |
| Humptulips | West & East Fork Confluence |
| Kettle | Canada Border |
| Klickitat | Little Klickitat River |
| Lewis | Swift Reservoir |
| Methow | Lost River |
| Naches | Nile Creek |
| Nisqually | Alder Lake |
| Nooksack | Glacier Creek |
| South Fork Nooksack | Hutchinson Creek |
| Okanogan | Osoyoos Lake |
| Palouse | Idaho Border |
| Pend Oreille | Idaho Border |
| Puyallup | Carbon River |
| Queets | Clearwater River |
| Quillayute | Bogachiel River |
| Sauk | Clear Creek |
| Satsop | Middle & East Fork Confluence |
| Skagit | Cascade River |
| Skokomish | Vance Creek |
| Skykomish | Beckler River |
| Snake | Idaho/Oregon Border |
| Snohomish | Snoqualmie River |
| Snoqualmie | Middle & North Fork Confluence |
| Sol Duc | Beaver Creek |
| Spokane | Idaho Border |
| Stillaguamish | North & South Fork Confluence |
| North Fork Stillaguamish | Boulder River |
| South Fork Stillaguamish | Canyon Creek |
| Toutle | North & South Fork Confluence |
| North Fork Toutle | Green River |
| White | Greenwater River |
| White Salmon | Trout Lake Creek |
| Wynoochee | Wishkah River Road Bridge |
| Yakima | Keechelus Lake |

**Rivers Exempted From Minimum Requirement 5**

***Figure 2-6.1***




**Factor of Safety for Detention Ponds and Vaults**

*Figure 2-6.2*

## 2-7 Minimum Requirement 6 — Wetlands

Stormwater runoff discharging to a wetland must be treated for water quality and quantity in a manner consistent with that described in Minimum Requirement 4 and 5. Stormwater treatment facilities should not be placed in the designated buffer for a wetland.

Wetlands are more sensitive to varying site specific and regional conditions. Thus every wetland must be evaluated on a case-by-case basis to determine impacts of stormwater discharges. The diversity in the values and functions of a wetland, as well as the uniqueness of the type of wetland, will need to be understood before determining if the treatment provided by Minimum Requirements 4 and 5 will adequately protect the receiving wetland. In addition, the management strategy for wetlands on a watershed basis will influence available stormwater control options. The best source of information regarding wetlands is the service center Biology Unit. Preliminary guidelines are provided in Section 5-2.10.

If a wetland is created to replace wetlands that were unavoidably destroyed during design and construction of a project, that wetland can not be used for stormwater treatment. Constructed wetlands can be designed to treat stormwater runoff. A constructed wetland must be in an area that was not a wetland and be designed specifically for the purpose of treating stormwater. The designers should see the Hydraulics Section for guidance if they want to use a Constructed Wetland BMP.

## 2-8 Minimum Requirement 7 — Downstream Analysis

An analysis shall be performed to determine the potential impacts from the project on the downstream system. At a minimum, the downstream analysis will include the area from the project site to a point one quarter of a mile downstream of the project site. The analysis must proceed far enough along the drainage course to determine that nothing downstream of the end point will be affected by the project's runoff. Chapter 5 contains a detailed description of how to perform a downstream analysis. The results of the analysis will be included in the Stormwater Site Plan.

## 2-9 Minimum Requirement 8 — Sensitive Areas and Basin Plans

There are some drainage basins throughout the state where local agencies (in particular, those with a stormwater utility) have performed detailed analyses of the basin's hydrologic characteristics. These basins have typically been studied because they are known to be sensitive areas and often require the stormwater runoff to be treated in a special manner. Along with studying the hydrologic characteristics, the local agency will publish a document that describes the method to be used for stormwater treatment in the specific drainage basin. These documents are referred to as basin plans.

When a project or a portion of a project is located within a basin that has an adopted basin plan with recommended design standards, the methodology found in the basin plan shall be used. There are two exceptions to using the methodology in the basin plan. The first exception occurs if the requirements of the basin plan are less stringent than the requirements of this manual, in which case the requirements of this manual shall be used. The other exception occurs when the designer can show that by applying the requirements of this manual, the receiving body is adequately protected.

## 2-10 Minimum Requirement 9 — Stormwater Site Plan

For each project subject to any of these requirements, the designers will develop an SSP. This will include the hydraulic report, the TESC Plan, the BMP Selection Form (found in Chapter 4), the project specific maintenance schedule and any other information that shows the design and implementation of the stormwater treatment measures. Chapter 5 of this manual gives a detailed description of the material that should be included in the SSP.

If the minimum requirements for a project have not been met because the designer has determined that it is not practicable to include the necessary BMPs, then an explanation must be provided in the SSP. The explanation shall include the reasons why the minimum requirements have not been met for the site and the amount of stormwater treatment that can be provided. The explanation will be used by the the Hydraulics and Environmental Sections and any agencies that will be issuing permits for the project to accept or reject the request to allow the project not to meet the minimum requirements.

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*3C:P3:HRM3*

## 3-1 Introduction

The purpose of this chapter is to define the computational standards required for the design of stormwater treatment and detention facilities. Within the chapter is an explanation of the method that is to be used for the design of stormwater facilities and the supporting data that will be needed to complete the design.

The method of analysis presented in this chapter is the Santa Barbara Urban Hydrograph (SBUH) method. It currently represents the best workable process for calculating total runoff during a storm event for a small basin. Designing a stormwater runoff facility using the volume of a storm event leads to significantly better results than designing the facility based on a peak intensity. Since the SBUH method is an improvement over methods based on the Rational Formula, it supersedes the method for stormwater facility design presented in Chapter 7 of the Washington State Department of Transportation (WSDOT) *Hydraulics Manual*.

The SBUH method is very computationally intensive. Calculations for even a single area would take several hours if done with a standard calculator. As a result of this, the only practical way to conduct an analysis is to use a computer application. The equations used are such that they could be incorporated into a spreadsheet program to provide the necessary computations. However, it is highly recommended that one of the commercially available computer programs that offers the SBUH method for analysis be used. The advantage of using commercial software is the overall consistency of input and output formats and the reliability of being tested in several different design circumstances. The Olympia Service Center Hydraulics Section uses, and encourages designers in the regional offices to use, the software package WaterWorks written by Engenious Systems. The examples presented in this chapter assume that the designer is using WaterWorks.

## 3-2 Project Considerations

Prior to conducting any stormwater runoff calculations, the overall relationship between the proposed project and the runoff that it will be creating must be considered. When the project layout is first being determined, estimates of the area that will be required for stormwater treatment must be known in order to provide for adequate purchase of right of way for the project. To successfully estimate the required area, several items need to be covered. The basic requirements for the stormwater facility design must be known, the general hydrologic characteristics of the site where the project is located must be known, and the basic alignment of the new project must be known.

In most instances, the basic requirements for stormwater facilities described within this manual will be adequate to meet other state agency and local jurisdiction requirements. Some projects will be located in areas that have been designated as requiring more stringent runoff control standards. The first part of any hydrologic analysis will be conducting research to determine if the project is located in an area where additional requirements exist. Typically, this can be accomplished by consulting with the district hydraulics or environmental sections.

When stricter standards do apply, they are usually in the form of increased rainfall duration or lower site discharge rates. Either case is easily applied to the method of analysis outlined in this chapter.

The basic hydrologic characteristics of the project site will dictate the amount of runoff that will occur and where stormwater facilities can be placed. Several sources exist that will be useful in determining the necessary information for runoff analysis. Drainage patterns and contributing areas can be determined from contour maps that were generated from preliminary surveys of the area for the proposed project or from contour maps for a previous project in the same area. Soil characteristics can be found in Soil Conservation Service (SCS) publications or from analysis done by the Materials Lab. Existing drainage facilities and conveyance system locations can be found in Hydraulics Reports from previous projects in the same vicinity or in plans for the existing roadway. Another source of information is the outfall inventory/field screening database. The final part of determining site characteristics is to visit the site of the proposed project. The field visit will serve to verify all of the information that was obtained through research and will show where that information may have been deficient. In nearly every instance, the information gained by visiting the site prior to designing the stormwater facilities is far more beneficial than the calculations that could have been performed by the designer if he/she had remained in the office.

Once the basic stormwater requirements are understood and the general hydrologic site characteristics are known, the necessary area for stormwater facilities can be estimated. This is done by examining the proposed layout of the project and determining the most suitable locations to place the facilities. Then the method described later in this chapter can be applied to the site and an estimate of the required area can be calculated. If this process is done early enough, then slight alterations to the project alignment can be made and adequate right of way can be purchased. A final design of the stormwater facilities will have to be performed when the project layout is finalized. The location of stormwater outfalls should be provided to local agencies and added to WSDOT's outfall inventory to facilitate compliance with NPDES and Highway Runoff Rule requirements.

## 3-3 Hydrograph Method

To correctly size an inlet, a pipe, or a ditch for conveyance of highway drainage, the designer needs to know the peak flow that will be required to pass through the system. Since only a single flow value is needed, a method such as the intensity duration based Rational Method presented in Chapter 2 of the WSDOT *Hydraulics Manual* will yield correct sizes. To correctly size some of the BMPs presented later in this manual, the designer must know the peak flow that will be generated from the site along with the total volume of runoff that will be generated and the timing that different flow rates will occur during the storm event. While there are ways to synthesize the required information from the results of a Rational Method analysis, it is more accurate to use a method that generates a hydrograph, the standard plot of runoff flow versus time, based on a volume of rainfall for a given time period.

At this time, the SBUH method represents the best approach for designing highway runoff BMPs which require a hydrograph analysis. The SBUH method models runoff by analyzing a given time period of rainfall to generate a hydrograph which is sensitive to variations in the rainfall preceding and following the peak unlike intensity duration models which are only sensitive to the peak rainfall intensity. It was specifically developed to model runoff from an urbanized, mostly impervious land use, unlike other popular event based models which where developed to model runoff from agricultural land uses. The SBUH method has easily understood input parameters unlike the data intensive and extremely complicated continuous simulation models.

A SBUH analysis requires that the designer understands certain characteristics of the project site such as drainage patterns, predicted rainfall, soil type, area to be covered with impervious material, method of drainage conveyance, and the BMP that will be used. 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, and type of BMP used will 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

### 3-3.1 Design Storm Hyetograph

The SBUH method requires the input of a rainfall distribution or design storm hyetograph. The design storm hyetograph is rainfall depth versus time for a given design storm frequency and duration. For this application, it is presented as a dimensionless table of unit rainfall depth (increment rainfall depth for each time interval divided by the total rainfall depth) versus time.

The SCS has developed several hyetographs that are used throughout the county for runoff calculations. For projects in western Washington, the SCS Type 1A hyetograph should be used. Eastern Washington projects should use the SCS Type 2 hyetograph. The reason for using different hyetographs is to account for the different types of rainfall patterns that occur throughout the state. Both of these hyetographs have a duration of 24 hours and both are encoded into the WaterWorks computer program.

The design storm hyetograph is constructed by multiplying the dimensionless hyetograph by the rainfall depth (in inches). The total depth of rainfall for storms of 24-hour duration and 2-, 10-, 25-, and 100-year recurrence intervals are presented in Figure 3-3.1. Obtain the value from the figure for the city that is closest to the project site. Another method for obtaining rainfall volumes for different storms is to use Isopluvial maps. Isopluvial maps for different storm durations and recurrence intervals are published by the National Weather Service. This information can be obtained from the Olympia Service Center Hydraulics Section.

| Location | 2-year | 10-year | 25-year | 100-year |
|---|---|---|---|---|
| Aberdeen and Hoquiam | 2.5 | 3.2 | 4.0 | 5.0 |
| Anacortes | 1.2 | 2.0 | 2.5 | 3.1 |
| Bellingham | 1.8 | 2.7 | 3.1 | 3.8 |
| Bremerton | 2.5 | 3.5 | 4.5 | 5.0 |
| Cathlamet | 3.5 | 5.0 | 5.7 | 6.8 |
| Centralia and Chehalis | 2.2 | 3.0 | 3.5 | 4.3 |
| Clarston and Colfax | 1.4 | 1.8 | 2.1 | 2.6 |
| Colville | 1.4 | 1.9 | 2.2 | 2.6 |
| Ellensburg | 1.5 | 2.3 | 2.7 | 3.5 |
| Elma | 3.0 | 4.2 | 4.7 | 6.0 |
| Everett | 1.5 | 2.3 | 2.6 | 3.2 |
| Forks | 5.5 | 7.5 | 8.5 | 10.0 |
| Gold Bar | 3.0 | 3.5 | 4.0 | 5.0 |
| Goldendale | 1.5 | 2.3 | 2.8 | 3.5 |
| Hoffstadt Creek | 4.5 | 6.0 | 7.5 | 9.0 |
| Hoodsport | 4.8 | 6.6 | 7.7 | 9.5 |
| Humptulips | 5.0 | 6.7 | 8.0 | 10.0 |
| Kelso and Longview | 2.5 | 3.5 | 4.0 | 5.0 |
| Leavenworth | 1.5 | 2.0 | 2.5 | 3.0 |
| Long Beach | 3.0 | 4.0 | 4.5 | 5.5 |
| Moses Lake | 0.7 | 1.1 | 1.3 | 1.7 |
| Mount Vernon | 1.7 | 2.6 | 3.0 | 3.7 |
| Naselle | 4.5 | 6.0 | 7.0 | 8.5 |
| North Bend | 4.0 | 5.0 | 6.0 | 6.5 |
| Olympia | 2.8 | 4.3 | 5.1 | 6.1 |
| Omak | 1.0 | 1.6 | 1.8 | 2.2 |
| Pasco and Richland | 0.8 | 1.3 | 1.6 | 2.0 |
| Port Angeles | 2.1 | 3.1 | 3.9 | 4.6 |
| Port Townsend | 1.0 | 1.7 | 2.0 | 2.5 |
| Poulsbo | 2.0 | 2.4 | 3.5 | 4.0 |
| Queets | 5.2 | 6.5 | 7.5 | 9.3 |
| Raymond | 3.5 | 4.9 | 5.5 | 6.5 |
| Seattle | 2.0 | 2.8 | 3.4 | 4.0 |
| Sequim | 1.5 | 2.0 | 2.5 | 2.8 |
| Shelton | 4.0 | 5.5 | 6.5 | 8.5 |
| Snoqualmie Pass | 5.5 | 7.0 | 8.0 | 10.0 |
| Spokane | 1.4 | 2.0 | 2.2 | 2.6 |
| Stevens Pass | 5.0 | 6.5 | 7.5 | 9.0 |
| Sumas | 2.5 | 3.3 | 3.8 | 4.5 |
| Sumner | 2.0 | 2.8 | 3.3 | 3.9 |
| Tacoma | 2.0 | 3.0 | 3.5 | 4.0 |
| Toledo | 2.3 | 3.0 | 3.5 | 4.2 |
| Vancouver | 2.3 | 3.0 | 3.5 | 4.3 |
| Vantage | 1.0 | 1.6 | 1.9 | 2.3 |
| Walla Walla | 1.2 | 1.9 | 2.0 | 2.4 |
| Wenatchee | 1.5 | 2.2 | 2.5 | 3.1 |
| White Pass | 4.5 | 6.0 | 7.0 | 8.0 |
| Yakima | 1.0 | 1.5 | 1.8 | 2.2 |

**24-Hour Duration Rainfall Volumes**

***Figure 3-3.1***

***Example***

Determine the 100-year design storm depth for a project:

1. Located Near Tacoma

   100-year 24-hour rainfall depth = 4.0 inches (102 mm)

2. Located Near Spokane

   100-year 24-hour rainfall depth = 2.6 inches (66 mm)

When a project requires a runoff quantity control BMP as described in Minimum Requirement 5 in Chapter 2, an SBUH method design must be done using the 2-year, 10-year, and 100-year return frequencies. The rainfall depths for the different storm recurrence intervals are obtained as previously explained. To design a water quality control BMP as described in Minimum Requirement 4 in Chapter 2, an SBUH method design may be required. If the BMP selected for use requires a hydrograph method design, then the correct hyetograph to use is the 6-month recurrence storm. The 6-month rainfall depth is equal to 64 percent of the 2-year, 24-hour volume.

***Example***

Determine the 6-month design storm depth for a project near Tacoma:

2-year, 24-hour rainfall depth = 2.0 inches

6-month design storm = (.64)(2yr 24hr storm)
= (.64)(2.0)
= 1.3 inches (33 mm)

For project sites with tributary drainage areas above elevation 1,000 feet Mean Sea Level, the designer must consider the effects of snow melt. At higher elevations, the worst cases of runoff often occur when warm rain from the design storm falls on snow, causing runoff not only from the precipitation of the storm but also from the melting snow. An inch of rain is roughly equivalent to 10 inches of snow. By increasing the 24-hour rainfall depth 1 to 2 inches, the effects of snow melt are usually well accounted for. There should be no increase applied to roadway sections that will have snow removed during the winter months.

### 3-3.2 Runoff Parameters

The SBUH method requires 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 three key parameters (area, curve number, and time of concentration) that along with the rainfall hyetograph develop the runoff hydrograph through use of the SBUH method.

The proper selection of contributing basin areas is required to obtain a high degree of accuracy in hydrograph analysis. The basin area used should be relatively homogeneous in land use and soil type. If the entire contributing basin is similar in these aspects, then the basin can be analyzed as a single area. If significant differences exist within a given drainage basin, then it must be divided into subbasin areas of similar runoff characteristics. For example, a drainage basin, consisting of a park and ride lot 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. Drainage basins larger than 10 acres should be divided into subbasins. By dividing large basins into smaller subbasins and then combining calculated flows, the timing aspect of the generated hydrograph is typically more accurate.

Basin areas can be determined with a contour map. Contour maps that are generated specifically for the project site are the most accurate way of obtaining the drainage area since they are done with 5-foot or less contours. If the drainage area extends past the limits of the maps generated for the project, then USGS Quadrangle contour maps can be used to obtain the basin area. New impervious area should always be measured from project specific maps.

To determine the basin area contributing to a project, the area first must be outlined on the contour map. This is done by locating the project's discharge point on the map then drawing a line along the ridge line of the basin, finally connecting back to the discharge point. This will need to be done for each discharge point of the project site. If the flow from two or more discharge points can be combined, then their basins can also be combined. Once the basin boundary is drawn on a map, it can be measured using a planimeter or digitized on a CAD station and scaled.

The SCS has conducted studies into the runoff characteristics of various land types. After gathering and analyzing extensive data, the SCS 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 (CN). Figure 3-3.2 shows suggested CN values for various land covers.

The factors that contribute to the CN value are known as the soil-cover complex. The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics. These soil groups are labeled Type A, B, C, and D with Type A generating the least amount of runoff and Type D generating the greatest. Figure 3-3.3 shows the hydrologic soil group of most soils in Washington State. The different soil groups can be described as:

- Type A — 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.
- Type B — 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.
- Type C — 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.
- Type D — 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.

| Land Use Description | | Curve Numbers by Hydrologic Soil Group A | B | C | D |
|---|---|---|---|---|---|
| Mountain brush — oak brush, aspen, maple: | | | | | |
| Good Condition: | ground cover > 70% | 40 | 40 | 41 | 48 |
| Fair Condition: | ground cover 30% to 70% | 40 | 48 | 57 | 63 |
| Poor Condition: | ground cover < 30% | 46 | 66 | 74 | 79 |
| Woods or forest land: | | | | | |
| Good condition: | Natural conditions | 40 | 55 | 70 | 77 |
| Fair condition: | Some forest litter | 40 | 60 | 73 | 79 |
| Poor condition: | No small trees or brush | 45 | 66 | 77 | 83 |
| Woods/Grass combination (orchard or tree farm): | | | | | |
| Good condition: | ground cover > 75% | 40 | 58 | 72 | 79 |
| Fair condition: | ground cover 50% to 75% | 43 | 65 | 76 | 82 |
| Poor condition: | ground cover < 50% | 57 | 73 | 82 | 86 |
| Brush with weeds and grass: | | | | | |
| Good condition: | ground cover > 75% | 40 | 48 | 65 | 73 |
| Fair condition: | ground cover 50% to 75% | 40 | 56 | 70 | 77 |
| Poor condition: | ground cover < 50% | 48 | 67 | 77 | 83 |
| Meadow — continuous grass: | | 40 | 58 | 71 | 78 |
| Residential districts: | | | | | |
| ¼ acre lots: | | 61 | 75 | 83 | 87 |
| ⅓ acre lots: | | 57 | 72 | 81 | 86 |
| ½ acre lots: | | 54 | 70 | 80 | 85 |
| 1 acre lots: | | 51 | 68 | 79 | 84 |
| Pasture or range: | | | | | |
| Good condition: | lightly grazed | 40 | 61 | 74 | 80 |
| Fair condition: | not heavily grazed | 49 | 69 | 79 | 84 |
| Poor condition: | heavily grazed w/no mulch | 68 | 79 | 86 | 89 |
| Newly graded areas (no vegetation established) | | 77 | 86 | 91 | 94 |
| Open spaces, lawns, parks, golf courses, cemeteries: | | | | | |
| Good condition: | grass cover > 75% | 40 | 61 | 74 | 80 |
| Fair condition: | grass cover 50% to 75% | 49 | 69 | 79 | 84 |
| Poor condition: | grass cover < 50% | 68 | 79 | 86 | 89 |
| Gravel roads and parking lots: | | 88 | 92 | 95 | 98 |
| Dirt roads and parking lots: | | 86 | 90 | 94 | 98 |
| Impervious surfaces: | pavement and roofs | 98 | 98 | 98 | 98 |
| Open water bodies: | lakes, wetlands, and ponds | 100 | 100 | 100 | 100 |

For a more detailed description of agricultural land use and arid region curve numbers, refer to Soil Conservation Service Technical Release 55, Chapter 2, June 1986.

**Runoff Curve Numbers**

***Figure 3-3.2***

| Soil Name | Class | Soil Name | Class | Soil Name | Class |
|---|---|---|---|---|---|
| Aabab | B | Bograp | B | Clayton | B |
| Adkins | B | Boistfort | C | Cle Elum | B |
| Aeneas | B | Bong | B | Cleman | B |
| Agnew | C | Bonner | B | Clint | B |
| Ahl | B | Bossburg | D | Cloquato | B |
| Ahren | B | Bow | C | Cocolalla | C |
| Ahtanum | C | Brew | C | Colockum | B |
| Aita | C | Brickel | C | Colter | B |
| Ats | B | Bridgeson | C | Colville | D |
| Alderwood | C | Brief | B | Conconully | B |
| Almota | C | Briscot | C | Copalis | B |
| Alpowa | B | Broadax | C | Cordy | B |
| Alvor | C | Bromo | B | Cotteral | B |
| Ampad | C | Buckhorn | B | Covello | B |
| Anatone | D | Buckley | C | Cowinch | B |
| Anders | C | Buhrig | C | Cusick | D |
| Ansaldo | B | Bunker | B | Custer | C |
| Antilon | B | Burbank | A | Dabob | C |
| Ardenvoir | B | Burch | B | Dalkena | B |
| Arents | B | Burke | C | Darland | B |
| Arta | C | Cagey | C | Dart | A |
| Ashoe | B | Calawah | B | Dearyton | B |
| Asotin | C | Calcuse | B | Dehart | B |
| Babcock | C | Carlsborg | A | Delphi | D |
| Badge | B | Carmack | B | Dick | A |
| Bagdad | B | Carstairs | A | Dimal | D |
| Baldhill | B | Casey | C | Dinkelman | B |
| Bamber | C | Cashmere | B | Dinkels | B |
| Barneston | A | Casmont | B | Disautel | B |
| Baumgard | B | Cassolary | B | Dobbs | B |
| Bear Prairie | B | Cathcart | C | Dome | B |
| Beausite | B | Cathlamet | B | Donavan | B |
| Beckley | B | Catla | D | Doty | B |
| Belfast | B | Cattcreek | B | Dougan | B |
| Beljica | B | Cedonia | B | Dougville | B |
| Bellicum | B | Centralia | B | Dragoon | B |
| Bellingham | C | Chamokane | B | Dungeness | B |
| Belzar | C | Chard | B | Dupont | D |
| Benco | B | Chehalis | B | Earlmont | C |
| Benge | B | Chelan | B | Edgewick | C |
| Benham | B | Chesaw | A | Ekrue | C |
| Bernhill | B | Chewawa | B | Eld | B |
| Bestrom | B | Cheney | B | Ellisforde | C |
| Beverly | B | Chesaw | A | Elochoman | B |
| Bickleton | B | Chewelah | B | Eloika | B |
| Bisbee | A | Chiwawa | B | Elwell | C |
| Bjork | C | Cinebar | B | Elwha | C |
| Boistfort | B | Cispus | A | Emdent | C |
| Booker | D | Clallam | C | Endicott | C |
| Boesel | B | Clato | B | Entiat | D |

**Hydrologic Soil Groups**

***Figure 3-3.3***

| Soil Name | Class | Soil Name | Class | Soil Name | Class |
|---|---|---|---|---|---|
| Ephrata | B | Hoypus | A | Ledow | A |
| Esquatzel | B | Huckleberry | C | Lickskillet | D |
| Everett | A | Huel | A | Linvelle | B |
| Everson | C | Hum | B | Littlejohn | B |
| Ewall | A | Humptulips | B | Logy | B |
| Farrell | B | Hunters | B | Loneridge | C |
| Finely | B | Hyas | B | Louella | B |
| Foss | B | Ilwaco | B | Lummi | D |
| Galvin | C | Indianola | A | Lynnwood | A |
| Garfield | C | Inkler | B | Lyre | A |
| Garrison | B | Jimcom | C | Lystair | B |
| Germany | B | Jonas | B | Lytell | B |
| Getchell | C | Jumpe | B | Mabton | B |
| Giles | B | Juno | A | Magallon | B |
| Glenoma | B | Kalaloch | B | Makah | B |
| Godfrey | D | Kapowsin | C | Maki | C |
| Gorskel | C | Karamin | B | Mal | B |
| Gorst | D | Kartar | B | Malaga | B |
| Govan | C | Kartar | B | Manley | B |
| Green Bluff | B | Katula | B | Marble | A |
| Greenwater | A | Kegel | C | Margerum | B |
| Grehalem | B | Kennewick | B | Marlin | D |
| Grisdale | B | Kiehl | A | Martella | B |
| Grove | A | Kilchis | C | Mashel | B |
| Gwin | D | Kiona | B | Maytown | C |
| Hagen | B | Kitsap | C | McDaniel | B |
| Hakker | C | Kittitas | D | McElroy | B |
| Halbert | D | Klaber | D | McKenna | C |
| Hale | B | Klaus | B | McMurray | D |
| Haley | B | Klicker | B | Melbourne | B |
| Hanning | B | Klone | B | Menzel | B |
| Hardesty | B | Knappton | B | Merkel | B |
| Harstine | C | Koehler | C | Meystre | C |
| Hartill | B | Koepke | B | Mikkald | C |
| Hartline | B | Koerling | B | Mippon | B |
| Hartnit | C | Konert | C | Mires | B |
| Harwood | C | Kohner | D | Mobate | C |
| Hatchey | C | Koseth | B | Molcal | B |
| Havillah | B | Kuhl | D | Molson | B |
| Hesseltine | B | Kydaka | D | Mondovi | B |
| Hesson | C | Lacamas | D | Montesa | C |
| Heytou | B | Laketon | B | Mopang | B |
| Hezel | B | Lance | B | Morical | C |
| Hodgson | C | Latah | C | Moscow | B |
| Hoffstadt | B | Lates | B | Mossyrock | B |
| Hoh | B | Le Bar | B | Mowich | C |
| Hoko | C | Leader | B | Moxee | D |
| Hoodsport | C | Leadpoint | B | Mukilteo | D |
| Hoogdal | C | Leavenworth | B | Murnen | B |
| Hoquiam | B | Lebam | B | Naches | B |

**Hydrologic Soil Groups**

***Figure 3-3.3***

| Soil Name | Class | Soil Name | Class | Soil Name | Class |
|---|---|---|---|---|---|
| Naff | B | Papac | B | Sagehill | B |
| Narcisse | B | Para | B | Sagemore | B |
| Nard | B | Pastik | C | Salal | C |
| Narel | B | Patit Creek | B | Salkum | C |
| Nargar | A | Pedigo | C | Saltese | D |
| National | B | Peoh | C | Salzer | D |
| Naxing | B | Peone | C | Sammamish | D |
| Neilton | A | Pheeney | B | San Juan | A |
| Nemah | C | Phelan | D | Sarkin | C |
| Neppel | B | Phoebe | B | Satsop | B |
| Nesika | B | Pickett | C | Sauvola | B |
| Nespeleh | B | Pilchuck | A | Saydab | C |
| Netrac | A | Pitcher | B | Scamman | C |
| Nevat | A | Pogue | B | Schawana | C |
| Nevine | B | Potchub | C | Schneider | B |
| Newaukum | B | Poulsbo | C | Schnorbush | B |
| Newberg | B | Prather | C | Schooley | D |
| Newbon | B | Prosser | C | Schumacher | B |
| Newruss | B | Prouty | B | Scoap | B |
| Newskah | B | Puget | C | Scoon | D |
| Nighthawk | B | Puyallup | B | Scocteney | B |
| Nimue | B | Queets | B | Scotia | B |
| Nisqually | A | Quilcene | C | Scrabblers | B |
| Nooksack | C | Quillayute | B | Sealak | D |
| Nordby | A | Quincy | A | Seastrand | C |
| Norma | B | Ragnar | A | Seattle | D |
| Novark | B | Rainer | C | Sekiu | D |
| Nuby | C | Raisic | B | Selah | D |
| O'Brien | B | Ralls | B | Semiahmoo | D |
| Ocosta | C | Raught | B | Sequim | A |
| Odo | B | Reardan | C | Shalcar | D |
| Ogarty | C | Reed | D | Shano | B |
| Ohana | C | Reichel | B | Shelton | C |
| Okanogan | B | Rennie | D | Si | C |
| Olequa | B | Renslow | B | Sifton | B |
| Olete | C | Renton | D | Siler | B |
| Olomount | C | Republic | B | Simode | C |
| Olympic | B | Ret | C | Sinclair | C |
| Onyx | B | Risbeck | B | Sinloc | B |
| Orcas | D | Ritel | C | Skaha | A |
| Oridia | D | Ritzville | B | Skamania | B |
| Orting | C | Rober | C | Skamo | B |
| Oso | C | Rock Creek | D | Skanid | C |
| Outlook | C | Roloff | C | Skate | B |
| Ovall | C | Royal | B | Skeller | B |
| Owhi | B | Roza | D | Skipopa | D |
| Oyhut | B | Rufus | C | Skoly | B |
| Ozette | C | Rugles | B | Skykomish | B |
| Palix | B | Sacheen | A | Smackout | B |
| Palouse | B | Sadie | C | Snahopish | B |

**Hydrologic Soil Groups**

***Figure 3-3.3***

| Soil Name | Class | Soil Name | Class | Soil Name | Class |
|---|---|---|---|---|---|
| Snohomish | D | Tebo | B | Waha | C |
| Snow | B | Tekison | C | Wahkiakum | B |
| Solduc | A | Tekoa | C | Wahlike | C |
| Solleks | B | Tenino | C | Wahtum | D |
| Spana | B | Terbies | B | Waits | B |
| Spanaway | A | Thout | C | Walla Walla | B |
| Speigle | B | Thow | B | Walville | B |
| Spens | B | Thrash | B | Wamea | B |
| Spofford | C | Tieton | B | Wanser | B |
| Spokane | B | Timberhead | B | Wapato | D |
| Springdale | B | Timentwa | B | Warden | B |
| Spukwush | B | Timmerman | A | Washougal | B |
| Squally | B | Tisch | C | Weirman | B |
| St. Martin | C | Tokul | C | Wellman | A |
| Stabler | B | Tonasket | B | Wenas | C |
| Stahl | C | Toppenish | B | Westport | B |
| Staley | B | Touhey | B | Wethey | B |
| Standup | B | Townsend | C | Whidbey | C |
| Starbuck | D | Track | B | White Swan | C |
| Startup | B | Tradedollar | B | Wiehl | C |
| Steever | B | Traham | B | Wilkeson | C |
| Stemilt | C | Triton | D | Willaby | B |
| Stevens | B | Tucannon | C | Willapa | C |
| Stevenson | B | Tukwila | D | Willis | C |
| Stimson | C | Tukey | C | Winchester | A |
| Strat | B | Tumac | B | Winston | A |
| Stratford | B | Tyee | D | Winthrop | A |
| Sulsavar | B | Uhlig | B | Wintoner | C |
| Sultan | C | Umapine | C | Wishkah | D |
| Sumas | C | Underwood | B | Wolfeson | C |
| Supplee | B | Undusk | B | Woodinville | B |
| Sutkin | B | Vader | B | Yakima | B |
| Swantown | D | Vailton | B | Yaxon | B |
| Swem | C | Vallan | D | Yeary | C |
| Sylvia | C | VanZandt | B | Yelm | C |
| Synarep | B | Varelum | C | Yost | C |
| Tacoma | D | Vassar | B | Zen | C |
| Taneum | C | Verlot | C | Zenker | B |
| Tanwax | D | Vesta | B | Zillah | B |
| Taunton | C | Voight | B | Zynbar | B |
| Tealwhit | C | Wadams | B | Zyzyl | B |

**Hydrologic Soil Groups**

***Figure 3-3.3***

The SCS has developed maps for Washington State that show the specific soil classification for any given location. These maps are compiled by county and are typically available from the regional SCS office. To determine which soil group to use for an analysis, locate the project site on the SCS map and read the soil classification that is listed. Use Figure 3-3.3 to convert from the specific soil classification to a hydrologic soil group. The WSDOT Materials Lab can also perform a soil analysis to determine the soil group for the project site. This should only be done if an SCS soils map cannot be located for the county which the site is in or if there is a reason to doubt the accuracy of the information on the SCS map for the particular site.

When performing an SBUH analysis for a basin, it is common to encounter more than one soil type within that basin. If the soil types are fairly similar (within 20 CN points), then a weighted average can be used. If the soil types are significantly different, then the basin should be separated into smaller subbasins, just as previously described for different land uses. Pervious and impervious soil types should always be analyzed separately. If the computer program WaterWorks is used for the analysis, then pervious and impervious land segments will automatically be separated but similar pervious soil types for a basin will have to be combined and weighted manually by the designer.

***Example***

Select CN values for a project near Tacoma:

Existing Land Use — forest (fair condition)

Basin Size — 10 acres

Future Impervious — 3.9 acres

Soil Type — 80% Alderwood, 20% Melbourne

Figure 3-3.3 shows that Alderwood soil belongs to the “C” hydrologic soil group and Melbourne soil belongs to the “B” group. Therefore, for the existing condition, CNs of 73 and 60 are read from Figure 3-3.2 and weighted to obtain a CN value of 70. For the developed condition, the impervious pavement for the interchange totals 3.9 acres. The 6.1 acres of pervious area consists of grassed open space in fair condition covering the same proportions of Alderwood and Melbourne soil. Therefore, CNs of 79 and 69 are read from Figure 3-3.2 and weighted to obtain a pervious area CN value of 77. The impervious area CN value is 98. The result of this example is summarized below:

| On-Site Condition | Existing | Developed |
|---|---|---|
| Land use | Forest | Interchange |
| Pervious area | 10 ac. | 6.1 ac. |
| CN of pervious area | 70 | 77 |
| Impervious area | 0 ac. | 3.9 ac. |
| CN of impervious area | — | 98 |

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.

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.

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 roughness coefficient) is used. These $n_s$ values are for very shallow flow depths of about 0.1 foot (3 cm) and are only used for travel lengths up to 300 feet (90 m). Figure 3-3.4 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 $T_t$.

$$T_t = (0.42\ (n_s L)^{0.8})/((P_2)^{0.527}(s_o)^{0.4})$$

where:

$T_t$ = travel time (min)
$n_s$ = sheet flow Manning's coefficient
$L$ = flow length (ft)
$P_2$ = 2-year, 24-hour rainfall (in)
$s_o$ = slope of hydraulic grade line (land slope, ft/ft)

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 Figure 3-3.4 in which average velocity is a function of watercourse slope and type of channel. After computing the average velocity using the Velocity Equation, the travel time ($T_t$) for the shallow concentrated flow segment can be computed by dividing the length of the segment by the average velocity.

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 on USGS Quadrangle maps. The $k_c$ values from Figure 3-3.4 used in the Velocity Equation 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 by dividing the length of the channel segment by the average velocity.

A commonly used method of computing average velocity of flow, once it has measurable depth, is the Velocity Equation:

$$V = (k)(s_o^{0.5})$$

where:

$V$ = velocity (ft/s)
$k$ = time of concentration velocity factor (ft/s)
$s_o$ = slope of flow path (ft/ft)

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.
- The equations given here to calculate velocity where developed by empirical means, as a result the values that are put in must be in English Units (such as inches) for the equation to yield a correct answer. Once the velocity is calculated, it can be converted to metric units to finish the travel time calculations in the case of shallow concentrated flow and channel flow.

| Sheet Flow Equation Manning's | $n_s$ |
|---|---|
| Smooth surfaces (concrete, asphalt, gravel) | 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 |
| **Shallow Concentrated Flow** | $k_s$ |
| 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)** | $k_c$ |
| 1. Forested swale with heavy ground litter (n = 0.10) | 5 |
| 2. Forested drainage course 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 |
| **Channel Flow** | $k_c$ |
| 1. Meandering stream with some pools (n = 0.040) | 20 |
| 2. Rock-lined stream (n = 0.035) | 23 |
| 3. Grass-lined stream (n = 0.030) | 27 |

**"n" AND "k" Values for Travel Time Calculations**

***Figure 3-3.4***

- 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 3-3.4 should be used to determine the outflow rating curve through the culvert or bridge.

***Example***

Calculate the travel times for each reach and the time of concentration for a drainage basin near Tacoma.

Given: P2 = 2.0 inches.

Segment 1: L = 100 ft. Forest with light brush (sheet flow)
$s_o = 0.03$ ft/ft
$n_s = 0.40$

Segment 2: L = 300 ft. Pasture (shallow concentrated flow)
$s_o = 0.04$ ft/ft
ks = 11

Segment 3: L = 300 ft. Grassed waterway (intermittent channel)
$s_o = 0.05$ ft/ft
$k_c = 17$

Segment 4: L = 500 ft. Grass-lined stream (continuous)
$s_o = 0.02$ ft/ft
$k_c = 27$

Segment 1: Sheet flow $T_t = (0.42\ (n_sL)^{0.8})/((P2)^{0.527}(so)^{0.4})$
$T_1 = ((0.42)((0.40)(100))^{0.8})/((2.0)^{0.527}(.03)^{0.4}) = 23$ min

Segment 2: Shallow concentrated flow $V = k_s\ s_o\ ^{0.5}$
$V_2 = (11)(0.04)^{0.5} = 2.2$ ft/s
$T_2 = L/60V = 300/(60)(2.2) = 2$ min

Segment 3: Intermittent channel flow
$V_3 = (17)(0.05)^{0.5} = 3.8$ ft/s
$T_3 = 300/(60)(3.8) = 1$ min

Segment 4: Continuous stream
$V_4 = (27)(0.02)0.5 = 3.8$ ft/s
$T_4 = 500/(60)(3.8) = 2$ min
$T_c = T_1 + T_2 + T_3 + T_4$
$T_c = 23 + 2 + 1 + 2 = 28$ minutes

If the computer program WaterWorks is used, then the travel time and time of concentration values do not have to be calculated by hand. When entering the parameters that describe a drainage basin, a time of concentration calculator can be called up. This calculator can handle up to five different land segments. The input for the calculator is the same input that is required for the above example. Once finished inputting the information, the time of concentration calculator will compute the travel times, sum them up, and insert the time of concentration into the correct place in the basin parameters menu.

### 3-3.3 Hydrograph Synthesis

The SBUH method applies the CNs selected to SCS equations to compute soil absorption and precipitation excess from the rainfall hyetograph. Each time step of this process generates one block of an instantaneous hydrograph with the same duration. The instantaneous hydrograph is then routed through an imaginary reservoir with a time delay equal to the basin time of concentration. The end product is the runoff hydrograph for that land segment.

The abstraction of runoff, S, is computed from the CN as follows:

$$S = (1000/CN) - 10$$

Using the abstraction value and precipitation for the given time step, the runoff depth, D, per unit area is calculated as follows:

$$D_{(t)} = (p_{(t)} - .2(S)^2)/(p_{(t)} + .8(S))$$

where:

$p_{(t)}$ = precipitation for the time increment (in)

The total runoff, $R_{(t)}$, for the time increment is computed as follows:

$$R_{(t)} = D_{(t)} - D_{(t-1)}$$

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:

A = area (acres)
dt = time interval (min)

**Note:** A time interval of 10 minutes is used for design storms of 24-hour duration.

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 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:

$w = dt/(2T_c + dt)$
$T_c$ = Time of concentration for the drainage basin

***Example***

The design process for the SBUH method is fairly easy to program into a spreadsheet or to write a stand-alone computer application. While the calculations can be performed using a standard hand-held calculator, it is not advisable due to the large amount of calculations that must be executed. This example is done with the use of the computer program WaterWorks.

Calculate two runoff hydrographs for a project site near Tacoma. The first hydrograph is for the 100-year design storm with the site in its existing conditions. The second hydrograph uses the same design storm for the site after an interchange has been constructed.

Given:

Existing Site — 10 acres forested

Future Site — 3.9 acres impervious, 6.1 acres grassed

100 year rainfall — 4.0 inches for 24 hour duration

Soils — 80% Alderwood, 20% Melbourne

The first thing that must be done for this example is to start the WaterWorks program. Before any data can be input, a data set for the project must be created. Do this by selecting the File option from Main Menu, then select New Data from the File Menu. A prompt appears for a name for the project. For this example, use the name “TACOMA” as the name of the data set.

Now that a data set has been created, the project information must be input. Since the project is west of the Cascade Range, Type 1A storm must be used. The isopluvial maps indicated that the 100-year, 24-hour rainfall totals 4.0 inches for the project site.

The two soil types present on the project site are similar enough that they can be combined and analyzed as one. Alderwood is Type C soil with a CN of 73, Melbourne is Type B soil with a CN of 60. The weighted average is:

$$CN = (.80)(73) + (.20)(60) = 70$$

To enter the data, select Basin from the Main Menu, then select Basin from the Basin Menu. This will bring up a blank input screen. Each basin or subbasin will need a unique set of data input into this area. It is advisable to also create a unique basin definition for the different design storms of each basin in the project. By doing this, the designer can quickly analyze different scenarios without having to change the information in the Basin Menu.

Enter the data for the basin into the input screen for the existing site conditions.

| | |
|---|---|
| Basin ID ............................ : | A1 |
| Description ......................... : | 100-year storm existing conditions |
| Area (acres) ........................ : | 10 |
| Rain Precip (in) .................. : | 4.0 |
| Time Interval (min) ........... : | 10 |
| Time Of Conc (min) .......... : | 28 |
| Rainfall Selection .............. : | 1 |
| Abstrac Coeff ..................... : | 0.20 |
| Base Flow .......................... : | 0.00 |
| Storm Dur (hrs) .................. : | 24 |
| Pervious Area ..................... : | 10.00 |
| Pervious CN ....................... : | 70 |
| Impervious Area ................ : | 0.00 |
| Impervious CN ................... : | 98.00 |

A short explanation of the input parameters follow:

**Basin Data** — This is the way that the program keeps track of the basin, any alpha numeric combination will work here. This name will be the way that the basin is accessed by other parts of WaterWorks.

**Description** — This is a description that is provided only for the convenience of the designer to serve as a reminder of the data that was input. Any short text string will work.

**Area** — This is the total area of the basin in acres.

**Rain Precip** — This is the total depth of the design storm hyetograph. The value used for this example was obtained in Example 3-3.1.1.

**Time Interval** — This is the interval, in minutes, at which the SBUH calculations are made. Use 10 for 24-hour analysis.

**Time of Conc** — This is the time of concentration used. The value for this example is the same as that in Example 3-3.2.2. The easiest way to establish this value is to highlight this menu selection then press the [F4] key. A time of concentration calculator will appear which uses the same input as the equations described earlier in this chapter. When finished with the calculator, press the [F10] key and the calculated value will be automatically input into the Time of Conc field.

**Rainfall Selection** — This is the dimensionless hyetograph that is selected for the SBUH method. If the analysis is for a project site in eastern Washington, then the Type II storm should be selected.

**Abstract Coeff** — Should remain at 0.20.

**Base Flow** — This provides the ability to add a constant base flow to the generated hydrograph.

**Storm Duration** — This is the total amount of time that the storm event will occur over.

**Pervious Area** — This is the total pervious area of the basin in acres.

**Pervious CN** — This is the corresponding SCS curve number for the pervious land segment.

**Impervious Area** — This is the total impervious area of the basin in acres. This value is automatically updated as the Pervious Area value is changed.

**Impervious CN** — This is the corresponding SCS curve number for the impervious land segment, typically this should be 98.

Once this data is input, the [F6] key can be selected and some quick calculations will be performed. Near the bottom of the screen three values for the basin will be displayed. These are:

Peak Hydrograph Time = 8.17 hrs

Peak Hydrograph Flow = 1.61 cfs

Total Hydrograph Vol = 1.10 Ac-ft.

At this point, the program has not generated a hydrograph that can be used, it has only generated a summary that can be used to quickly check the basin. To save the basin information that was just input, press the [PgDn] key. Since basin A1 has been saved, the second basin for this example can now be input by overwriting the portions of basin A1 that are different.

Enter the data for the basin into the input screen for the project site conditions.

| | | |
|---|---|---|
| Basin ID | : | A2 |
| Description | : | 100 year storm project conditions |
| Area (acres) | : | 10 |
| Rain Precip (in) | : | 4.0 |
| Time Interval | : | 10 |
| Time Of Conc (min) | : | 12 |
| Rainfall Selection | : | 1 |
| Abstrac Coeff | : | 0.20 |
| Base Flow | : | 0.00 |
| Storm Dur (hrs) | : | 24 |
| Pervious Area | : | 6.10 |
| Pervious CN | : | 77 |
| Impervious Area | : | 3.90 |
| Impervious CN | : | 98.00 |

Notice that the Time of Conc has changed. This is a result of sheet flow on a smoother surface than in the existing conditions. Also, the Pervious CN has increased due to the change in land cover. Once again, select the [F6] key to display the quick results:

Peak Hydrograph Time = 8.00 hrs

Peak Hydrograph Flow = 5.14 cfs

Total Hydrograph Vol = 2.13 Ac-ft.

Now that both basins have been input, they can be used to create a working hydrograph. From the Main Menu select Hydrograph, then from the Hydrograph Menu select Add/Subt Hyd. This will bring up another small menu. Select the Move Basins option from this menu. This option will present a table that permits up to 10 defined basin hydrographs to be moved to hydrograph storage registers. WaterWorks has the ability to create as many defined basins as the designer has a need for. However, only 20 hydrographs can be made available for use at any one time. As a result, during a large project the designer may have to repeat this “move” step several times to completely analyze a basin. Fill in the opened input table so basin A1 is moved to hydrograph register 1 and basin A2 is moved to hydrograph register 2. To actuate the move command, press the [F6] key, then press [F10] until the prompt is at the Main Menu.

To view the hydrographs, select Hydrograph from the Main Menu, then select List hydro from the Hydrograph Menu. There are two options for listing a hydrograph. The first is a graphical display, the other is a listing of the peak values. Since the peak values are already known, the Graphic option should be selected. A table will pop up with the numbers 1 through 20 on it. These numbers represent the

20 hydrograph registers that are available within WaterWorks. Highlight the 1 and 2 by moving the cursor underneath them with the arrow keys and pushing the [Enter] key. When both are highlighted, press the [F10] key and both hydrographs will be graphical displayed.

### 3-3.4 Hydrograph Routing

This section presents the methodology for routing a hydrograph through a stormwater facility using hydrograph analysis. Hydrograph routing is done the same way regardless of the method used to generate the hydrograph. Therefore, this part of the analysis is no longer unique to the SBUH method. The level pool routing technique presented here is one of the simplest and most commonly used hydrograph routing methods. It is based on the continuity equation:

Inflow — Outflow = Change in Storage

$$((I_1 + I_2)/2) - ((O_1 + O_2)/2) = S_2 - S_1$$

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

The time interval for the routing analysis 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. The variables can be rearranged to obtain the following equation:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2$$

If the time interval is in minutes, the units of storage (S) are now [cf/min] which can be converted to cfs by multiplying by 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. As with the synthesis of a hydrograph, the computations are fairly simple but very voluminous. The best way to route a hydrograph through a stormwater facility is to use a computer program. WaterWorks has many features that make hydrograph routing an easy process.

***Example***

Using the hydrographs developed in the previous example, develop a detention pond and route the project runoff hydrograph through it.

Given: The pond is allowed to release at a rate after the project is constructed that is equal to the rate of runoff prior to the construction of the project. A dry pond should be used as the storage structure with a maximum depth of 5 feet and side slopes of 4:1.

A pond must exist before a hydrograph can be routed through it. The pond must also have an outlet structure which will release the flow from the pond at the allowed release rate. The amount of storage required is a function of the shape of the inflow hydrograph and the allowed release rate. A good first estimate of required volume is the difference between the existing conditions hydrograph's total volume and the project hydrograph's total volume. The outlet structure is based on the maximum allowed release rate. In this case, the peak flow of the existing conditions hydrograph.

Estimated Pond Volume = $V_{A2}$ — $V_{A1}$ = 2.13 — 1.10 = 1.03 Ac-ft

Maximum Release Rate = $Q_{pA1}$ = 1.61 cfs

Start WaterWorks from the Main Menu select File, then from the File Menu select Open Data. A box will be displayed that will show all of the previously created data sets. Highlight the one that is titled TACOMA and press the [Enter] key. These steps can be skipped if WaterWorks was not shut down since following through the last example on hydrograph synthesis.

From the Main Menu, select Storage. This will display the Storage Menu. There are three predefined storage structures to select from and two options for creating customized structures if none of the predefined ones will work for the given design situation. For this example, select Trapezoidal basin. A trapezoidal basin as used in this context is an open pond that is rectangular in plan view and trapezoidal in cross section. To obtain the estimated 1.03 Ac-ft of storage required, fill in the Trapezoidal basin item as follows:

Storage Structure ID .......... : S1
Name .................................. : Detention Pond
Length ................................ : 85
Side Slope1 ........................ : 4
Side Slope2 ........................ : 4
Width.................................. : 65
Side Slope3 ........................ : 4
Side Slope4 ........................ : 4
Infiltration Rate.................. : 0
Starting Elev ...................... : 325.0
Max Elev ............................ : 330.0
Stg-Sto Increm ................... : 0.1

**Storage Structure** — This is the name the computer will use for this pond. Any alpha numeric combination will work.

**Name** — This is a description that is provided only for the convenience of the designer. It serves as a reminder about which pond this is.

**Length** — A trapezoidal basin is rectangular in plan view and trapezoidal in cross. This is the distance along one dimension of the bottom of the pond as observed in plan view.

**Side Slope1** — This is the slope of one side of the pond along the length dimension. Each of the four sides of a trapezoidal basin can be input with a unique slope. The input is in the form of a ratio of x:1, where only the x value needs to be included.

**Side Slope2** — This is the slope of the other side of the pond along the length dimension.

**Width** — This is the distance along the other dimension of the bottom of the pond.

**Side Slope3** — This is the slope of one side of the pond along the width dimension.

**Side Slope4** — This is the slope of the other side of the pond along the width dimension.

**Infiltration Rate** — This is the infiltration rate of the soil in the bottom of the pond in minutes per inch. If this rate is known then it should be input even if the pond is not intended to be an infiltration pond. If no information about the infiltration rate of the soil is available then a zero should be input. It is usually a good design procedure to only input 50 percent of the measured infiltration rate. This will account for the reduction in infiltration that often occurs when fines accumulate along the bottom of the pond.

**Starting Elev** — This is the elevation where calculations start. Typically this is the bottom of the pond.

**Max Elev** — This is the elevation where calculations stop. Typically this is the top of the pond or overflow elevation.

**Stg-Sto Increm** — This is the increment in feet that the stage-storage calculations are done at. For ponds that are no deeper than six feet, use 0.1 for this value.

Near the bottom of the screen the volume of the pond is displayed. This should nearly match the estimated value.

The next step in designing a detention pond is to specify an outlet structure for the pond. From the Main Menu, select Discharge. This will display the Discharge Menu. There are seven predefined discharge structures to select from and an option for creating customized structure if none of the predifined structures match the situation under design. For this example, select Orifice design. WaterWorks will automatically design the correct orifice size given an input hydrograph, a peak flow to match, and a storage facility. To allow for an orifice design, only input the general characteristics of the discharge structure into the input screen.

| | |
|---|---|
| Discharge Structure ID ...... : | D1 |
| Elev of Lowest Orifice ...... : | 325.0 |
| Outlet Elev ......................... : | 325.0 |
| Max El Above Outlet......... : | 330.0 |
| Stg-Disch Increm ............... : | 0.1 |

**Discharge Structure ID** — This is the name the computer will use for this outlet. Any alpha numeric combination will work.

**Elev of Lowest Orifice** — This is the elevation of the lowest or first orifice.

**Outlet Elev** — This is the elevation of the outlet pipe or channel. The flow out through any orifice is calculated relative to this elevation.

**Max El Above Outlet** — This is the elevation where calculations stop. Typically this matches the top of the pond that the discharge structure serves.

**Stg-Disch Increm** — This is the increment in feet that the stage-discharge calculations are done at. For ponds that are no deeper than six feet, use 0.1 for this value.

Now that a detention facility has been defined, a hydrograph can be routed through it. This is done using the level pool routing technique. From the Main Menu, select Level pool. This will bring up a menu of different routing options. Select Input table to define the hydrograph to be routed, the storage structure to route the hydrograph through, and the discharge structure to use for the outlet. An input table will appear that has several lines on it. This provides the ability to do several level pool routing processes at one time. For this example only, the first line needs to be filled in as follows:

| | |
|---|---|
| Description ......................... : | 100-year storm |
| Pre Hyd # ........................... : | 1 |
| Inflo Hyd # ......................... : | 2 |
| Stg Stor ID ......................... : | S1 |
| Stg Dis ID .......................... : | D1 |
| Outflow Hyd # ................... : | 10 |

A short explanation of the input parameters follow:

**Description** — This is a description provided for the use of the designer. The computer program does not use this parameter for any calculations.

**Pre Hyd #** — This item is not required for level pool routing unless an orifice design is being performed. During an orifice design, WaterWorks will use the peak flow value of the indicated hydrograph as the maximum allowed release rate of the storage structure. If the designer prefers to match the outflow of a pond to a value other than the peak of one of the hydrographs, a real number can be input. To input a real number, a decimal point and a tenth value must be included so WaterWorks can distinguish it from a hydrograph number.

**Inflow Hyd #** — This is the number of the hydrograph to route through the storage structure.

**Stg Stor ID** — This is the storage structure through which the hydrograph will be routed.

**Stg Dis ID** — This is the outlet structure that will control flow from the storage structure. In the case of this example, WaterWorks will calculate the size of the orifice to use as an outlet.

**Outflow Hyd #** — This is the number of the hydrograph that was created during the level pool routing process. Once created, it can be viewed through the use of the View hydro.

Once all of the parameters have been input, press the [F10] key to return to the Level pool Menu. Since this example is designing an orifice, the analysis selection must be Basin Design. If an orifice size had been given for the outlet structure or if a weir had been designed as the outlet structure, then the selection from this menu would have been Compute table.

When the Basin Design option is selected, a box will appear on the screen. WaterWorks will step through a number of iterations until it selects an orifice size that allows a peak outflow no greater than the flow rate indicated in the Pre Hyd # input parameter. Once this process is finished, press the [F10] key to return to the Level pool Menu. Select the Display table option to display the results of the analysis.

Orifice Size = 6.12 in (155 mm)

Pond Depth = 2.51 ft (770 mm)

### 3-3.5 Multiple Design Storm Routing

The example presented in the previous section is an accurate but simplified version of the hydrograph routing that must be done for an actual detention facility to meet the requirements of this manual. To meet Minimum Requirement 5 in Chapter 2, the outlet of the detention facility must be sized based on three different storms. For the existing conditions of the site, runoff must be calculated for the 2-year, 10-year, and 100-year return frequency storms. The runoff from the site after the project is completed can be no greater during the 2-year storm than 50 percent of the 2-year existing conditions runoff, no greater during the 10-year storm than the 10-year existing conditions runoff, and no greater during the 100-year storm than the 100-year existing conditions runoff.

As a result of this multiple storm requirement, a different approach to designing an outlet structure is used. Instead of designing a single outlet for the detention facility, multiple outlets are designed to allow for increased outflow during larger storm events. The easiest approach to solving this problem (especially if WaterWorks is used for the design) is to size three different orifices. The first orifice would be placed near the bottom of the pond and would be sized by routing a 2-year storm through the detention facility. The second orifice would be placed just above the maximum surface elevation that occurs during the 2-year storm and would be sized by routing a 10-year storm through the detention facility. The third orifice would be placed just above the maximum surface elevation that occurs during the 10-year storm and would be sized by routing the 100-year storm through the detention facility.

Another method of designing a detention facility outlet is to use a combination of an orifice and a weir, or a combination of an orifice and a standpipe. The orifice would be designed by routing a 2-year storm through the detention facility. The weir or standpipe would be designed by routing the 100-year storm through the detention facility. The 10-year storm would then have to be routed through the facility to ensure that its release did not exceed the allowed rate.

The triple orifice configuration is slightly easier to design than the combination of orifice and weir, mainly because WaterWorks will actually design an orifice size but will not design a weir size. The advantage of the orifice and weir combination is that often a smaller volume for the detention facility is needed. Also, a weir or standpipe is less prone to becoming plugged due to debris.

Whenever designing an orifice as an outlet structure, the diameter selected should never be less than 1 inch. This will create problems on small sites since they will have allowed release rates that will dictate the use of a smaller orifice. However, an orifice smaller than 1 inch becomes plugged too easily to be considered practical from a maintenance standpoint. If the site has a very low allowed release rate, then a weir outlet or infiltration should be used.

***Example***

Design a pond for a site in Tacoma that follows the design criteria of Minimum Requirement 5. Use a triple orifice outlet structure as the control.

Given:

Same site as Example 3-3.4.1.

10-year rainfall = 3.0 in

2-year rainfall = 2.0 in

To begin the analysis, start WaterWorks and open the data set named TACOMA. Four additional hydrographs have to be generated for this design, two more hydrographs for the existing conditions, and two more hydrographs for the project conditions. The best way to do this is to create four additional basins. Use the existing basins as templates and write over the input parameters that change. The only changes will be the Basin ID, the Description, and the Rain Precip. Enter the data as follows:

Basin ID ............................. : B1 (copy other data from Basin A1)
Description ......................... : 10-year storm existing conditions
Rain Precip ......................... : 3.0

Basin ID ............................. : C1 (copy other data from Basin A1)
Description ......................... : 2-year storm existing conditions
Rain Precip ......................... : 2.0

Basin ID ............................. : B2 (copy other data from Basin A2)
Description ......................... : 10-year storm project conditions
Rain Precip ......................... : 3.0

Basin ID ............................. : C2 (copy other data from Basin A2)
Description ......................... : 2-year storm project conditions
Rain Precip ......................... : 2.0

Press the [F6] for each of the existing conditions basins and record the peak runoff that is generated.

A1 = 1.61 cfs

B1 = 0.59 cfs

C1 = 0.20 cfs

A1 and B1 will be the allowed release rate for the project for the 100-year and 10-year storms respectively. Fifty percent of C1 will be the allowed release rate from the project site during the 2-year storm.

Allowed Release Rate:

100-year storm = 1.61 cfs

10-year storm = 0.59 cfs

2-year storm = 0.10 cfs

Using the Move Basin command in the Hydrograph Menu, move all of the basins for the project conditions into a hydrograph register.

A2 — Hydrograph 1

B2 — Hydrograph 2

C2 — Hydrograph 3

Since a detention pond has already been defined (Stg Stor ID = S1) and since the new outlet design will write over the existing outlet structure (Stg Dis ID = D1), there is no need to define another detention facility. Select the Input table command from the Level pool Menu. Fill in the input table as follows:

**Level Pool Routing Instructions**

| **Description** | **Pre Hyd #** | **Inflo Hyd #** | **Stg Stor** | **Stg Dis** | **Outfl Hyd #** |
|---|---|---|---|---|---|
| [2-year design storm ] | 0.10 | 3 | S1 | D1 | 13 |
| [10-year design storm ] | 0.59 | 2 | S1 | D1 | 12 |
| [100-year design storm] | 1.61 | 1 | S1 | D1 | 11 |
| [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
| [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
| [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |
| [ ] | [ ] | [ ] | [ ] | [ ] | [ ] |

Once this is input, press [F10] to return to the Level pool Menu. Then select the Basin Design option from the menu. WaterWorks will run through several iterations as it designs an orifice for each storm event. When this process is finished, press the [F10] key to return to the menu and select Display table to determine the maximum water surface elevation during the 100-year storm. This will show how deep to make the final pond. Return to the Main Menu and select Discharge. Then select View Dis-Struct. This will display the sizes of the orifices and the elevations at which to locate them. The final pond design should be as follows:

Length = 85 ft (25.9 m)

Width = 65 ft (19.8 m)

Max Depth = 4.43 ft (1.35 m)

1st Orifice: Size = 1.39 in (35 mm)
Elevation = 325.0 ft

2nd Orifice: Size = 4.84 in (123 mm)
Elevation = 328.7 ft

3rd Orifice: Size = 20.81 in (529 mm)
Elevation = 329.4 ft

This example has essentially designed a Dry Pond (BMP RD.11). The final step in designing this type of BMP is to apply the appropriate factor of safety. Since 39 percent of the project site is impervious, the factor of safety is 1.28 (see Figure 2-6.2). The pond volume must be increased by 28 percent without increasing the average depth. Also it should be noted that the top orifice, with a diameter of 20.8 inches, would typically be impractical to construct. The orifice should be reduced to a more practical size and the hydrographs should be routed through the pond again.

## 3-3.6 Hydrograph Summation

One of the key advantages of hydrograph analysis is the ability to accurately describe the cumulative effect of runoff from several basins 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 begins with selecting a discharge point of interest where it is important to know the effects of the runoff generated on the project site. Next, route each individual hydrograph through conveyance system that carries it to the point of interest. The final step is to sum the flow values for each hydrograph for all of the time intervals. This will yield a single discharge hydrograph.

***Example***

Determine the effects of combining the flow from the detention pond designed in the example of Section 3-3.5 with another basin located adjacent to the project site. The event of concern is the 100-year storm.

Given:

Basin ID ............................ : A3
Description ......................... : 100-year storm off site
Area (acres) ........................ : 15
Rain Precip (in) .................. : 4.0
Time Interval ..................... : 10

| | |
|---|---|
| Time Of Conc (min) .......... : | 36 |
| Rainfall Selection .............. : | 1 |
| Abstrac Coeff ..................... : | 0.20 |
| Base Flow .......................... : | 0.00 |
| Storm Dur (hrs) .................. : | 24 |
| Pervious Area ..................... : | 15.0 |
| Pervious CN ....................... : | 65 |
| Impervious Area ................ : | 0.0 |
| Impervious CN ................... : | 98.00 |

Begin by starting WaterWorks and opening the TACOMA data set. Enter the new basin information for Basin A3. The easiest way to do this would be to write over Basin A1 or A2 since much of the information is the same. Once the basin is defined, it needs to be moved to a hydrograph storage register. From the Main Menu, select Hydrograph, then Add/Subt Hyd, then Move. From the Move input box, move Basin A3 into hydrograph register 5. Press [F10] to return to the Add/Subt Hyd Menu.

The other hydrograph that is to be combined with the newly generated one is the output from the detention pond during the 100-year storm. The last example stored this hydrograph in register 11. Since the two basins are located next to each other, there is no need to route either hydrograph through a conveyance system. From the Add/Subt Hyd Menu, select the Add Hydrograph option. Fill in the input table such that hydrograph 5 is added to hydrograph 11 to equal hydrograph 6. Press [F10] twice, then view the results using the List hydro option on the Hydrograph Menu.

Hydrograph 6

Peak Flow = 2.71 cfs (0.08 cms)

Time of Peak Flow = 10.33 hours

Total Volume = 2.89 Ac-ft (0.36 ha-m)

### 3-3.7 Widening Projects

The example that has progressed through most of this chapter deals with an idealistic situation where the roadway being constructed is completely new. This is the simplest scenario for stormwater runoff design because all of the runoff from the newly constructed road is routed through the treatment facility.

A more common project would involve the improvement of a roadway section such as adding lanes or widening shoulders. Currently, WSDOT projects are required to treat the stormwater runoff from any new impervious surfaces that are created by the project. If the runoff from existing impervious surfaces is treated, then the project is considered to be retrofitted for stormwater treatment. At some time in the future, all WSDOT roadways will be retrofitted for stormwater treatment to the extent practicable.

The designer should always consider the possibility of retrofitting a project site. There are times when a retrofit can be accomplished for very little additional cost. There are also times when even though the cost of retrofitting is high, doing so will create a large benefit to a natural resource. For all projects that involve stormwater treatment, the designer must determine the cost of retrofitting the entire roadway section and record the estimated cost in the Hydraulics Report. Information on the benefits that will be gained by retrofitting a specific project can be obtained from the regional Environmental Section, the Department of Fish and Wildlife, the Department of Ecology, and many local agencies.

The remainder of this section deals with the situation where only the runoff from the newly created impervious surface will be treated. The biggest problem that occurs with this scenario is that runoff from the new roadway will mix with runoff from the existing roadway.

There is no possible way to separate out the runoff from the new roadway area once it has mixed with runoff from other areas. However, it is possible to treat an amount of runoff from both sources that is equal to the volume of runoff from the new impervious area. For water quantity treatment, this can be accomplished by sizing the outlet device to have a maximum flow out equal to the sum of the peak flow of the existing area runoff and the allowed peak flow for the new area runoff.

While stormwater detention, or water quantity treatment for a widening project can be handled by properly adjusting the release rate of the pond, water quality facilities must use a different approach. Water quality facilities rely on a set volume or a set area for treatment. If extra flow is introduced, the pollutant removal of the facility will not be as high as expected. For a water quality facility to operate correctly, it can only accept flow from the amount of area that it was designed for. This can be accomplished in a couple different ways.

One method would be to create a diversion structure and separate conveyance system which allows an amount of flow equal to that from the existing area to bypass the stormwater facility. A better method would be to treat some of the existing area runoff and only a portion of the new runoff. For example, if there was a ½-mile section of roadway that was going to be widened from two lanes to four lanes, a water quality facility could be designed in either of two ways. The design could follow the first method discussed and separate out the flow from the two new lanes for the entire ½-mile section and route that flows through a facility. The design could otherwise follow the second method and route the flow from all four lanes for the first ¼-mile section of the project through a facility. Either way, a total of one-lane mile is being treated, which is equal to the amount being constructed. The second method is preferred because it would be less expensive to construct and would be easier to incorporate into a program of retrofitting existing highway sections with stormwater facilities. It is important to always consider the future possibility of retrofitting and what can be done to make that process easier.

***Example***

A section of highway near the city of Vancouver is scheduled to be improved with an additional lane in each direction. The existing configuration consists of two 12-foot lanes with a 6-foot shoulder on one side and an 8-foot shoulder on the other in each direction. The northbound and southbound lanes are separated by an existing 50-foot grassed median. All of the pavement is sloped towards the median which is “V” shaped and acts as the conveyance system. There are ditches outside of the lanes which prevent off-site drainage from entering the project area. The proposed project will add one 12-foot lane in each direction, while maintaining the current shoulder widths. Both lanes will be added inside of the existing lanes.

The soil in the project vicinity has an SCS identification as Elochoman. The median area is grassed with no appreciable amount of brush. Using this information, design a detention pond for this 2,500-foot section of roadway that will meet the required release rates of Minimum Requirement 5.

The rainfall for the Vancouver area is obtained from Figure 3-3.1. The rainfall amounts are 2.3 inches for the 2-year recurrence, 3.0 inches for the 10-year recurrence, and 4.3 inches for the 100-year recurrence.

Figure 3-3.3 shows that Elochoman soil is SCS Type B soil. A curve number can be obtained from Figure 3-3.2 for the pervious land segments. 98 is always used as the curve number for the paved areas. Given the described conditions of the median, a curve number of 58 should be used.

Calculating the area contributing to the pond being designed indicates that there is a total of 7.23 acres. The existing roadway configuration has 4.36 acres of impervious and 2.87 acres of pervious land contributing flow. After the project is completed, there will be 5.74 acres of impervious and 1.49 acres of pervious land contributing flow.

To best analyze this basin for the tristorm requirement, the designer should define 6 basins within WaterWorks. The 2-year storm, the 10-year storm, and the 100-year storm will each use two basins, one to model the existing conditions and one to model the project conditions.

The basins would be entered into WaterWorks as follows:

Basin ID ............................ : A1
Description ......................... : 2YR EXISTING CONDITIONS
Area (acres) ........................ : 7.23
Rain Precip (in) .................. : 2.3
Time Interval ..................... : 10
Time Of Conc (min) .......... : 24.21
Rainfall Selection .............. : 1
Abstrac Coeff ..................... : 0.20
Base Flow .......................... : 0.00
Storm Dur (hrs) .................. : 24
Pervious Area ..................... : 2.87
Pervious CN ....................... : 58
Impervious Area ................ : 4.36
Impervious CN ................... : 98

(Repeated Information is not Shown for Remaining Basins)

Basin ID ............................ : A2
Description ......................... : 2YR PROJECT CONDITIONS
Time Of Conc (min) .......... : 20.55
Pervious Area ..................... : 1.49
Impervious Area ................ : 5.74

Basin ID. ........................... : B1
Description ......................... : 10YR EXISTING CONDITIONS
Time Of Conc (min) .......... : 24.21
Pervious Area ..................... : 2.87
Impervious Area ................ : 4.36

Basin ID ............................ : B2
Description ......................... : 10YR PROJECT CONDITIONS
Time Of Conc (min) .......... : 20.55
Pervious Area ..................... : 1.49
Impervious Area ................ : 5.74

Basin ID ............................ : C1
Description ......................... : 100YR EXISTING CONDITIONS
Time Of Conc (min) .......... : 24.21
Pervious Area ..................... : 2.87
Impervious Area ................ : 4.36
Basin ID ............................ : C2

Description ......................... : 100YR PROJECT CONDITIONS
Time Of Conc (min) .......... : 20.55
Pervious Area ..................... : 1.49
Impervious Area ................ : 5.74

Press the [F6] key each time the information is entered for a basin to display the peak rate of flow that will occur from the basin. The peak flow rates are mainly a concern for the existing conditions. The results will indicate 1.66 cfs for basin A1, 2.20 cfs for basin B1, and 3.28 cfs for basin C1. From these figures, the allowed release rates can be obtained. They will be 0.83 cfs for the 2-year storm (50 percent of basin A1), 2.20 cfs for the 10-year storm, and 3.28 cfs for the 100-year storm.

Hydrographs from the three project conditions basins will have to be routed through the pond being designed. Before any hydrographs can be routed, they have to be created. From the Main Menu select Hydrograph; from the Hydrograph

Menu select Add/Subt Hyd; and from the Add/Subt Menu select Move Basins. Move basin A2 to hydrograph 1; basin B2 to hydrograph 2; and basin C2 to hydrograph 3.

The next step in the design is to define a pond. The best first estimate for a pond volume is the difference between the volume of the existing conditions hydrograph for the 100-year storm and that of the project conditions hydrograph. When the [F6] key was used to display the peak runoff rates while in the basin, part of the program the volume of the storm is also displayed. For this example, the difference between the two 100-year hydrographs is approximately 0.4 acre-foot.

To define the pond, select the Trapezoidal Basin option from the Storage Menu. There are several different layouts that can be used for any pond. Typically, the site will dictate the shape of the pond; however, no one configuration is realistically any better than any other as long as it fits the site. Fill in the information as follows:

Storage Structure ID .......... : S1
Name .................................. : Detention Pond
Length ................................ : 70
Side Slope1 ........................ : 4
Side Slope2 ........................ : 4
Width.................................. : 10
Side Slope3 ........................ : 4
Side Slope4 ........................ : 4
Infiltration Rate.................. : 0
Starting Elev ...................... : 200.0
Max Elev ............................ : 205.0
Stg-Sto Increm ................... : 0.1

The final thing that must be defined before routing the hydrographs through the pond is the discharge structure. Instead of using a three-orifice configuration, as was done in the last example, this pond will use one orifice in the side of a standpipe. The orifice will control the 2-year storm. The standpipe will control the 10-year storm and the 100-year storm. This will be done by designing the orifice alone using the 2-year storm hydrograph then designing the standpipe overflow in conjunction with the orifice using the 100-year storm hydrograph. The system is then checked to ensure that the 10-year storm release rate is less than the maximum allowed.

The design of the orifice is simply done by using the Basin Design option of the Level Pool Menu, the same way it was done in the previous example. The design of the standpipe is best done with a trial and error analysis of the design storm. A Riser (standpipe) is defined such that its top elevation is at least 0.10 feet higher than the 2-year water surface elevation. The 100-year storm is then routed through the pond and the maximum rate of discharge from the pond is checked against the allowed rate. If the actual rate is larger than the allowed rate, then the riser diameter can be decreased or the top elevation can be increased. This process is repeated until the flows match.

To accomplish this, three outlet structures have to be defined.

(Orifice Design)

Discharge Structure ID ...... : D1

Name ................................. : Orifice Outlet

Lowest Orifice Dia (in) ..... : 4.0

Elev of Lowest Orifice ...... : 200.0

Outlet Elev ......................... : 200.0

Max El above Outlet .......... : 205.0

Stg-Sto Increm ................... : 0.1

(Riser Inflow)

Discharge Structure ID..: D2

Description ......................... : Standpipe

Riser Diameter (inches) ..... : 10

Riser Elevation (feet) ......... : 204.0

Maximum Elevation (ft) .... : 205.0

(Combination)

Discharge Structure ID ...... : D3

Name ................................. : Combined

Structure 1 .......................... : D1

Structure 2 .......................... : D2

When these structures are defined, the hydrographs can be routed through the pond. To do this, use the Compute Table command from Level Pool Menu. The Input Table will define which storm is being analyzed. The three entries on the Input Table will be as follows:

Description ......................... : 2-year storm

Pre Hyd # ........................... :

Inflo Hyd # ......................... : 1

Stg Stor ID ......................... : S1

Stg Dis ID.......: ................. D3

Outflow Hyd # ................... : 18

Description ......................... : 10-year storm

Pre Hyd # ........................... :

Inflo Hyd # ......................... : 2

Stg Stor ID ......................... : S1

Stg Dis ID .......................... : D3

Outflow Hyd # ................... : 19

Description ......................... : 100-year storm

Pre Hyd # ........................... :

Inflo Hyd # ......................... : 3

Stg Stor ID ......................... : S1
Stg Dis ID .......................... : D3
Outflow Hyd # ................... : 20

Notice that the Pre Hyd# is left blank. This is only needed if an orifice is being designed with the Basin Design command. After the hydrographs are routed through pond, the display will show that release rates from the pond either match or are below the allowed release rates so the pond is sized correctly. In a real situation, it will take several trial runs to get the pond size correct and the outlet structures sized correctly to achieve the allowable release rates; however, these trial runs will only take a few minutes to perform once all of the other data has been entered.

The final step with this design would be to apply a factor of safety of 1.42 since 80 percent of the basin is impervious. This must be done without increasing the depth of the pond. The easiest way to do this is to determine the required volume and then change the length and width of the pond in the View Structure command of the Storage Menu. For this example, the highest elevation that the pond filled to during the 100-year storm was 204.44 feet. This gives the pond a total volume of 0.26 Ac-ft. Increasing that by 42 percent gives a required pond volume of 0.37 Ac-ft. By increasing the length of the pond to 90 feet and the width of the pond to15 feet, this volume is achieved.

As an additional note, the water quality treatment (Minimum Requirement 4) for this project would most likely be accomplished by using the median as a filter strip. Another very likely option would be a biofiltration swale immediately upstream of the detention pond.

## 3-4 Conveyance Systems

A conveyance system includes all portions of the surface water system, either natural or man-made, that transport stormwater runoff. The purpose of the conveyance system is to drain surface water from areas such that no damage will result from the flow. A properly designed system will maximize hydraulic efficiency while minimizing erosion and allowing for enhancement of water quality.

Open, vegetated channels are the preferred method of conveyance. The vegetation will help keep the channel from eroding and will provide some water quality treatment. Pipe systems are very efficient at transporting flow but offer no water quality benefits and are more difficult to maintain. As a result, pipe systems should only be used when open channel conveyance is not practical.

The WSDOT *Hydraulics Manual* discusses in detail the design methodologies for different types of conveyance systems. Since all of the material presented in the *Hydraulics Manual* concerning conveyance systems is still valid when used in conjunction with the material presented earlier in this chapter, the *Hydraulics Manual* should be used as the reference guide when designing a conveyance system.

The design of a conveyance system requires that the engineer knows the peak flow that will likely occur at the system. The Rational Method, as presented in the *Hydraulics Manual*, is the quickest way of determining the peak runoff flow for a project site. However, there are two instances when the SBUH method should be used instead of the Rational Method. The first instance is when the basin becomes too complex to accurately analyze with the Rational Method. This can occur from either the basin becoming too large (over 50 acres) or having several different land cover and soil types. The other instance is when the conveyance system is located downstream of a stormwater detention facility, the Rational Method does not have the ability to account for a reduction in flow resulting from detention.

It should be noted that for a basin with a short time of concentration (15 minutes or less) the Rational Method will yield a higher peak flow rate than the SBUH method. This is particularly true for basins in western Washington. The reason this occurs is that the Rational Method uses the highest possible peak intensity rainfall whether it occurs during a 3-hour thunderstorm or during a 7-day continuous rainfall event. The SBUH method on the other hand uses a specific duration, 24 hours. The longer duration storms do not have the extremely intense peaks that occur during storms of very short duration. As the time of concentration increases, the peak intensity that the Rational Method uses more closely matches the peak intensity of the SBUH hyetograph. This difference in flow values should not be of concern to the designer since basins with a time of concentration less than 15 minutes are fairly small and will typically be analyzed with the Rational Method.

To design a conveyance system using the SBUH method, develop a hydrograph for the area of interest as described previously in this chapter. Use the highest flow value from that hydrograph and proceed with the design steps given in the *Hydraulics Manual*.

Most computer programs that calculate hydrographs based on the SBUH method also offer the ability to design or analyze conveyance systems based on the generated hydrographs. WaterWorks offers the ability to analyze ditches, pipes, and gutters. A complex network of these different conveyance systems can also be analyzed. This feature can also be used to route a hydrograph through a long system causing the timing of the hydrograph flows to become shifted. The analysis of hydrograph shifting is important when analyzing the effects of a stormwater facility in a subbasin on a downstream location in the drainage basin.

***Example***

Design the outlet conveyance system for the detention pond designed in the Tacoma Example. The outlet will consist of 200 feet of CMP pipe leading from the pond and outletting to a channel. The channel will run 500 feet and empty into a nearby stream. The conveyance system should be designed for the 100-year storm.

Given:

Average Slope to Stream = .015 $^{ft}/_{ft}$

Manning's n for CMP = .012

Manning's n for Grassed Channel = .030

Discharge Stream's 100-year Surface Elevation = 311.5

Begin by starting WaterWorks and opening the data set TACOMA. From the Main Menu, select Basin, and then select Pipe. This will bring up the input table for a pipe. Since a computer program offers the ability to quickly run "what if" scenarios, the best way to design a pipe or any other conveyance system structure is to assume a size and use the program to see if that size is correct. If not, use the results to select a different size. Using this philosophy, fill in the pipe input table as follows:

| | |
|---|---|
| Reach Number .................. : | R1 |
| Pipe Diameter (in) ............ : | 12 |
| Pipe Length (ft)................. : | 200 |
| Pipe n Coefficient ............. : | .012 |
| Pipe Slope (ft/ft) ................ : | .02 |
| Upstream IE ...................... : | 325 |
| Downstream IE .................. : | 321 |
| Upstream Node ID............. : | (leave blank) |
| Downstream Node ID ........ : | (leave blank) |
| Contributing Basin............. : | (leave blank) |

Most of the input parameters are self explanatory, the ones that may not be are defined as follows:

**Upstream IE** — The invert elevation at the upstream end of the pipe. This is the elevation of the lowest inside part of the pipe.

**Downstream IE** — The invert elevation at the downstream end of the pipe. This is the elevation of the lowest inside part of the pipe. This value will be filled in automatically by WaterWorks if the slope and upstream elevation are filled in.

**Upstream Node ID** — This is the name of the node that the upstream end of the pipe is connected to. Nodes are only used when large pipe networks are being modeled and head losses through the nodes become significant. An example of a node would be a catch basin or a manhole.

**Downstream Node ID** — This is the name of the node that the downstream end of the pipe is connected to.

**Contributing Basin** — This is the name of the basin that will have its hydrograph routed through the pipe. Using this option will save the step of having to transfer the basin hydrograph to a hydrograph storage register. For this example, this option cannot be used since the hydrograph of interest has to be routed through a detention pond prior to being routed through the pipe.

When all of the information has been entered, press [F10] twice to return to the Main Menu. Select Hydrograph, then select Route hydro. This brings up the hydrograph routing input table, from the earlier example hydrograph 11 was created by routing the 100-year storm through a detention pond, route hydrograph 11 through reach R1 to analyze the pipe. Press [F6] to do the routing.

After the routing is complete, a table will be displayed which shows the design elements of the pipe. The table shows that a 12-inch CMP pipe at .02 ft/ft grade will work for the 100-year flow from the pond. If the pipe had been over capacity, WaterWorks would have alerted the designer.

Pipe Capacity = 27%

Pipe Velocity = 6.1 $^{ft}/_{sec}$

Next, the channel leading from the pipe to the stream must be designed. From the Main Menu, select Basin, and then select Ditch. This will bring up the input table for a channel reach. As with the pipe design, the best way to design a channel using WaterWorks is to estimate a channel size and see if it will work. If it does not, then change the size based on the answer from the first analysis. Input the information as follows:

Reach ID ........................... : R2

Ditch Length (ft) ................ : 500

Ditch Width (ft) ................. : 2

Side Slope1 (H:1V) ........... : 2

Side Slope2 (H:1V) ........... : 2

Ditch Slope ........................ : .02

Mannings n Coeff .............. : .040

Contrib Basin ..................... : (leave blank)

Downstream IE .................. : 311

Downstream WS ................ : 311.5

# of Trials........................... : 10

An explanation of the parameters that are different from previously used parameters follows:

**Ditch Width** — This is the width of the bottom of the channel.

**Side Slope(1 and 2)** — The side slope of the channel section, WaterWorks has the ability to analyze channels with different slopes on the right and left side.

**Ditch Slope** — The longitudinal slope of the channel.

**Downstream WS** — This is the controlling water surface elevation at the downstream end of the channel. For this example, it is the surface elevation of the stream that the channel discharges to.

**# of Trials** — WaterWorks conducts a step backwater analysis when analyzing a channel reach. This parameter is the maximum number of iterations that will occur.

Once the data is input, press [F10] twice. Select Hydrograph, then select Route hydro. This will bring up the same input table that was used to route a hydrograph through the pipe. Use hydrograph 11 again and route it through reach R2. When the analysis is complete, a table will appear that indicates the following:

Maximum Depth = 0.30 ft

Velocity in Channel = 2.01 ft/sec

This would indicate that a channel depth of approximately .5 foot (150 mm) should be used for this site.

P3:HRM3

# Contents



*4C:P3:HRM4*

## 4-1 Introduction

The purpose of this chapter is to provide guidance to designers in the application of best management practices (BMPs). A selection process will be presented as well as some design considerations for the BMPs.

Permanent as well as temporary water quality and quantity controls must be designed and installed for all required projects through the use of BMPs. BMPs are the physical, structural, and/or managerial practices that when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater. The designer should, at each stage of the design, evaluate the potential for stormwater degradation and utilize the design with the least impact.

The most efficient pollution control strategy is to emphasize first prevention then treatment. By preventing pollution from occurring in the first place, the need for treatment can be reduced or, in some cases, eliminated. This approach results in three types of BMPs with different means of accomplishing the goal of improved stormwater discharge:

1. Source control BMPs which prevent pollution. These are designed to keep additional pollution from occurring, and to keep soil from being exposed to excessive runoff.
2. Water quality BMPs which provide pollution treatment. These are designed to assure that there is no increase in the pollution in stormwater leaving the site. The most common quality BMPs used by the Washington State Department of Transportation (WSDOT) include grass filter strips, biofiltration swales, wet ponds, and wet vaults.
3. Water quantity BMPs which offer protection to stream ecosystems from erosion and sedimentation, and reduce the potential of flooding. These are designed to keep the volume of stormwater leaving the site from increasing due to construction of the project. Infiltration ponds, dry ponds, and dry vaults are typical WSDOT water quantity BMPs.

WSDOT must allow passage of all off-site flows; however, no treatment is required for the off-site flow. WSDOT must provide quality and quantity treatment for all stormwater runoff from new projects with 5,000 or more square feet (465 $m^2$) of additional impervious surface. The goal is to have no impact to downstream properties resulting from the building of the project.

The designer must consider stormwater treatment for construction and usage. The project should be designed to take advantage of the topography, soils, waterways, and natural vegetation at the site. The designer must plan the project so that construction can take place without excessive sedimentation being produced and without excessive flow leaving the site. Finally, the project must be designed so that the required maintenance can be carried out.

## 4-2 Permanent Stormwater Control Features

Permanent stormwater management features are those that are designed into the project and will remain in place throughout the service life of the project. The designer must make sure that the feature(s) will provide the desired results and be able to be maintained in order to continue functioning as designed.

Permanent stormwater control features should be clearly identified as such on the design plan sheets and on the as-built construction plans that will be retained after the project is completed. This documentation is necessary since after a few years of operation some stormwater BMPs, particularly Constructed Wetlands, often begin to resemble natural wetland sites. While wetland resemblance is desirable since it increases pollutant removal and is visually pleasing, undue problems and costs with future maintenance will result if a stormwater BMP is incorrectly considered a jurisdictional wetland by a regulatory agency. A stormwater BMP is designed, constructed, and maintained for stormwater treatment and is not to be considered a jurisdictional wetland at any time in the future.

### *4-2.1 Stormwater Source Control Best Management Practices*

The first consideration in design should be source control. Stormwater source controls are designed to prevent pollutants from entering stormwater by eliminating the source of pollution or by preventing contact of pollutants with rainfall and runoff. Source control BMPs shall be applied to the entire project, both existing and additional areas.

Other than street sweeping, there are almost no permanent source control BMPs that can be regularly used for a roadway. Source control BMPs will be used more commonly during construction and for the permanent portion of non-roadway projects such as rest areas and park and ride lots. The source control BMPs to be used during construction are detailed in Chapter 5. When a project involves the storage or transfer of hazardous materials or any waste products, the designer should refer to Section IV-4 of the *Puget Sound Stormwater Management Manual* for guidance on selecting proper source control BMPs.

### *4-2.2 Stormwater Quality Best Management Practices*

Stormwater quality controls are designed to remove pollutants contained in runoff. Quality treatment BMPs utilize a variety of mechanisms to remove pollutants from stormwater including sedimentation, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Water quality BMPs are designed to treat the runoff from a 6-month 24-hour design storm. Studies have shown that a majority of the total runoff volume occurs during storms with a return frequency of six months or less. Therefore, only minimal improvements to water quality are achieved by designing treatment facilities to handle rare storm events, while the cost is greatly increased.

The Department of Ecology has identified two categories of pollutants targeted for runoff quality treatment: conventional pollutants and nutrients. Conventional pollutants are those that are typically associated with particles. These include total suspended solids and heavy metals. Nutrients exist in both suspended and dissolved phases and can be more difficult to remove. Examples are phosphorus and nitrogen. Research conducted on the pollutants found in highway runoff has produced inconsistent results; however, in general most studies indicate that highway runoff is not a major source of nutrient pollution. WSDOT will treat for conventional pollutants on all projects with 5,000 square feet of additional impervious area. Treatment for nutrients will only be performed on those projects located in areas designated by local jurisdictions or the Department of Ecology as having a need for nutrient removal and having 5,000 square feet of additional impervious area.

Water quality treatment to remove pollutants can best be accomplished before the flow is concentrated. Therefore, a grass filter strip is one of the most efficient as well as cost effective water treatment BMPs. Grass filter strips run parallel to the roadway, and runoff from the roadway flows off of the roadway, across the shoulder and then across the grass filter. The flow then can be conveyed in a ditch or other system.

Biofiltration swales are another effective means of removing conventional pollutants that also have a relatively low cost. A biofiltration swale is generally at least 200 feet (60 m) long in the direction of flow and from 2 to 8 feet (0.6 to 2.4 m) wide. Concentrated flow from the roadway section is directed to the high end of the swale. Swales can be part of the stormwater conveyance system.

Wet ponds provide a majority of their water quality treatment by settling suspended solids. Some additional treatment is provided through biological action of plants and bacteria. Wet ponds have a constant pool (dead storage) volume equal to the volume of runoff from the 6-month 24-hour design storm. Wet ponds can be designed for treatment of conventionl pollutants only or conventional pollutants and nutrients. Wet ponds can also be designed to provide water quantity benefits by adding a detention volume (live storage) above the dead storage.

Water quality infiltration ponds typically offer the highest level of pollutant removal. The treatment is achieved through settling, biological action, and filtration. Due to the large space requirements and strict soil requirements, this BMP is not suitable for many project locations; however, it is the preferred method of water quality treatment due to its effectiveness at removing pollutants. For this type of infiltration pond, only the 6-month 24-hour design storm runoff is routed to the pond. All runoff from larger storms is bypassed. The water quality infiltration pond is preceded by a settling basin that removes most of the sediment particles that would otherwise reduce the infiltrative capacity of the soil in the infiltration pond.

Ponds, biofiltration swales, and filter strips can visually enhance an area, as well as provide water quality benefits. Swales and filter strips need to be designed for good grass growth. Ponds are more attractive, and appear more natural, if they are not rectangles. The pond may be designed using a rectangular shape to make the calculations simpler, but then be slightly altered to become more aesthetically pleasing.

Wet vaults are commonly used for projects that have limited space and thus cannot provide a location for a biofiltration swale or a pond. They have a dead storage volume equal to the 6-month 24-hour design storm. While wet vaults are appealing due to the minimal right of way requirements, they do not offer as much water quality treatment as other BMPs because sedimentation is the only mechanism cleaning the water. In addition to their reduced pollutant removal, wet vaults create maintenance problems resulting from poor access to perform the necessary maintenance and reduced ability to determine when maintenance should be done. Typically the increased construction and maintenance expenses offset any initial cost benefits derived from smaller right of way purchases. As a result, wet vaults are the least preferred method of water quality treatment. In many projects where wet vaults are proposed, a better form of treatment could have been utilized if stormwater considerations had been taken into account earlier in the design phase. To ensure that wet vaults are only used when absolutely necessary, the use of a wet vault must receive prior approval from the Hydraulics Section.

### 4-2.3 Stormwater Quantity Best Management Practices

Stormwater quantity BMPs are designed to prevent an increase in the amount of runoff leaving a site after development. Increased flows can cause downstream damage due to flooding as well as degrading water quality because of channel and streambank erosion.

Controlling the quantity of stormwater through the use of detention facilities can provide benefits including: reduction of runoff rate increases caused by urban development; mitigation of downstream drainage capacity problems; recharge of ground water resources; and reduction or elimination of the need for downstream outfall improvements.

Detention of stormwater can also have water quality benefits including: decreased downstream channel erosion; control of sediment deposition; and improved water quality through stormwater filtration.

The best method of providing stormwater quantity control is with a pond. There are two types of ponds that will accomplish this. The first type of pond is an infiltration pond. All of the stormwater from a basin flows into the pond and then infiltrates into the ground. The other type of pond is a dry pond, they are sometimes called detention ponds. Dry ponds store the stormwater that runs into them and release flows in accordance with Minimum Requirement 5. When applicable the infiltration pond is preferred since it not only reduces potential flooding but also recharges the local ground water table. However, dry ponds are a very good method of controlling water quantity and will be the most widely used of the water quantity BMPs.

Another method of providing stormwater quantity control is with a dry vault. Dry vaults are commonly used for projects that have limited space and thus cannot provide a location for a pond. They store the stormwater that drains into them and release flows in accordance with Minimum Requirement 5. While dry vaults are appealing, due to the minimal right of way requirements, they do not function as well as ponds. Dry vaults create maintenance problems resulting from poor access to perform the necessary maintenance and reduced ability to determine when maintenance should be done. Typically the increased construction and maintenance expenses offset any initial cost benefits derived from smaller right of way purchases. As a result, dry vaults are the least preferred method of water quantity treatment. In many projects where dry vaults are proposed, a better form of treatment could have been utilized if stormwater considerations had been taken into account earlier in the design phase. To ensure that dry vaults are only used when absolutely necessary, the use of a dry vault must receive prior approval from the Hydraulics Section.

### *4-2.4 Process for Selecting Water Quality and Quantity BMPs*

The designer should follow the instructions in Chapter 3 to calculate the peak release rates and detention volumes needed for each basin on the project. The selection of BMPs begins with an investigation of the need for treatment and existence of additional restrictions. The project, then each subbasin, is evaluated for applicability of dual purpose BMPs. If no dual purpose BMP is selected, the designer selects both a quality and a quantity BMP. Figure 4-1, Best Management Practices for Stormwater Treatment, is provided to record the decision process.

Complete standards and specifications for each BMP are provided in Chapter 8. BMPs with a “T” in the title have had design modifications from the way they are presented in the DOE Stormwater Management Manual for Puget Sound Basin. An “E” in the title of a BMP indicates that it is an experimental BMP. See Section 4-5.2 for more information on experimental BMPs.

#### 4-2.4.1 Project Concerns

If the project is adding less than 5,000 square feet (465 $m^2$) of additional impervious surface, then there is no requirement for stormwater quality or quantity treatment except for temporary erosion and sediment control for earth work. There may be opportunities to improve the water quality by minor changes within the scope of the project. For example, shoulders or ditches could offer increased stormwater quality benefits by being grassed. The designer should evaluate enhancement opportunities as well as looking for obvious concerns in need of repair such as eroding ditches or shoulders.

When designing for sites where the need for additional stormwater control measures has been identified through a basin plan, watershed ranking process under Chapter 400-12 WAC, or through the Growth Management Act, the most restrictive criteria may apply. The Hydraulics Section should be contacted to determine if more restrictive criteria is to be used for the project. If a plan calls for nutrient control for highway runoff, infiltration BMPs should be used for either quality or quantity treatment. If infiltration BMPs are not suitable for the site then a nutrient control wet pond BMP must be used.

#### 4-2.4.2 Basin Concerns

Each on-site drainage basin must be separately evaluated. If there are minor culvert discharges that combine before reaching a significant stream, it may be possible to combine the basins in order to reduce the number of BMPs required. It is generally preferable to provide stormwater quality treatment before flows are concentrated.

#### 4-2.4.3 Dual Purpose Treatment Best Management Practices

The designer begins BMP selection by evaluating dual purpose treatments. These treatment BMPs provide both water quality and quantity treatments in one facility. Therefore, they are often less expensive to construct and have reduced maintenance costs when compared to two separate facilities.

Enter YES (**Y**) or NO (**N**) for each question until treatments to meet all requirements are identified. If **N,** go on to the next question. For each **Y** use the BMP listed or contact the support group listed. Continue until all required treatment is provided.

| **Project Wide** | **BMP/Contact** | **Y/N** |
|---|---|---|
| Does project include earthwork? | TESC if Y | |
| Less than 5,000 sf of impervious added? | End if Y | |
| Additional Requirements from area plans? | Hydraulics | |
| Is nutrient removal required? | Hydraulics | |

Answer each question for each on-site basin.

| | **BMP/Contact** | **Basin** | | | | |
|---|---|---|---|---|---|---|
| **Dual Purpose Treatment** | | | | | | |
| 1. Regional treatment facility available? | Hydraulics | | | | | |
| 2. Will a wet pond with detention fit the site? | BMP RD.05/RD.06 | | | | | |

Any untreated stormwater runoff must have both a quality and a quantity treatment BMP.

| **Quality Treatment** | | | | | | |
|---|---|---|---|---|---|---|
| 1. Will an infiltration pond fit the site? | BMP RI.05 | | | | | |
| 2. Will a wet pond fit the site? | BMP RD.05/RD.06 | | | | | |
| 3. Will a filter strip fit on site? | BMP RB.10T | | | | | |
| 4. Will a biofiltration swale fit on site? | BMP RB.05 | | | | | |
| 5. Possible to purchase more right of way? | Proj. Eng. | | | | | |
| 6. Will a wet vault fit on site? | BMP RD.15 | | | | | |
| 7. No practicable quality treatment? | Hydraulics | | | | | |

| **Quantity Treatment** | | | | | | |
|---|---|---|---|---|---|---|
| 1. Drains to marine water, lake, large river? | Hydraulics | | | | | |
| 2. Will an infiltration pond fit on site? | BMP RI.06 | | | | | |
| 3. Will a dry pond fit on site? | BMP RD.11 | | | | | |
| 4. Possible to purchase more right of way? | Proj. Eng. | | | | | |
| 5. Will a detention vault fit on site? | BMP RD.20 | | | | | |
| 6. No practicable detention? | Hydraulics | | | | | |

**Best Management Practices for Stormwater Treatment**

***Figure 4-1***

The designer evaluates each basin by answering a series of questions, in the given order, until the required level of treatment has been met by the selected BMPs. This process will help in the selection of the most effective BMP(s) for the site, both in terms of cost and efficiency. Sound engineering principles should always apply. The questions are as follows.

***Is there a regional detention pond or water quality treatment facility available?***

Stormwater treatment is very effective when done on a regional basis. Instead of creating a large number of small facilities spread throughout the drainage basin which all need to be designed, constructed, and maintained, one large facility is used to provide treatment for all of the basin. Because the design is done by engineers that specialize in stormwater treatment and are familiar with the local area, the overall treatment is usually better. Because only one facility is being constructed, the total construction cost is less than that of the combined costs of the smaller ponds. Because there is only one facility to maintain, the maintenance is performed on a more regular basis and at a lower total cost than for several facilities.

The option of routing stormwater runoff to a regional facility is often not available for a couple of reasons. For a regional pond to exist, the local agency must have done a detailed study of the drainage basin and designed a facility based on the study. Also the facility must have been designed to treat the additional flow from the new WSDOT project. However, if these two cases exist then an effective method of stormwater treatment would be to route the runoff to the regional facility. Typically the local agency will charge a fee to connect to the facility, but this should always be less than constructing an onsite facility.

*Summary of Design Guidelines*

Determine if the regional facility meets all the water quality and quantity treatment requirements and if it was designed to include treatment of the runoff from this project. The conveyance system to the facility must have capacity for the full flow that will be passed.

***Can a wet pond, including both dead storage and live storage be designed to fit site?***

If a wet pond with detention storage can fit with in the project limits, the designers should evaluate BMP RD.05.

*Summary of Design Guidelines for RD.05*

- Dead storage, below the outlet, is equal to the volume of the runoff from the 6-month 24-hour design storm.
- Live storage is designed to meet Minimum Requirement 5.
- Provide 1 foot (0.3 m) freeboard above the highest design water level.
- Side slopes should be no steeper than 3:1. If portions are steeper, provide provision to keep people and equipment from being endangered by the steep slope, for example, a fence.
- The pond should be at least three times longer than wide; five to one is preferred.

- Design pond with two cells, separated by a berm.
- Provide access for maintenance to reach the control device.
- Provide an emergency overflow weir.
- Total water depth should not exceed 6 feet (2 m).

If no dual purpose treatment BMPs are applicable, the designers must work through the next two Sections (4-2.4.4 and 4-2.4.5) to select first a water quality BMP and then a water quantity BMP.

### 4-2.4.4 Quality Treatment Best Management Practices

***Can a water quality infiltration pond be designed to fit the site?***

If so, design an infiltration pond and go to the detention section. (See BMP RI.05.)

*Summary of Design Guidelines for RI.05*

- Infiltration rate of the soil must be between 0.50 and 2.5 inches per hour.
- The pond must infiltrate all runoff from the 6-month storm within 24 hours after the end of precipitation.
- All runoff that exceeds the maximum rate of runoff from the 6-month storm must bypass the infiltration pond.
- A settling basin must precede the pond.
- Provide 1-foot (0.3 m) freeboard above the highest design water level.
- Side slopes should be no steeper than 3:1. If portions are steeper, provide provisions to keep people and equipment from being endangered by the steep slope, for example, a fence.
- Provide an emergency overflow weir.
- Total water depth should not exceed 6 feet (2 m).

***Can a wet pond, with just dead storage, be designed to fit site?***

If so, design a wet pond and go to detention selection. (See BMP RD.05,

*Summary of Design Guidelines for RD.05)*

- Dead storage, below the outlet, is equal to the volume of the runoff from the 6-month design storm.
- Provide 1-foot (0.3 m) freeboard above the highest design water level.
- Side slopes should be no steeper than 3:1. If portions are steeper, provide provision to keep people and equipment from being endangered by the steep slope, for example, a fence.
- The pond should be at least three times longer than wide — five to one is preferred.
- An outlet structure will release at the maximum inflow rate.
- Design pond with two cells separated by a berm.
- Provide access for maintenance to reach the control device.

- Provide an emergency overflow weir.
- Total water depth should not exceed 6 feet (2 m).

***Can a filter strip be designed to fit the site?***

If so, design a filter strip and go to detention selection. (See BMP RB.10T.)

*Summary of Design Guidelines for RB.10T*

- The runoff leaves the roadway as sheet flow.
- There is 10 feet (3 m) for the grassed filter strip. There will typically be a bare earth zone between the edge of pavement and the start of the filter strip.
- The filter strip slope is 1 to 15 percent.
- The roadway ADT is less than 30,000.
- The road longitudinal slope is not greater than 5 percent.
- No more than two lanes contribute to the filter strip.

***Can a biofiltration swale be designed to fit the site?***

If so, design a biofiltration swale and go to the detention selection. (See BMP RB.05.)

*Summary of Design Guidelines for RB.05*

- The swale will typically be 200 feet (61.0 m) long.
- The maximum width of a swale is 10 feet (3.1 m), parallel swales can be used if a greater width is required.
- The swale must be designed to flow less than 4 inches (100 mm) deep during the peak runoff from the 6-month design storm.
- The swale should be trapezoidal in cross section. Side slopes should be no steeper than 3:1.
- The swale slope is 1 to 5 percent.
- The 100-year developed condition storm must be able to be conveyed through the swale or be bypassed around the swale.
- The flow must enter the swale evenly.

***Can additional right of way be purchased to provide the treatment?***

Seek management guidance on the appropriateness of acquiring additional right of way to provide the required treatment. If additional right of way is acquired, select the BMP to use by returning to the beginning of the selection process.

***Can a wet vault be designed to fit the site?***

If so, design a wet vault and go to the detention selection. (See BMP RD.15.)

*Summary of Design Guidelines for RD.15*

- Dead volume is equal to the volume of the treatment storm.

- Maintenance cleanouts are provided at least every 100 feet (30 m). There must be at least one for each cell of the vault.

***Can it be shown that implementing stormwater BMPs will not be practicable?***

If the project is to be built, seek advice from the Hydraulics Section. The designers should document the process for selection of BMPs, clearly defining why no BMP could be designed to fit the project. A report must be written which describes the effects to the area downstream of the project resulting from not providing any water quality treatment. This report will be included in the Stormwater Site Plan.

## 4-2.4.5 Quantity Treatment Best Management Practices

***Does the runoff flow directly to a lake, large river, or marine water?***

If so, provide water quality treatment and evaluate releasing the undetained flow to the receiving body. Consult with the Hydraulics Section when considering this option.

***Does the soil in the area have a infiltration rate of at least 6.0 inches/hour (150 $^{mm}/_{hr}$)?***

If so, evaluate the use of an infiltration pond. (See BMP RI.06.)

*Summary of Design Guidelines*

- An in-depth soils investigation is required to confirm the following, but the designer can use SCS soil maps to make the first estimate of the appropriateness of this BMP.
- The soil infiltration rate is at least 6.0 inch/hour (150 $^{mm}/_{hr}$).
- The pond can infiltrate the 10-year storm out of the basin in 24 hours and the 100-year storm in 48 hours.
- There is at least 3 feet (1 m) of soil between the bottom of the pond and the highest ground water level and/or the highest impermeable layer.
- There is at least 20 feet (6 m) to any up slope structure foundation and 100 feet (30 m) to any down slope structure. There is at least 20 feet (6 m) to a Native Growth Protection Easement.
- 1 foot (0.3 m) freeboard must be provided above the highest design water level.
- Side slopes should be no steeper than 3:1. If portions are steeper, provide provisions to keep people and equipment from being endangered by the steep slopes, for example, a fence.
- Provide an emergency overflow weir.
- Total water depth should not exceed 6 feet (2 m).

***Can a dry pond be designed to fit the site?***

If so, design a pond and quality treatment. (See BMP RD.11.)

*Summary of Design Guidelines*

- The pond volume is determined by the method in Chapter 3, and meets Minimum Requirement 5.
- 1 foot (0.3 m) freeboard provided above the highest design water level.
- Side slopes should be no more than 3:1. If portions are steeper, provide provision to keep people and equipment from being endangered by the steep slope, for example, a fence.
- Provide access for maintenance to reach the control device.
- Provide an emergency overflow weir.
- Total water depth should not exceed 6 feet (2 m).

***Can additional right of way be purchased to provide the treatment?***

Seek management guidance on the appropriateness of acquiring additional right of way to provide the required treatment. If additional right of way is acquired, select the BMP to use by returning to the beginning of the selection process.

***Can a dry vault be designed to fit the site?***

If so, design a dry vault and quality treatment. (See BMP RD.20)

*Summary of Design Guidelines*

- Live volume is determined by the method in Chapter 3, and meets Minimum Requirement 5.
- Maintenance cleanouts provided at least every 100 feet (30 m). There must be at least one for each cell of the vault.

***Can it be shown that implementing stormwater BMPs will not be practicable?***

If the project is to be built, seek advice from the Hydraulics Section. The designers should document the process for selection of BMPs, clearly defining why no BMP could be designed to fit the project. A report must be written which describes the effects to the area downstream of the project resulting from not providing any water quantity treatment. This report will be included in the Stormwater Site Plan.

## 4-3 Temporary Erosion and Sediment Controls

The purpose of this section is to provide guidelines and background information that will assist the designer in choosing the most suitable BMPs to control erosion and sediment from projects that involve earthwork. 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 8.

After designing the permanent erosion controls, the designers must develop BMPs to control sediment and erosion during construction. Construction of roadways can expose large expanses of soil to the eroding effects of water and wind. The first consideration should be to disturb as little of the site for the shortest possible time. Furthermore, the designers must develop the Temporary Erosion and Sediment Control plan to prevent any increase in sediment from leaving the site. The design should be such that the flow leaving the site during construction is no greater in pollution loading, velocity, or quantity than it was before construction started. All temporary conveyance systems are to be stable during 2-year storm events.

### 4-3.1 Factors Affecting Erosion Potential

The inherent erosion potential of any area is determined by four principal factors: soil characteristics, vegetative cover, topography, and climate. A soil with a high silt content will be most easily eroded. By knowing the soil types on the project, the designer can evaluate the severity of the erosion potential.

Vegetative cover plays an important role in controlling erosion because it shields the soil from the impact of rain, holds the soil particles in place, maintains voids in the soil to allow absorbance of water, and physically slows the water. Native vegetation should be left as long as possible and to the extent possible. New vegetation, including temporary seeding, should be provided as soon as possible.

The existing topography should be utilized in the design process. The designer can control the climate only through selection of the season in which land disturbing procedures occur. If clearing and grubbing operations can be conducted during the drier summer months, there is considerable reduction in potential for erosion.

The designer is encouraged to utilize temporary erosion and sedimentation control BMPs as permanent BMPs whenever it is practical. Often ponds used for sediment control during construction can be designed and built as the detention facilities that will be used after the project is constructed. This will eliminate the construction of two separate ponds. If the pond is used for temporary sediment control during construction, the contractor must clean the pond before it becomes a part of the final stormwater management system. Ponds that are designed to include infiltration must not be used as a sedimentation pond during construction since there is no way to clean the trapped particles from within the soil. The sediment laden soil will yield a lower infiltration rate than expected and the pond will not function properly. Additionally, conveyance channels during the construction phase may be able to be utilized as permanent conveyance or even swales, if they are cleaned and seeded as required.

### 4-3.2 Sediment Retention

Most projects with earthwork will require at least one BMP to retain sediments on the site. The designers will have to evaluate the following BMPs to determine which is the most applicable to their project.

E3.10 Filter Fence — This is a very effective BMP that is simple to install.

E3.15 Straw Bale Barrier — This BMP is used when flows are concentrated.

E3.20 Brush Barrier — This uses material from the site.

E3.25 Gravel Filter Berm.

E3.30 Storm Drain Inlet Protection — This must be used if there are functioning storm drains that could receive runoff from the project.

E3.35 Sediment Trap.

E3.40 Temporary Sediment Pond or Basin — This can sometimes be combined with the permanent detention pond.

### 4-3.3 Temporary Cover Practices

When there is the likelihood that large areas of disturbed soil will be subject to erosion, the designer must consider the need to provide temporary cover. The BMPs to be considered include, in order of priority:

E1.10 Temporary Seeding of Stripped Areas — This is useful if an area will remain undisturbed for a growing season.

E1.15 Mulching and Matting — There are a variety of materials available. This method is good for shorter times periods or where future landscaping would be negatively impacted by the grass seeding.

E1.20 Plastic Covering — This BMP can be effective in controlling sedimentation, but it can result in increased downstream runoff because no water can be absorbed by the ground. This BMP should be used only if the other cover practices can not be used.

### 4-3.4 Structural Erosion Control BMPs

The designers should evaluate the project for the need for any of the following BMPs:

E2.10 Stabilized Construction Entrance and Tire Wash — This must be used if there is earthwork and there is an entrance to the site from a paved road.

E2.15 Construction Road Stabilization.

E2.20 Dust Control.

E2.25 Pipe Slope Drains — Consult with the Hydraulics Section if there is a need for this BMP.

E2.50 Level Spreader — This can also be a permanent BMP in wide biofiltration swales.

E2.55 Interceptor Dike and Swale.

E2.60 Check Dams — This can be a permanent BMP in swales to reduce the flow velocity.

## 4-4 Experimental and Other Best Management Practices

### 4-4.1 Additional DOE BMPs

There will be projects requiring more extensive BMPs, having requirements not met by the BMPs listed in this manual, or where it is not possible to use BMPs included in this manual. The Hydraulics Section can assist the designer in finding other appropriate BMPs. Additional BMPs are available in the Department of Ecology Stormwater Management Manual for the Puget Sound Basin. These include:

C2.10 Use of Sandblasting Grits

E2.30 Subsurface Drains

E2.40 Gradient Terraces

| | |
|---|---|
| E2.45 | Bioengineered Protection of Very Steep Slopes |
| E2.70 | Outlet Protection |
| E2.75 | Riprap |
| E2.80 | Vegetative Streambank Stabilization |
| E2.85 | Bioengineering Methods of Streambank Stabilization |
| E2.90 | Structural Streambank Stabilization |
| RI.10 | WQ Infiltration Trench |
| RI.11 | SBEC Infiltration Trench |
| RI.15 | Roof Downspout System |
| RI.20 | WQ Porous Pavement |
| RI.30 | WQ Concrete Grid/Modular Pavement |
| RI.31 | SBEC Concrete Grid/Modular Pavement |
| RF.05 | Sand Filtration Basin |
| RF.10 | Sand Filtration Trench |
| RF.15E | Aquatard System (Experimental) |
| RD.09 | Constructed Wetland |
| RD.10 | Presettling Basin |
| RO.05 | Spill Control (SC) Oil/Water Separator |
| RO.10 | API Oil/Water Separator |
| RO.15 | CPS Oil/Water Separator |
| RS.05 | Vegetative Streambank Stabilization |
| RS.10 | Bioengineering Methods |
| RS.15 | Structural Streambank Stabilization |
| S1.10 | Fueling Stations |
| S1.20 | Vehicle/Equipment Washing and Steam Cleaning |
| S1.30 | Loading and Unloading Liquid Materials |
| S1.40 | Above Ground Tanks for Liquid Storage |
| S1.50 | Container Storage of Liquids, Food Waste, or Dangerous Wastes |
| S1.60 | Outside Storage of Raw Materials, By Products, or Finished Products |
| S1.70 | Outside Manufacturing Activities |
| S1.80 | Emergency Spill Cleanup Plans |

### 4-4.2 Experimental BMPs

In addition to the BMPs listed in this manual and in the DOE Stormwater Manual, WSDOT can propose experimental BMPs. Experimental best management practices are defined as BMPs which have not been tested and evaluated by the Department of Ecology. Designers are encouraged to propose experimental BMPs whenever they feel that they have developed a BMP which can better perform the required treatment of stormwater runoff than one of the existing BMPs. Most experimental BMPs will likely be variations of an existing BMP, altered to better fit a given project.

The designers must consult with the regional Hydraulics Section when considering an experimental BMP. The Hydraulics Section will provide help in the design and application of the proposed BMP. The regional Hydraulics Section will then work with the Olympia Service Center Hydraulics Section to make the application to the Department of Ecology for an experimental BMP. The request shall include a description of:

- The BMP and how it is intended to function.
- The site or sites at which use of the experimental BMP is being proposed.
- Why the experimental BMP is being requested.
- Applicable construction techniques.
- Sampling and monitoring procedures.

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# Contents

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## 5-1 Introduction

The purpose of this chapter is to provide guidelines for the preparation of Stormwater Site Plans (SSP). These plans will show the measures that will be taken during and after project construction which address erosion and sediment control and stormwater runoff. A completed SSP will be a comprehensive report for several aspects of the site. It will include certain reports that are currently required for all projects. It will replace the Water Pollution Control Plan and contractor's Temporary Water Pollution Control Plan which are described in the WSDOT *Design Manual*. It will satisfy the NPDES/Baseline General Permit requirement for a Stormwater Pollution Prevention Plan. It will satisfy the erosion control and stormwater requirements for all other permits that will be required for the project and will aid in completing HPA, Shoreline, and Corps of Engineer Permits.

This chapter only describes how to prepare an SSP. The Best Management Practice (BMP) selection and design processes are discussed in Chapters 3, 4, and 8.

Dependent upon the type of project, the SSP will include different items. Projects that involve earthwork with only a minimal addition of impervious ground cover will have to address erosion and sediment control. Projects that involve the addition of over 5,000 square feet (465 square meters) of impervious surface will also have to address stormwater runoff along with erosion and sediment control.

Complete copies of Stormwater Site Plans should be sent to the regional environmental staff and the Olympia Service Center Water Quality Unit for review. Hydraulics Section, Water Quality Unit, and Maintenance Office/ Environmental Compliance Branch, will review and comment on items of the SSP pertinent to their respective areas of expertise and responsibility.

## 5-2 Contents of Stormwater Site Plans

The items that shall be included in all SSPs are as follows:

- A project overview.
- A Temporary Erosion and Sediment Control (TESC) Plan.
- A BMP Selection Form.
- A project specific Maintenance and Operations Schedule.
- A Vegetation Management Plan.

If the following items are developed for a project, they should also be included in the SSP:

- A Hydraulics Report.
- A Downstream Analysis Report (required when more than 5,000 $ft^2$ of impervious surface is added).
- An explanation of non-practicability.

## 5-2.1 Project Overview

The project overview is a general description of the project. It shall include a discussion of the location of the project and what is to be accomplished by constructing the project. A description of the existing site must be included along with a description of how the site will be altered as a result of the project. The project overview shall also include a site map which shows the right of way limits, the existing and proposed roadway, any significant structures, and drainage basins.

## 5-2.2 Temporary Erosion and Sediment Control Plan

A TESC Plan shall provide for the prevention, interception, and treatment of all potential silt-laden runoff that could occur during clearing, grading, construction, and site stabilization. The TESC Plan shall describe stabilization and structural practices, both of which shall be implemented to minimize erosion and the transport of sediments. TESC plans will typically be submitted with the hydraulic report as a separate but related document. The TESC Plan, in combination with the contractor's addendum to the plan, will satisfy the requirements of the NPDES/Baseline General Permit. Instructional Letter 22-51, effective 10/18/93, should be consulted for procedural requirements of the NPDES/Baseline General Permit.

TESC Plans are required for all projects that involve land disturbance during construction, but NPDES permit coverage is required for only those projects that involve five or more acres of disturbance. TESC Plans are designed by district Project Development staff, and their development should be coordinated with the design of permanent stormwater runoff BMPs since some temporary BMPs can be modified into permanent ones. Most work required by the TESC Plans should be compensated with unit bid items. Work such as ditch and channel excavation, and BMPs such as silt fences, straw bales, and erosion control blankets, can be easily defined and measured. When completed, the TESC Plans become part of the contract documents.

The Temporary Erosion and Sediment Control Plan consists of two parts: a narrative and a set of site plans. The narrative explains and justifies the erosion and sediment control elements of the plan, contains concise information on-site conditions, and includes the construction schedule. The site plans show the location of all features of the TESC Plan. These site plans do not have to be separate from the construction plan sheets, as long as the plan sheets that make up the TESC Plan, and the BMPs themselves, are clearly identified. If the construction plan sheets are utilized for the TESC Plan, there should be one official copy maintained as the TESC Plan on which any changes are documented.

The TESC Plan shall include a description of stabilization BMPs which involve protection of exposed soils, and site-specific scheduling of the implementation of the practices to minimize erosion. Stabilization measures shall be initiated as soon as practicable in portions of the site where construction activities have temporarily or permanently ceased.

In addition to stabilization practices, the TESC Plan shall include a description of structural BMPs to divert flows from exposed soils, store flows, filter out sediment from sheet flow, or otherwise limit runoff and discharge of pollutants from exposed areas of the site to the degree practicable.

### 5-2.3 Minimum Requirements for Erosion and Sediment Control

The following list constitutes minimum requirements for erosion and sediment control that must be met by a TESC Plan. In order to be compliant with the NPDES/Baseline General Permit, which has statewide application, and be consistent with the Department of Ecology *Stormwater Management Manual for the Puget Sound Basin*, some of these minimum requirements have two parts. The first part is the statewide requirement, the second part is the Puget Sound regional condition. Some of the minimum requirements apply only in the Puget Sound basin.

1. Stabilization and Sediment Trapping: All exposed and unworked soils shall be stabilized by suitable and timely application of BMPs. All exposed soils, including cut and fill slopes that are partially completed to grade, must be stabilized during the first available period and shall not be allowed to sit idle for long periods of time without receiving the erosion control specified in the TESC Plan. Prior to leaving the site, stormwater runoff shall pass through a sediment pond or trap, or other appropriate BMP.

   Puget Sound Condition: From October 1 to April 30, no soils shall remain unstabilized for more than two days. From May 1 to September 30, no soils shall remain unstabilized for more than seven days.

2. Delineate Clearing and Easement Limits: Existing vegetation (trees, bushes, shrubs) should be preserved when its removal is not necessary for the construction of the project. In the field, stake vegetation and objects selected to remain, and stake clearing limits and/or areas not to be disturbed including easements, setbacks, sensitive/critical areas and their buffers, and drainage courses.

3. Protection of Adjacent Properties: Properties adjacent to the project area shall be protected from sediment deposition.

4. Timing and Stabilization of Sediment Trapping Measures: Sediment ponds and traps, filter fences, 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 used for sediment control such as dams, dikes, and diversions shall be stabilized as soon as possible.

   Puget Sound Condition: Earthen structures shall be seeded and mulched, or otherwise stabilized, according to the timing and dates indicated in Minimum Requirement 1, Puget Sound Condition.

5. Cut and Fill Slopes: Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion.

6. Controlling Off-Site Erosion: Properties and water bodies downstream from the construction site shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site.

7. Stabilization of Temporary Conveyance Channels and Outlets: Stabilization adequate to prevent erosion of outlets and adjacent stream banks shall be provided at the outlets of all conveyance systems.

   Puget Sound Condition: 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.

8. Storm Drain Inlet Protection: All storm sewer inlets utilized to discharge runoff from the construction site shall be protected so that stormwater runoff does not enter the conveyance system without first being filtered or otherwise treated to remove sediment.

9. Puget Sound Minimum Requirement — Underground Utility Construction: The construction of underground utility lines shall be subject to the following conditions:

   a. Where feasible, no more than 500 feet of trench shall be opened at one time.

   b. Where consistent with space and safety considerations, excavated material shall be placed on the uphill side of trenches.

   c. Trench dewatering devices shall discharge into a sediment trap or sediment pond.

10. Construction Access Routes: Wherever construction vehicle access routes intersect paved roads, provisions must be made to minimize the transport of sediment and mud onto the paved roads. If sediment is transported onto a road surface, the roads adjacent to the construction site shall be cleaned on a regular basis. Street washing shall be allowed only after other methods to prevent the transport or to remove the sediments are unsuccessful.

    Puget Sound Condition: 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.

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.

12. Puget Sound Condition — Dewatering Construction Sites: Dewatering devices shall discharge into a sediment trap or sediment pond.

13. Maintenance: All temporary and permanent erosion 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 this manual.

### 5-2.4 Contractor's Addendum to TESC Plan

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. For the control of pollutants other than sediment, the contractor will be required to develop an addendum to the TESC Plan. Control of pollutants other than sediment includes, but is not limited to: management of oil, gasoline, and solvents used in the operation and maintenance of vehicles and machinery; spill control and containment measures; identification of proper wood waste fill and stockpile locations; and waste disposal methods and locations. Since the nature of the contractor's operations will not be known before the contract is awarded, it is the intent of this procedure to require the contractor to develop and implement an addendum to reflect his or her operations and supplement the TESC Plan, in order to provide comprehensive pollution control at the construction site.

If a construction site is large enough, and/or in existence for a long duration of time, it is likely that the contractor will utilize staging areas for some or all of the above-listed activities. The addendum needs to address only those activities that will be present at the construction site. A general special provision will be included in the contract to require the addendum to prevent pollution from these activities from entering stormwater.

The most economical and effective controls for pollutants generated on construction sites other than sediment are the exercise of 'good housekeeping' practices, and an awareness that pollution can be prevented by keeping potential pollutants out of contact with stormwater. This can be achieved by proper storage of materials by covering or other method of protection from the elements. BMPs C1.10 through C2.20 found in Section 8.1 should be utilized for pollutants other than sediment.

### 5-2.5 BMP Selection Form

Chapter 4 contains a one page form that is to be used during the selection of stormwater BMPs. This completed form must be included in the SSP. For projects that only deal with earthwork, no permanent BMPs will be selected; however, the form must still be included to show that the project was evaluated for the need of a stormwater BMP.

### 5-2.6 Maintenance and Operations Schedule

The SSP shall contain a description of the required maintenance for BMPs used in the project. The description shall state what type of maintenance is to be done for each BMP selected and the frequency at which the maintenance is to be performed. Chapters 7 and 8 will aid the designer in determining the proper maintenance for the specific BMP.

### 5-2.7 Vegetation Management Plan

Each project will require that a plan be developed addressing the management of vegetation for the site. This plan must be included in the SSP. Chapter 6 will aid the designer in selecting proper vegetation management practices for the site.

### 5-2.8 Hydraulic Report

For any project that deals with drainage structures, a Hydraulic Report must be submitted. The Hydraulic Report will have the same contents as Hydraulic Reports that were created prior to the implementation of this manual and should still be written as a stand alone document. When submitted as part of the SSP, the Hydraulic Report will provide the technical background and design parameters used for the design of all drainage structures. Chapter 1 of the WSDOT *Hydraulics Manual* contains a description of the material to be included in the Hydraulic Report.

When designing a stormwater BMP, it is important that an accurate description of the existing conditions and after project conditions of the drainage basins be included in the report. This will enable the project reviewers to determine the effectiveness of the stormwater facilities that were designed using the methodology described in Chapter 3. This is important because the most common cause of substandard stormwater BMPs is the improper evaluation of the site in its existing conditions.

### 5-2.9 Downstream Analysis Report

The downstream analysis will show what impacts, if any, a project will have on the hydraulic conveyance systems downstream of the project site. The analysis is divided into three parts that should be followed sequentially. The three parts include: review of resources, inspection of the affected area, and analysis of downstream effects.

During the review of resources, the designer will review any existing data concerning drainage of the project area. This data will commonly include area maps, floodplain maps, wetland inventories, stream surveys, habitat surveys, engineering reports concerning the entire drainage basin, inventories of known drainage problems, and previously completed downstream analyses. The district Hydraulics and Environmental Sections will be able to provide most of this information. Other sources of information include the Department of Ecology, the Department of Fish and Wildlife, and local agencies.

The next step is to inspect the project site and its downstream area. The designer will physically inspect the drainage system at the project site and downstream of it. During the inspection, the designer should investigate any problems or areas of concern that were noted during the review of resources. The designer should also identify any existing or potential capacity problems in the drainage system, any existing or potential areas where flooding may occur, any existing or potential areas of channel destruction, and any existing or potential areas of significant destruction of aquatic habitat.

The final step is to analyze the information that has been gathered in the first two parts. This is done to determine if construction of the project will create any drainage problems downstream or will make any existing problems worse. Often, if the other minimum requirements are met, the project will not negatively impact the downstream drainage system. However, there are some situations that even when the minimum requirements are met the project will still have negative impacts. An example of this would be if the project discharged runoff into a small closed basin wetland; even though a detention pond was installed to comply with Minimum Requirement 5, the total volume of runoff draining to the wetland will increase which could cause long term damage to the habitat in the area. Whenever a situation is encountered where there will be downstream impacts resulting from the project, mitigation measures must be included in the project to correct for the impacts. During these circumstances, the designer should contact the regional Hydraulics or Environmental Section to determine the best method of mitigation.

### 5-2.10 Natural Wetlands

The offsite analysis requires gathering data to determine if any wetlands are hydraulically connected to the project site. Altering the land cover and natural drainage patterns may cause the addition or deletion of stormwater to surrounding wetlands. 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 biofilters and wet ponds.

The following guidelines are adapted from Chapter III-5 of the SMMPSB. Please refer to the SMMPSB for expanded discussions on the topics presented.

In general there are three situations that will warrant further analysis to ensure that stormwater management and wetlands protection are achieved. The receiving body of water for highway runoff is a wetland which is less than 0.25 mile from the project boundary, (a longer distance may be appropriate if negative impacts are likely or the drainage conveyance is tight lined) and:

1. The sensitivity of the wetland necessitates additional controls beyond the minimum requirements for upland water quality and quantity control. Wetlands in Category I, II, or III (per Puget Sound Water Quality Authority guidelines) are likely to be very sensitive to changes brought on by urbanization. The additional stormwater quantity or quality controls will be incorporated within the project boundary or in an upland area offsite prior to discharge to the receiving wetland.

2. The receiving wetland needs significant restoration or enhancement. The wetland has been previously disturbed by human activity, as evidenced by agriculture, fill, ditching, and/or introduced or invasive weedy plant species. Other characteristics of a candidate wetland include: monotypic vegetation of similar age and class, lack of special habitat features, isolated from other aquatic systems, has been drained, or has experienced a lengthened summer dry period. These characteristics are common to Category IV wetlands. Upgrading of wetland functions can be accomplished along with benefiting runoff quality and quantity control. The controls may be applied in the upland, buffer, or in the wetland. An exemption will be needed if water quality treatment is not provided prior to discharge.

The incentives to provide the off-site wetland improvements are as follows:

1. The sizing of on-site controls are reduced to offset the costs for providing off-site improvements.
2. The wetland enhancement is considered for credit according to the Wetland Banking Agreement.
3. WSDOT may be mitigating wetland loss on a project by creating a wetland. Consult with the wetland design team to determine if the pretreated stormwater runoff can serve as a source of water for the created wetland.

Other site specific issues may arise related to comprehensive basin planning. Local jurisdictions and resource agencies may be trying to achieve several objectives including flood control, stream channel erosion and improved stormwater quality. This may influence the offsite analysis related to wetlands. If the above situations are applicable seek guidance from the Environmental Section in coordinating a design acceptable to resource agencies and local jurisdictions. The following four paragraphs provide guidance for data gathering and analysis.

Perform an analysis of the contributing and receiving drainage catchments to define the type and extent of runoff water quality and quantity problems associated with the project. This analysis should include a hydrologic assessment, identification of key water pollutants, and evaluation of the potential effects of hydrologic conditions and water pollutants throughout the drainage system.

Perform an analysis of the contributing drainage catchment to assess possible alternative best management practices that can be applied on-site. In addition determine if a regional treatment facility is available.

As a start for data analysis, obtain the relevant soil survey, the National Wetland Inventory, topographic, and land use maps, and the results of any local wetland inventory. The comprehensiveness and certainty of the outcome will vary with the amount and quality of information employed. Consult the Environmental Section to determine the availability of information related to wetland type, fish and wildlife inhabitants, hydrologic characteristics, and management and monitoring plans as defined by local, state, or federal jurisdictions. The permits required will vary from site to site.

Some level of monitoring will likely 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. There will be several levels of monitoring, ranging from minimal to extensive requirements. Wetland baseline monitoring before the implementation of the stormwater management project will be specified when necessary to provide a basis for comparison to assess impacts.

When wetlands receive treated stormwater there will likely be extensive analysis, design, and long term monitoring and maintenance activities to consider. Cooperative agreements with the local jurisdiction may be used to share the cost and work load involved in accomplishing both WSDOT and local basin objectives. The effort to coordinate the regulatory work should be discussed at an early stage to determine concurrence on project objectives and reduce local, state, and federal regulatory burdens.

The following additional General Wetland Protection Guidelines should be used to incorporate wetland protection into the stormwater site plan. The goal being to protect the ecological structure and functioning of wetlands that are modified to supply runoff water quantity or quality control benefits.

1. Comply with the water quality standards (Ch. 173-200 WAC and Ch. 173-201A WAC).
2. Maintain the wetland buffer to the maximum extent practicable.
3. Provide spill containment in conjunction with on-site pretreatment where there has been a history of accidents and spills or where there is a high volume of hazardous materials transported in the project area. If monitoring reveals high oil concentrations then consider an oil/water separator.
4. If the contributing catchment exhibits any of the following characteristics, then install a level of treatment in addition to Minimum Requirement 4 and 5:
   a. More than 20 percent of the catchment area is committed to commercial, industrial, and/or multiple family residential land uses; or
   b. The combination of all urban land uses (including single family residential) exceeds 50 percent of the catchment area; or
   c. The concentration of total cadmium, copper, lead, or zinc in the open water of the wetland exceeds current Environmental Protection Agency criteria.

For the additional treatment consider using infiltration or wet pond methods. This can include expanding the size of control methods needed to meet minimum requirements or constructing additional control structures. The additional level of treatment provided should be comparable to that required or provided by other new and redevelopment projects in the vicinity.

5. 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.
6. For stormwater discharges tributary to severely impacted wetlands, consider actions that restore the pre-disturbance hydrology.
7. For sensitive wetlands where the goal is to maintain plant communities or protect fish and wildlife habitat, consult the Olympia Service Center Biology Unit to determine the appropriate hydroperiod characteristics that should be maintained. Results from the Puget Sound Wetlands and Stormwater Management Research Program regarding Hydroperiods are included in Section 5-2.10.1.
8. Minimize the need for heavy equipment impacts on a wetland to avoid compaction. Restore and replant areas of construction disturbance according to recommendations provided by the Environmental Section. This includes removal or damage of nurse logs and snags. Avoid introduction of exotic wetland species.
9. Limit access and design for minimal maintenance. Fences should not be used.

10. To receive water quality benefits over the long-term, maintenance guidelines will need to be agreed upon by WSDOT and any jurisdiction involved in the project. Sediment removal and plant harvesting may be needed.

If additional water quality control is needed beyond that required for Minimum Requirement 4 and 5, and a wetland is downstream then there are many options still available for further water quality treatment. Water quality benefits to down-stream 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.

1. Select the wetland according to criteria that promote water quality improvement. The key criteria is maximizing the actual water residence time. Short-circuiting of flow from the inlet to the outlet should be avoided.
2. Engineer the drainage system at the entrance to the wetland to promote stormwater quality improvement. Reduce the inflow velocity and/or spread and redirect the inlet flow.
3. Modify the wetland (the portions with monotypic low-value vegetation such as cattails or reed canary grass) to incorporate features that promote stormwater quality improvement
    a. Enlarge the wet pool area. A minimum wetlands area/watershed area ratio to design to is 0.01, however preferably greater than 0.025.
    b. Deepen to increase volume, or alter depth contours to achieve a range of depths such as advised for constructed wetlands.
    c. Raise the outlet or control the outlet rate to increase volume and residence time.
    d. Plant dense, fine, native herbaceous plants

It is most desirable to maintain the natural drainage pattern while accommodating stormwater control and wetland protection objectives. Two circumstances may present the opportunity to choose between wetlands that will receive highway runoff: 1) substantial cut and fill activity is planned and the drainage pattern can easily be modified to direct water via surface runoff or enclosed pipes towards a wetland; 2) there is more than one wetland near or within the project limits. When more than one wetland is under consideration for enhancement, the preferred site is the wetland that most exhibits the following characteristics:

1. 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 pretreated stormwater can be used to augment the water supply.
2. The wetland allows runoff discharge at the natural location.
3. The wetland requires little construction activity for structural or hydrologic modification in order to solve the problem.
4. 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).

5. 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.
6. 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.

### 5-2.10.1 Wetland Hydroperiod Management

This is a concise summary of one topical area that is being covered by the Puget Sound Wetlands and Stormwater Management Research Program. It will be updated periodically as new information becomes available. A list of Research Summaries for other topical areas and a Publications List is available from King County Resource Planning.

Hydroperiod refers to the depth, frequency, duration, and pattern of wetland inundation. Research results to date have shown that hydroperiod alteration by urban runoff can have a more immediate and greater effect on the composition of vegetation and amphibian communities than reduced water quality has, at the levels of water quality experienced by wetlands in developing areas around Puget Sound. Water level fluctuation (WFL), measured as the difference between maximum depth and average base depth in a time period, was found to be a key determinant of plant and amphibian species richness, with significantly less rich communities of both resulting when average monthly WLF exceeds 20 cm.

The following specific management guidelines were developed from the research findings:

**Depth limits** (all wetlands, all year)

Limit post-development increase in annual maximum depth to 30 cm (for 1.01 to 100 year frequency rainfall events).

Limit post-development average monthly WLF (for each month in the year) to: (1) an increase of 5 cm if pre-development WLF is greater than or equal to 15 cm; or (2) a maximum of 20 cm if pre-development WLF is less than 15 cm.

**Frequency and duration limits** (Note: These guidelines envision a fluctuating stage over time before development that could fluctuate more, both higher and lower, after development; these greater fluctuations are called “excursions.” The guidelines set limits on the amount of the excursions and the total time, over one or more episodes, that they can occur in a given period.)

Wetlands with breeding native amphibians, (1 February-31 May):

Limit the magnitude of post-development stage excursions above or below the pre-development stage to no more than 8 cm, and limit the duration of these excursions to no more than 24 hours in any 30-day period.

All wetlands (1 February-30 September):

Limit the magnitude of post-development stage excursions above or below the pre-development stage to no more than 30 cm for any length of time.

Limit post-development stage excursions of 15-30 cm above or below the pre-development stage to a total duration of no more than 72 hours in any 30-day period.

Limit post-development increase or decrease in dry period (when pools dry down to the soil surface everywhere in the wetland) to 2 weeks in any year in wetlands with pre-development dry periods averaging greater than 8 weeks.

Peat wetlands (bogs and fens):

Limit post-development stage excursions above the pre-development stage to a total duration of 24 hours in any year.

Forested wetlands and zones (wetlands or zones with at least 30 percent cover of trees at least 20 ft tall):

Limit the magnitude of post-development stage excursions above the pre-development stage to no more than 20 cm, and limit the duration of these excursions to no more than 48 hours in any 7-day period during the early growing season (1 March-31 May) and to 96 hours total over the full growing season (1 March-31 August).

Avoid sediment accumulation of more than 20 cm in any year.

Sedge meadows (wetlands or zones with at least 20 percent cover by Carex, Eleocharis, Scirpus, or Dilichium):

Avoid sediment accumulation of more than 15 cm in any year.

### 5-2.11 Explanation of Nonpracticability

For some projects, it will be physically or economically not practicable to include stormwater BMPs. If the designer feels that this is the case for a specific project, a document must be prepared which states why, in the designers judgment, a prescriptive treatment should be considered nonpracticable. This document should yield a strong argument that supports the decision to not fully treat the stormwater runoff. The document will be reviewed by the Hydraulics and Environmental Sections and any agencies that will be issuing permits for the project. Poor planning is not a valid reason to allow release of untreated stormwater from a site.

This document should also discuss the stormwater treatment measures that will be used in the project even though they will be less than required. Every project site will have the ability to provide some amount of stormwater treatment, even if it is nothing more than the use of grassed ditches as a portion of the conveyance system.

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# *Chapter 6*

This chapter is currently being written by the Olympia Service Center Highways Maintenance office.

# Contents



*7C:P3:HRM7*

## 7-1 Disposal of Highway Generated Waste

The Washington State Department of Transportation (WSDOT) advocates effective, consistent, and environmentally responsible maintenance of the state highway system. Maintenance programs strive to protect the road user, public investment, and environmental quality that enhances user safety in a cost-effective manner. Roadsides are to be maintained as nearly as possible in the condition to which they were constructed or subsequently developed, and in a manner that makes a contribution to the safety, convenience, and pleasure of the public and the preservation and protection of the roadway itself. All maintenance activities are applicable, subject to the availability of funds.

The disposal of vactor wastes, street sweepings, and other highway maintenance generated waste solids has become a problem. Some of the solid wastes exceed contamination threshold values that allow for disposal at lined municipal landfills or for use in maintenance activities. Most highway wastes have contamination limited to petroleum products and may be treated with bio-remediation by WSDOT personnel.

WSDOT intends to pursue the development of facilities to properly treat and, where possible, re-use contaminated wastes after treatment. These facilities could be funded in cooperation with local jurisdictions and the operating costs proportionally shared. Bio-remediation of the contaminated wastes currently is the most practicable and cost-effective treatment method.

### *7-1.2 Catch Basin Maintenance*

#### 7-1.2.1 Pumping

**Schedule and Frequency.** Inlets, catch basins, and manholes are to be periodically inspected and cleaned out using a vacuum truck. WSDOT maintenance staff should conduct inspections during storms to ensure that inlet grates are not becoming clogged with water-borne debris.

Catch basins are inspected regularly by WSDOT maintenance staff and cleaned to ensure adequate function as needed. At a minimum, all catch basins are pumped annually. Emphasis is on cleaning catch basins in urban traffic areas after the first storm at the beginning of autumn with a rainfall volume greater than 1 inch. This practice will remove much of the pollutant load deposited during the dry months.

If upon inspection the wastes in the catch basins appear excessively oily, of foul odor, or show a fluorescent anti-freeze coloration, illicit dumping may be the cause and the catch basin should not be pumped. This waste could contaminate the truck and create disposal problems. The waste in the catch basin should be sampled and analyzed to determine appropriate disposal. Contact either regional environmental or Olympia Service Center maintenance staff to initiate actions to characterize the waste.

### 7-1.2.2 Equipment

The removal of catch basin wastes is done with a vactor truck. No manual cleaning occurs. The vactor truck currently used is an 88 Model International Vactor f2575 W/F/Eductor or equivalent.

### 7-1.2.3 Decant Water

Decant water is defined as water which results from flushing solids out of a catch basin. Minimal data exists for the pollutant quality of decant water from highway maintenance activities. A recent study of urban and rural roadway maintenance activities (Herrera Environmental Consultants, 1991) indicates decant water has the potential to carry metals, solids, toluene, xylenes, and volatile and semi-volatile compounds. Data suggests decant water has greater potential for pollutant load when carrying large amounts of suspended solids (Serdar, 1992).

The practical method of handling the water associated with catch basin sludge has been to decant the water directly back into the catch basin. Vactor trucks must decant water from the storage tank periodically to allow more room for sediments storage. Vactor trucks typically decant water two to three times a day depending upon on the weather, truck capacity, and the system being cleaned. Storm drains located in nonsensitive areas are selected for discharge of decant water. Frequent decanting can be necessary to prevent excessive weight and load shifting problems. The vehicle operator determines when decanting is necessary.

Opportunities for safe disposal of the liquid fraction of vactor waste, without extensive testing, are limited to approved decant stations and sanitary sewers. WSDOT District 1 has made use of decant stations for the disposal of decant water, where practicable, in the Seattle metropolitan area. Three decant stations in Bellevue allow access to WSDOT. Users of the stations maintain a record of all discharges as required by the municipality.

Permission to discharge decant water to sanitary sewer systems varies widely among municipalities and sewer districts. There is little consistency among sanitary sewer authorities in the Puget Sound basin to accept highway generated catch basin wastes. District maintenance staff will utilize available options for disposal of decant liquid to decant stations.

WSDOT is currently exploring the development of vactor waste decant and sludge treatment facilities, similar to the facility located in Thurston County. With legislative appropriation of specifically designated funds, WSDOT is developing decant and solids treatment facilities in conjunction with other jurisdictions.

### 7-1.2.4 Catch Basin Solids

Sufficient data exists, both with WSDOT catch basin solids and and other municipalities, to be sufficiently able to characterize the material. While the pollutant content of vactor waste varies widely depending upon a variety of factors, it can be generally characterized as being contaminated with petroleum and some heavy metals.

Evolving environmental regulations and limited waste disposal options have caused WSDOT to initiate a waste characterization program in the fall of 1993, for cost effective and appropriate disposal options. The emphasis of this program is to utilize clean wastes within WSDOT maintenance activities, and to dispose properly of those wastes that cannot be re-used.

Until more practicable options exist, vactor wastes will be disposed of in a two-step process: interim and final disposal. Interim disposal will allow for characterization of the waste to provide the data necessary to determine proper final disposal. For interim disposal, the vactor sludge is placed at available district pit sites at least 100 feet from property boundaries, surface water boundaries, or water supply wells. After decant of the liquid fraction, the vactor sludge and wastes are placed on an impermeable surface. The area is bermed with straw bales or dirt, and the waste piles covered with 3 mil plastic or similar impervious material. This cover will prevent water infiltration into the vactor sludge and introduction of the sludge into runoff. The waste piles should be limited in size to 100 cubic yards.

Care must be taken to segregate the dirtiest wastes from those wastes that appear cleaner. Currently, dirtier wastes are characterized by visual observations of an oily sheen or detection of foul or chemical odors. Under no circumstances should vactor wastes be mixed with street sweepings or ditch cleaning spoils. Within the currently funded vactor characterization program, WSDOT will explore the possibility of using field test kits to determine the presence of petroleum hydrocarbons and polyaromatic hydrocarbons (PAHs) for waste segregation purposes.

An initial characterization program will determine baseline data for disposal of all highway generated waste solids. As noted above, current practice involves determinations from the sight and smell of the wastes, using Department of Ecology published guidelines, and possible use of field test kits for waste segregation and disposal requirements. Periodic samples will be processed by an analytical laboratory for confirmation of the accuracy of field test kits. This characterization program will consist of sampling three representative locations within a 100 cubic yard pile of catch basin sludge. All samples will be processed by an analytical laboratory certified by the Department of Ecology, and tested for the following methods:

| Test | Parameter |
|---|---|
| EPA Method 6010 | Total Metals — arsenic, barium, cadmium, chromium, lead, mercury, nickel, selenium, silver, copper, zinc |
| Toxic Characteristic Leaching Procedure (TCP) | Metals |
| EPA WTPH-HCID | Total Petroleum Hydrocarbons (TPH) |
| EPA WTPH-G | To quantify gasoline contamination |
| EPA WTPH-D | To quantify diesel contamination |
| EPA WTPH-418.1 (Modified) | For heavy fuel hydrocarbons |
| EPA Method 8020 | Benzene-toluene-ethyl benzene-xylene (BTEX) |

Final disposal options for petroleum contaminated soils will be based on contaminant concentrations and their appropriate end uses. Under the requirements of the Solid Waste Management Act (Chapter 70.95 RCW) and the Model Toxics Control Act (MTCA — Chapter 70.105D RCW), highest priority shall be given to recycling, reuse, and permanent solutions rather than landfill disposal.

Method A of the MTCA Cleanup Regulation (Chapter 173-340 WAC) will be used to determine the cleanup levels of petroleum contaminated soils. Vactor solids contaminated with pollutants other than petroleum must also meet the cleanup standards for those constituents (e.g., metals, solvents, etc.) or be taken to appropriate approved disposal facilities.

Vactor wastes with the single limiting factor of petroleum hydrocarbon contamination will be bio-remediated at a WSDOT-approved pit site. Detoxification is an acceptable technology as per the Cleanup Regulation (WAC 173-340-360). Vactor wastes requiring bio-remediation will follow current WSDOT practices to accomplish the treatment.

Treated soils will be classified and handled in the following three ways:

Class 1 Soils — These soils contain residual concentrations of petroleum contaminants at or below analytical detection limits. They are considered clean and can be used as fill for any project.

Class 2 Soils — These soils contain detectable levels of petroleum contaminants below the Cleanup Regulation Method A cleanup standard — 100 parts per million of TPH. Appropriate uses shall include fill or other uses that will not cause a threat to human or environmental health.

Class 3 Soils — These are soils with high levels of heavy hydrocarbons that may not meet cleanup standards even after treatment. Soils receiving adequate treatment should be able to meet the cleanup levels for light petroleum fractions. Those soils that cannot attain cleanup standards should be used at the original site or disposed of in an existing, permitted municipal landfill.

### *7-1.3 Street Sweepings*

Various studies debate the effectiveness of street sweeping for removal of pollutants from impervious surfaces. Most studies have focused on nonhighway applications of street sweeping programs for reduction of pollutants.

The Department of Ecology *Stormwater Management Manual for the Puget Sound Basin* (SMMPSB) states: “Street sweeping is a common maintenance method in most urban areas, but is seldom thought of a means to control pollutants.” Nationally, some study results document or indicate that street sweeping can be effective in removing pollutants. But, the results of street sweeping in the Puget Sound basin seem to be less than certain. It appears that a combination of low intensity rainfall, which fails to clear roads of all dirt and debris, and the fact that pollutants adsorb onto silt and clay sized particles, results in low effectiveness of street sweeping for pollutant removal (SMMPSB, 1992, p. IV-4-27).

The National Urban Runoff Program (NURP) found street sweeping generally ineffective for controlling pollutants in urban runoff and minimal data exists for the effectiveness of sweeping highways. NURP studies indicate that sweeping just prior to the rainy season could reduce some pollution in runoff. Studies demonstrating the effectiveness of street sweeping as a mechanism for pollutant reduction have centered on parking lots and urban streets, not highway settings.

The performance of a street cleaning program depends on the condition of the street surface, the particle size distribution of pollutants, the amount of pollutants present initially, the number of passes per treatment, and the interval between treatments.

#### 7-1.3.1 Frequency

Sweeping operations should be scheduled to prevent the accumulation of leaves, paper, or other debris that will clog the highway drainage system. Debris accumulation may require sweeping to occur as frequently as twice a month. Currently, scheduling is dictated by debris accumulation.

#### 7-1.3.2 Equipment

Two types of street sweepers are available for removal of solids from highway surfaces. The commonly used design is a mechanical street cleaner that combines a rotating gutter broom with a large cylindrical broom to carry the material onto a conveyor belt and into a hopper.

The vacuum assisted sweepers, found to potentially remove more fine particles from the impervious surface, are impracticable due to their slow speed in highway maintenance operations.

Operators will be trained 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 particulate removal.

### 7-1.3.3 Disposal

Each street sweeping pile should be limited in size to 100 cubic yards. Care will be taken to segregate the dirtiest wastes from those wastes that appear cleaner. Dirty wastes are characterized by oily sheen, foul odor, or those sweepings from areas of known elevated pollutant loads. Under no circumstances should street sweepings be mixed with vactor waste.

All street sweeping piles must be placed on an impermeable surface. The area must be bermed with straw bales or dirt and the waste piles covered. The cover is to prevent water infiltration into the street sweeping pile and mixing with runoff.

Sufficient data exists to characterize the pollutant load of street sweepings, WSDOT intends to continue sampling sweeping piles to verify the average pollutant concentrations in the 1995-97 biennium. Periodic sampling will occur to confirm consistency in disposal practices after completion of the waste characterization program.

Initial testing will consist of sampling three representative locations within a 100 cubic yard pile of street sweeping debris. Samples will be processed for the same parameters as vactor sludge piles.

WSDOT is currently exploring the option of re-use of uncontaminated street sweepings. The intent is to explore screening of the sweepings for removal of the larger debris and garbage. After removal of the large debris and smaller (< 200) particle fraction, a portion of the remaining material could be re-used for the originally intended use, i.e., road abrasive.

Final disposal options for contaminated sweepings will be based on contaminant concentrations and their appropriate end uses. Under the requirements of the Solid Waste Management and Model Toxics Control Acts, highest priority will be given to recycling, reuse, and permanent solutions rather than landfill disposal.

Method A of the cleanup regulation shall be used to determine the cleanup levels of petroleum contaminated sweepings. Contaminants other than petroleum must also meet the cleanup standards for those constituents (e.g., metals, solvents, etc.) or be taken to appropriate approved disposal facilities. Street sweeping wastes with the single limiting factor of petroleum hydrocarbon contamination will be remediated (land farmed) at an approved WSDOT pit site and re-used in maintenance activities. Sweepings requiring bio-remediation will follow current WSDOT practices to accomplish this treatment.

## 7-2 Maintenance of Stormwater Facilities

Drainage facilities are to be maintained and preserved as nearly as possible in the condition and at the capacity for which they were originally designed and constructed. Maintenance practices for drainage channels and oil/water separators are found in this chapter. Maintenance practices for erosion and sediment control best management practices (BMPs), water quality and quantity BMPs, and construction site pollution control BMPs, are found in Chapter 8.

Maintenance personnel must be continually alert to see that all natural water course channels crossing the right of way remain open.

### *7-2.1 Channel Conveyance*

Maintenance of ditches has focused historically on the hydraulic performance of drainage facilities. In some instances, vegetation within the ditches may provide an opportunity for water quality enhancement but could interfere with the hydraulic capacity. Cleaning of the ditches resulting in exposed soils may result in increased sediment load and the subsequent downstream impact.

The preservation of the hydraulic capacity of ditches must be recognized in the maintenance approach. The following recommendations are intended to augment the existing WSDOT ditch maintenance program.

Ditches should be inspected by WSDOT maintenance staff twice each year to identify sediment accumulations, localized erosion and other problems. Ditches should be cleaned on an annual basis or more frequently if needed. Ditches and gutters must be kept free of rubbish and debris and all cracks and breaks must be repaired as required.

Water should not pond in ditches and a ditch should never be deeper than the culvert flow lines, unless the ditch is designed for storage. Vegetation in ditches often prevents erosion and cleanses runoff waters. Vegetation should be removed only when flow is blocked or excess sediments have accumulated. Emphasis shall be placed on performing maintenance in late spring to enable the vegetation the opportunity to reestablished by the next wet season thereby minimizing erosion of the ditch as well as making the ditch effective as a biofilter.

Open ditches will be routinely checked and maintained to the line, grade, depth, and cross section to which they were constructed. Where practicable, ditches should be modified to produce a relatively flat, shallow ditch to enhance motorist safety.

Diversion ditches on top of cut slopes that are constructed to prevent slope erosion by intercepting surface drainage must be maintained to retain their diversion shape and capacity.

Surplus material derived from regular maintenance of ditch cleaning can often be used for widening, as long as the material placed into the adjacent portions of the highway or disposal areas and does not obstruct or impair other roadside drainage areas. Care must be taken to avoid causing erosion problems or loose unstable fills.

Ditch cleanings are not to be bladed across roadway surfaces. Dirt and debris remaining on the pavement after the ditch cleaning operations will be swept from the pavement.

Culverts will be inspected on a regular basis for scour around the inlet and outlet, and repaired as necessary. Priority will be given to those culverts located in perennial or salmonid-bearing streams, and culverts near streams in areas of high sediments load, such as those near construction activities.

### 7-2.2 Oil/Water Separators

The SMMPSB recognizes the limited application of oil/water separators for stormwater treatment. Such mechanisms are not suitable for treatment of the "waste water" characteristics of highway runoff. The SMMPSB recommends oil/water separators be used for spill control as their primary application.

Oil/water separators should be inspected annually. Oil/water separators should be cleaned to prevent accumulated oil from escaping during storms. Emphasis will be placed on inspection of and cleaning as needed by Autumn to remove material that has accumulated during the dry season. Currently, oil/water separators are cleaned in conjunction with catch basins.

All removal of oil/water separator wastes will be done with a vactor truck. No manual cleaning will occur. Care will be taken to prevent mixing of catch basin wastes (potentially the more contaminated) and the liquid waste from the oil/water separators. The vactor truck used will be an 88 Model International Vactor f2575 W/F/Eductor or equivalent.

Minimal options exist for disposal of the liquid fraction of the waste from oil/water separators. Where available and permissible, the liquid waste shall be disposed of at decant stations or municipal sanitary sewer systems. WSDOT district environmental or headquarters maintenance staff will explore, case by case, the need for alternative disposal options with waste oil vendors. All solid material produced from oil/water separator maintenance will be temporarily stored for characterization, and disposal options similar to the methods prescribed for vactor solids.

## 7-3 Snow and Ice Control Operations

It is the intent and practice of WSDOT to remove snow from regularly traveled state routes as the snow accumulates. The removal of snow and ice from the roadway takes precedence over non-emergency work. The roadway is to be plowed and sanded if necessary, to ensure the safety of the traveling public. Priorities and service levels are determined by usage and average daily traffic levels. Greater priority is given to the Interstate System and those sections of highway having an average daily traffic of 10,000 or more.

Snow control operations consist of removing accumulated snow from the traveled way, shoulders, widened areas and public highway approaches within the right-of-way. When accumulated snow becomes compact and removal is not possible with available equipment, the accumulation shall be treated as an ice control operation.

### 7-3.1 Deicing Materials and Road Abrasives

Ice control operations consist of application of abrasives and/or chemicals to ice or compact snow. WSDOT emphasizes efficient use of deicing products and traction abrasives through effective plowing and spreading equipment, and the use of weather and roadway monitoring systems (e.g., pavement sensors). The "anti-icing" operation focuses the application of deicing chemicals at the beginning of the snow fall, preventing ice or snow from bonding to the roadway surface.

Historically the corrosive effects of chloride deicers and traction abrasives on the highway infrastructure has directed research efforts. Arguments emphasize evaluating the real cost of chloride deicers by including the destructive effect on steel bridges and concrete roadways.

Research of the environmental impacts from winter ice control activities includes evaluating damage to roadside vegetation from excessive and improper salt use, deposition of traction sand on roadside aquatic environments, and estimating the contribution of abrasives to non-attainment thresholds for air quality standards.

### 7-3.2 Chemical Deicers

Both solid and liquid chemical deicers are used for deicing in a multitude of settings. The use of deicing chemicals containing chlorides, such as common salt and calcium chloride, is discouraged. Emphasis is placed on selection of alternative deicers that are less corrosive and provide an effective level of service over the increased cost. The regional Administrator approves the use of chlorides only in those areas where the detrimental effects do not outweigh the benefits of such applications.

When removal of compact snow and ice is not possible, road abrasives and deicers are applied at bridges, curves, intersections, railroad crossings, steep grades and isolated shaded areas. Deicers facilitate the effectiveness of abrasives, reducing the amount necessary to enable adequate traction. Deicers are also applied to abrasives stockpiles keeping the pile workable in freezing weather and to help set the sand into the ice surface.

In selected areas WSDOT is exploring the use of liquid deicers. Liquids deicers (a calcium magnesium product) are used as pre-treatment on paved areas and on bridges where abrasives provide a negative effect. Liquid deicers properly applied prior to snowfall, inhibits snow or snow and ice from bonding to the pavement or forming on the pavement as in the case of black ice.

### 7-3.3 Roadway Abrasives

Road abrasives must be heavy enough to stay in place, small enough not to damage vehicle windshields or paint, and clean enough so as not to pollute water bodies. The following is the specification for that abrasive:

**Roadway Abrasive Specification**

| **3/8 - #10** | |
|---|---|
| 1/2 Square | 100% |
| 3/8 Square | 90-100% |
| 1/4 Square | 50-75% |
| U.S. #10 | 0-10% |
| U.S. #200 | 0-1.0% |

At least 75 percent of the material shall have one fractured face. The finished product shall be clean, uniform in quality, and free from wood, bark, roots and other deleterious material.

If evidence supports the need to address potential discharge of suspended solids into an adjacent water body sensitive to suspended sediments, the following practices implemented may reduce the sediment contribution to the drainage system:

- Increased scheduling of roadside sweeping.
- Increased maintenance of catch basins/drainage systems.
- Emphasis will be placed on reduction/elimination of the use of high volume water flushing to roadsides adjacent to water bodies which are sensitive to the temporary loading of suspended solids. Flushing in conjunction with sweeping may be required in areas of air quality concerns. Regional or Olympia Service Center Environmental staff can be contacted for additional guidance.

### *7-3.4 Storage*

If the deicers are not shipped in water tight containers, they are stored undercover and on pallets until they are mixed with the abrasive. Mixing ratios can be from 30:1 up to 1:1. In most parts of the state, a ratio of 20:1 and lighter can be stored in the same fashion as the abrasive, and is considered the proper ratio for keeping the stockpile workable. Heavier ratios are sometimes kept in smaller amounts for problem areas like stop sign locations, hills or bad curves. These stockpiles will be covered or protected with berms if there are signs of leaching.

Each stockpile should be located on a smooth, level surface with a maximum exposure to the sunlight. If the stormwater runoff is a problem, the stockpile site may need to be covered or a berm built around the perimeter to collect the drainage.

## 7-4 Water Quality Protection During Bridge Maintenance

Maintenance of steel bridges can have an adverse impact on the surrounding environment if certain practices are not employed. During bridge cleaning or preparation of bridge members for painting, careless pressure washing can remove pollutants in concentrations sufficient to exceed water quality standards. Abrasive blasting can be a hazard to workers and the environment due to dust from the fracturing of blast material, and toxic compounds in the paint (e.g., lead and chromium) and sometimes in the blast material itself. If the bridge to be painted is located over a water body, paint and other debris should be kept out of the water to avoid pollution. The blast debris and paint residue needs to be properly contained during the blasting operation, and once contained, this waste material could be designated hazardous and proper disposal be required.

WSDOT Guidelines for Bridge Painting Practices (in draft form as of this writing) address bridge painting impacts in a comprehensive fashion. This section of the manual will only address the impacts of bridge maintenance on water quality.

### *7-4.1 Minimizing Water Quality Impacts*

When pressure washing is used to clean a bridge, pollutants that have settled on bridge members will be washed off with the water. These pollutants can include oil and grease, heavy metals, sediment, bird guano, and deicing chemicals. Depending on several factors, this wash water could adversely affect the water quality of the receiving water body. These factors include the size of the bridge, average daily traffic, amount of time since last cleaning, type of receiving water body (marine water, lake, watercourse, etc.), and amount of flow if a watercourse. There should not be a problem with marine waters and rivers because of sufficient dilution, but there may be problems if the receiving water body is a lake or small watercourse. A short-term modification of water quality standards, and/or containment of the washing operation, may be necessary. The Olympia Service Center Water Quality Unit will be contacted for more information. Chlorine bleach will not be used in the pressure washing operation.

When abrasive blasting takes place over a body of water, most of the paint debris sinks immediately upon landing on the water surface. The smaller particles can float for awhile and form a scum on the water surface. All the particles eventually sink, and lead compounds have extremely low water solubility. Mostly due to insolubility of the encapsulated lead compound, there is little information indicating long-term detrimental effects on aquatic biology by the lead particles deposited on the bottom of a water body. Research conducted in British Columbia indicated that juvenile salmonids may ingest paint flakes, which are then dissolved by acids in the fish gut. Some Washington State fish biologists disagree with these research findings. An additional water quality concern is paint getting into water as a result of dripping or spilling during the painting operation. State law prohibits the introduction of pollutants into waters of the state.

WSDOT is changing the contract requirements for environmental protection during bridge painting operations. When implemented, these requirements will address the need for containment during bridge painting projects to prevent water pollution from abrasive blasting and painting. The above-mentioned guidelines will be the mechanism by which containment structures are incorporated into a project.

### 7-4.2 Painting Management Practices

Bridge painting projects should incorporate the following good painting management practices that address the storage, mixing, moving, and use of paint:

1. Paint spillage and dripping shall be prevented from entering state waters.
2. The contractor will have a plan to remove paint accidentally spilled into state waters. The contractor will have all equipment and materials required to implement the cleanup available at the site at all times work is being performed.
3. Paints will be stored and mixed in a secure, contained location off the bridge to eliminate potential spills into water.
4. Equipment will not be cleaned in state waters, nor will cleaning runoff be allowed to enter state waters.
5. Paint containers, lids, brushes, or other debris will not be allowed to enter state waters.
6. Paint pails will contain a maximum of two (2) gallons of paint.

If a containment structure is utilized to contain the blast material, and the structure is removed upon completion of the abrasive blasting operation, a drip tarp or similar type of under-containment should be installed before application of the paint to prevent spillage into the water body below the bridge.

## 7-5 References

Herrera. 1991. Vactor truck operations and disposal practices. Prepared by Herrera Environmental Consultants, Inc. for Washington Department of Ecology, Stormwater Unit. August 15, 1991.

Serdar, D. 1992. First progress report on survey of contaminants in vactor truck wastes: results of July 1991 sampling. Prepared for Helen Pressley, Washington Department of Ecology Water Quality Program.

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# Contents



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# 8-1 BMPs For Controlling Pollutants Other Than Sediment on Construction Sites (Non-ESC BMPS)

### *8.1.1 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 should only be used in conjunction with Integrated Pest Management (IPM). IPM utilizes a needs assessment which determines the necessity of controlling a pest population and which method to use. 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. IPM is further discussed in Chapter 6, Roadside Vegetation Management.

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 (WSDA), WAC 16-228-285. The Environmental Protection Agency (EPA) has produced a pamphlet entitled *Suspended, Canceled and Restricted Pesticides* (January 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 in 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 a garden center, landscape service, or similar business.
- Triple rinse containers before disposal, reuse rinse waters as product.

*Hazardous Waste Pesticides — Determining if Your Pesticide is a Hazardous Waste*, Department of Ecology Publication 89-14, provides guidance and is available from Ecology’s Publications Office. For more information, contact the headquarters hazardous materials specialists in the Environmental Branch, or call Hazards Line (587-3292) or Hazardous Substance Information Hotline (1-800-633-7585).

Pesticide storage areas on the construction site should be enclosed or otherwise protected from the elements (especially rainfall and runoff), 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:

- Establish a locked, weather-resistant storage area.
- Container lids should be tightly closed.
- Keep pesticides 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 storage area.
- The applicator must follow the notification requirements of the WSDA. 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 pre-construction or safety meetings about proper storage and handling of materials.

### 8.1.2 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 and kerosene; lubricating oils; and grease. Petroleum products usually occur, and can become mixed with stormwater, in vehicle storage areas and on-site fueling or equipment maintenance areas. 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 the chances of petroleum products contaminating construction sites. One of the greatest concerns confronting uses of 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). Contact the headquarters hazardous materials specialists in the Environmental Branch for more information on recycling and disposal. 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 storage area with cover and wind protection, and construct impervious berm around the perimeter of storage area.
- Capacity of bermed area should be 110 percent of largest container.
- Line the storage area with double layer of plastic sheeting or similar material.
- All products should be clearly labeled.
- Keep tanks off the ground.
- Keep lids securely fastened.
- 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.

### 8.1.3 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 and can contribute to 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 pounds per acre of fertilizer could be dressed with about 125 pounds 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 district or Headquarters landscape architects.

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.

### 8.1.4 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 road construction and during the installation of structures, and from the demolition 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 other materials. 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 clean construction sites and minimizes the exposure of waste to stormwater. Waste containers should be labeled 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 can be converted into wood chips 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 control of soil erosion 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.

### 8.1.5 BMP C1.50 — Use of Chemicals During Construction

Many types of chemicals may be used during construction activities. These chemicals are found in paints, acids for cleaning masonry surfaces, cleaning solvents, asphalt products, soil additives used for stabilization and other purposes, concrete-curing compounds, and many others. When used or stored improperly, these chemicals can become mixed with stormwater and carried by sediment and runoff from construction sites.

A large percentage of these chemicals 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 headquarters hazardous materials specialists in the Environmental Branch, local health department or the Hazardous Substance Information Hotline (1-800-633-7585).

### 8.1.6 BMP C1.60 — Managing Hazardous Products

Listed below are general guidelines for managing or minimizing hazardous substances used at construction sites:

- Buy and use only what is needed. Leftovers need to be stored, reused, given away, recycled, or disposed of safely.
- Read labels and follow directions on the label. Hazardous products may include one or more of the following words on the label:

| | | | | |
|---|---|---|---|---|
| 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 re-label, 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 headquarters hazardous materials specialists in the Environmental Branch, or the district or headquarters materials engineers)
- Use all of the product before disposing of the container.

### 8.1.7 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 local 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 WSDOT hazardous materials specialists.

### 8.1.8 BMP C1.80 — Spill Control Planning and Cleanup

Contractors will be developing and implementing a spill control plan as part of their addendum to Temporary Erosion and Sediment Control Plans, if appropriate for the construction site involved. These spill control plans will 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):
- Locally, notify the regional Department of Ecology offices:

  Northwest Region — Redmond (206) 649-7000 (24-hour)

  Southwest Region — Olympia (360) 753-2353 (24-hour)

  Central Region — Yakima (509) 575-2490 (24-hour)

  Eastern Region — Spokane (509) 456-2926 (24-hour)

  Or call the state of Washington Emergency Management Division, 24-hour emergency number: (800) 258-5990
- Within the city of Bellevue: Storm & Surface Water Utility (206) 455-7846 (24-hour)
- For EPA and Coast Guard Reporting: National Response Center (800) 424-8802

When reporting a spill, the following information must be provided:

- Reporting Party
- Material Released
- Concentration
- Contact Phone Number(s)
- Resource Damages (e.g., dead fish)
- Location
- Responsible Party
- Quantity of Spill
- Cleanup Status

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 cleanup instructions for different products handled on-site.
- Assign a person to be in charge of cleanup assistance.
- Prepare spill containment and cleanup lists that are easy to find and use.
- Post a summary of the cleanup plan at appropriate locations.
- If a spill occurs, demobilize it as quickly as possible.
- If there is a chance 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.

### *8.1.9 BMP C1.90 — Treatment and Disposal of Contaminated Soils*

Contaminated ground water or soil may be encountered during earthwork activities or caused by the spill or leak of a hazardous product. The contaminant may be known or unknown. Trained personnel may need to conduct field investigations, sampling or laboratory tests to determine the cause and extent of the contamination, the pollutant(s) involved, and the cleanup and disposal options.

Procedures contained in the *Implementing Agreement Between the Department of Ecology and the Department of Transportation Concerning Hazardous Waste Management*, effective April 1, 1993, shall be followed if contaminated soils are encountered or caused at a construction site. District or headquarters hazardous materials specialists should be contacted immediately for the appropriate course of action. If an emergency exists due to on-going migration of the contamination, the situation should be treated as a spill.

### *8.1.10 BMP C2.00 — Concrete Trucks*

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 disposed of as solid waste.
- 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.

DO NOT dispose of truck washout water by dumping into:

- Sanitary sewer.
- Storm drain.
- Soil or pavement which carries stormwater runoff.

# 8-2 Erosion and Sediment Control BMPs

## *8-2.1 Temporary Cover Practices*

### 8-2.1.1 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 rapidly growing plants. This provides temporary soil stabilization to areas which would remain bare for more than seven days where permanent cover is not necessary or appropriate.

#### *Conditions Where Practice Applies*

- Permanent structures are to be installed or extensive regrading 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 percent for 100 feet (30 m) 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 plastic covering (see BMP E1.20).
- If sown on subsoil, growth may 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.

### *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.
- 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 to 4 inches (50 to 100 mm) of tilled topsoil is required.
- Seeding — Seeding mixtures will vary depending on the exact location, soil type, slope, etc. Information on mixes may be obtained from the Environmental Section and the headquarters horticulturist.
- “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.
- Reseeding — Areas which fail to establish vegetative cover adequate to prevent erosion shall be re-seeded as soon as such areas are identified.

## 8-2.1.2 BMP E1.15 — Mulching and Matting

Code: (MU) Symbol: ←(MU)→

### *Definition*

Application of plant residues or other suitable materials to the soil surface. This provides 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.

## 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.

## Organic Mulches

Straw — Straw is the mulch most commonly used in eastern Washington in conjunction with seeding. Its use is recommended where immediate protection is desired and preferably where the need for protection will be less than three 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).
4. Keeping moist. Natural precipitation can often provide sufficient moisture.

Corn Stalks — These should be shredded into 4- to 6-inch (100 to 150 mm) 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 (6 Kg per metric 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.

Wood Fiber — Wood fiber is the mulch most commonly used in western Washington in conjunction with seeding. It is 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, critical areas, and severe climate conditions.

Manure Mulches — Manure mulches should be well-aged and are not recommended for use near water bodies.

### *Chemical Mulches, Soil Binders, and Mats*

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. There are some organic materials, such as jute and excelsior, that are available in the form of mats.

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.

| **Technique[2]** | **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 |

[2]The estimated cost of seeding where it was used is based on hydro-seeding (approximately $500/acre).

**Summary of Estimated Service Lives and Costs**
**1988 Base**

*Figure 8-2.1*

## Design Criteria

- Site Preparation — Same as Temporary Seeding.
- Mulch Materials, Application Rates, and Specifications — See Figure 8-2.2
- 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 (1 to 1.25 m) wide shall weigh an average of 1.2 lbs./linear yard (0.6 Kg per linear meter). 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 (150 mm) long, with an overlap of 3 inches (75 mm).
- Excelsior blankets are considered protective mulches and may be used alone on erodible soils and during all times of year.
- See Figure 8-2.3 for orientation of netting and matting.

## Maintenance

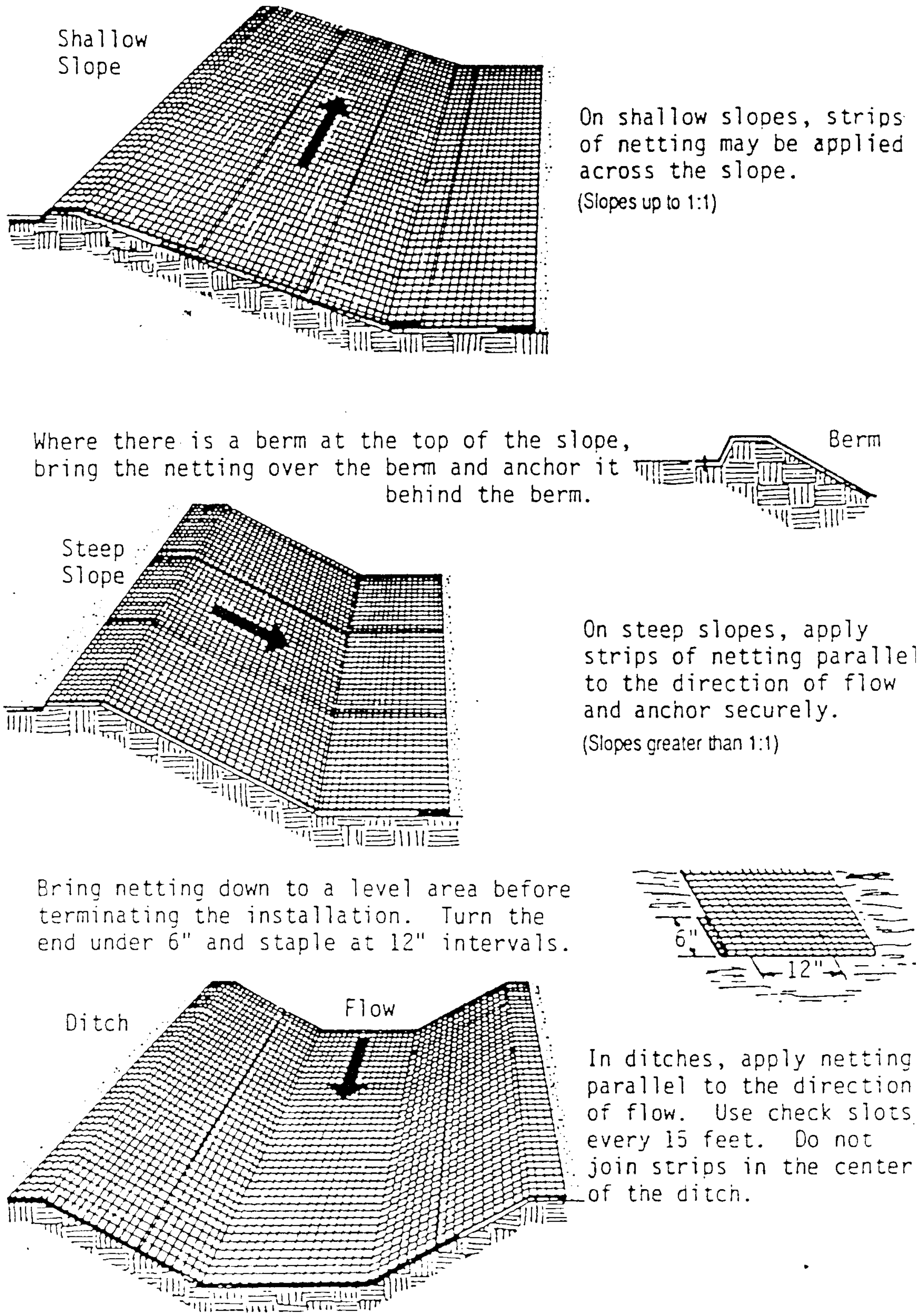
- Mulched areas should be checked periodically, especially following severe storms, when damaged areas of mulch or tie-down material should be repaired.
- All temporary erosion and sediment control measures that prohibit vegetative growth shall be removed within 30 days after final site stabilization 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.

| Mulch Material | Quality Standards | Application Rates (/100m$^2$ /1000 ft$^2$ | (/hectare) /acre | Depth of Application | Remarks[1] |
|---|---|---|---|---|---|
| Gravel, slag or crushed stone | Washed, ¾ - 1½″ size 19.05 mm to 38.1 mm | 9 yds$^3$ (7.5 m$^3$) | | 3 inches (80 mm) | Excellent mulch for short slopes and around woody plants and ornamentals. Use where subject to foot traffic. Approximately 2,000 lbs/yd$^3$ (1,200 Kgm$^3$). |
| Hay or straw | Air dried, free from unwanted seeds and coarse material | 75 - 100 lbs. or 2 - 3 bales (40 - 50 Kg or 2 - 3 bales) | 1½ - 2½ tons or 90 - 120 bales 3.5 - 6 metric tons or 225 - 300 bales | Minimum of 2 inches (50 mm) | Use where the mulching effect if to be maintained >3 months. Is subject to wind blowing unless kept moist or tacked down. Most common and 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. (13 - 15 Kg) | 1,000 - 1,500 lbs. 1,100 - 1,700 Kg | | If used on critical areas, double the normal application rate. Apply with hydromulcher. No tie-down required. Packaged in 100 pound (45 Kg) bags. |

[1]All mulches will provide some degree of (1) erosion control, (2) moisture conservation, (3) weed control, and (4) reduction of soil crusting.

**Guide to Mulch Materials, Rates, and Uses**

***Figure 8-2.2***




**Orientation of Netting and Matting**

***Figure 8-2.3***

## 8-2.1.3 BMP E1.20 — Plastic Covering

Code: PC Symbol: ←PC→

### *Definition*

The covering with plastic sheeting of bare areas which need immediate protection from erosion. This provides immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, in particular during the specified seeding periods. Plastic is also used to protect disturbed areas which must be covered during short periods of inactivity to meet November 1 to March 31 cover requirements. Because of many disadvantages, 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 plastic covering for germination and protection from heavy rains.)

### *Advantages*

- Plastic covering is a good method of protecting bare areas which need immediate cover and for winter plantings.
- May be relatively quickly and easily placed.

### *Disadvantages/Problems*

- There can be problems with vandals and maintenance.
- The sheeting will result in rapid, 100 percent 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.
- The plastic may blow away if it is not adequately overlapped and anchored.
- Ultraviolet 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*

- 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 (3-m) 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 (300 to 600 mm) overlap of all seams. Seams should then be rolled and staked or tied.
- Covering shall be installed immediately where required 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. Re-anchor or replace the plastic as necessary.

## 8-2.2 Permanent Cover Practices

### 8-2.2.1 BMP E1.25 — Preserving Vegetation

Code: VEG    Symbol: ←VEG→

### Definition

Minimizing exposed soils and consequent erosion by clearing only where construction will occur.

### Condition Where Practice Applies

- Vegetation should be preserved on steep slopes, near perennial and intermittent watercourses or swales, and on construction sites in wooded areas.

### Advantages

Preserving vegetation will:

- Help reduce soil erosion.
- Reduce stormwater runoff.
- Beautify an area.
- Save money on landscaping costs.
- Provide areas for wildlife.
- 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.

### *Design Criteria*

Vegetation can be preserved in natural clumps or as individual trees, shrubs, and vines. The district or headquarters landscape architect or the headquarters horticulturist should be contacted when determining whether or not to remove vegetation.

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.
- 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, oak, elm, 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. It is expensive to cut a large tree and to remove the tree and stump from a developed area.
- 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.
- 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. 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.

Lowering the natural ground level can seriously damage trees and shrubs. The highest percentage of the plant roots are in the upper 12 inches (300 mm) of the soil and cuts of only 2 to 3 inches (70 to 100 mm) 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.

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:

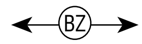
- Cut as few roots as possible. When you have to cut — cut clean.
- Backfill the trench as soon as possible.
- Tunnel beneath root systems as close to the center of the main trunk to preserve most of the important feeder roots.
- Some problems that can be encountered with a few specific trees are:
- 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 tip over hazard of Pacific silver fir is high while that of Western hemlock is moderate. The danger of tip over increases where dense stands have been thinned. Other species [unless they are on shallow, wet soils under 20 inches (0.5 m) deep] have a low tip over hazard.

## Maintenance

- Inspect flagged areas regularly to make sure flagging has not been removed. If tree roots have been exposed or injured, recover and/or seal them.

### 8-2.2.2 BMP E1.30 — Buffer Zones

Code: (BZ)

Symbol: 

***Definition***

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 project costs.

***Design Criteria***

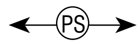
- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Leave all unstable steep slopes in natural vegetation.
- Fence or flag clearing limits and keep all equipment and construction debris out of the natural areas.
- Keep all excavations 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 (30 m) wide on each side with increases subject to other on-site sensitive conditions, existing vegetative conditions and erosion hazard potential. Contact the district Environmental Section for setback guidelines.

***Maintenance***

- Inspect the area frequently to make sure flagging remains in place and the area remains undisturbed.

### 8-2.2.3 BMP E1.35 — Permanent Seeding and Planting

Code: PS

Symbol: 

#### Definition

The establishment of perennial vegetative cover on disturbed areas. This is done to prevent soil erosion by wind or water, and to improve wildlife habitat and site aesthetics.

#### 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.
- Wet or dry ponds as required.

#### Advantages

- Well established grass and ground covers can give an aesthetically pleasing, finished look to a project.
- 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.
- May require regular irrigation to establish and maintain.

#### 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 (50 to 150 mm) 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. Cultivation and raking should be done along the contour lines and compaction should be done perpendicular to the contour lines. The seedbed should be firm with a fairly fine surface.

- Soil Amendments — Rates will depend on-site characteristics and soil. Scatter amendments uniformly and work into the soil during seedbed preparation.
- Seeding — Seeding mixtures will vary depending on the exact location, soil type, slope, etc. Information on mixes may be obtained from the Environmental Section or the headquarters horticulturist.

Cover the seed with topsoil or mulch no deeper than 2 inches (50 mm). 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.

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.

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. 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.
2. Competing vegetation should be controlled in 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 percent 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.

## 8-2.2.4 BMP E1.40 — Sodding

Code: SO Symbol: ←SO→

### *Definition*

Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod. This is done 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 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 (25 to 50 mm) 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 (300 mm). Staple if on steep slopes.
- 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 [approximately 1 inch (25 mm)] 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.

## 8-2.2.5 BMP E1.45 — Topsoiling

Code: TO    Symbol: ←TO→

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. This provides 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.

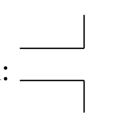
- Unless carefully located, storage banks of topsoil may also obstruct site operations and therefore require double handling.
- Topsoiling can delay seeding or sodding operations, increasing exposure time of denuded areas.
- Most topsoil contains some weed seeds.

### *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 (100 to 150 mm) 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 seven 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.

## *8-2.3 Structural Erosion Control BMPS*

### 8-2.3.1 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. This reduces 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.

### Design Criteria

- Material should be quarry spalls (where feasible), 4 inches (100 mm) to 8 inches (200 mm) in size.
- The rock pad shall be at least 12 inches thick and 100 feet (30 m) in length for sites more than 1 acre; and may be reduced to 50 feet (15 m) 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 or 6 m).
- Additional rock should be added periodically to maintain proper function of the pad.
- See Figure 8-2.4 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.

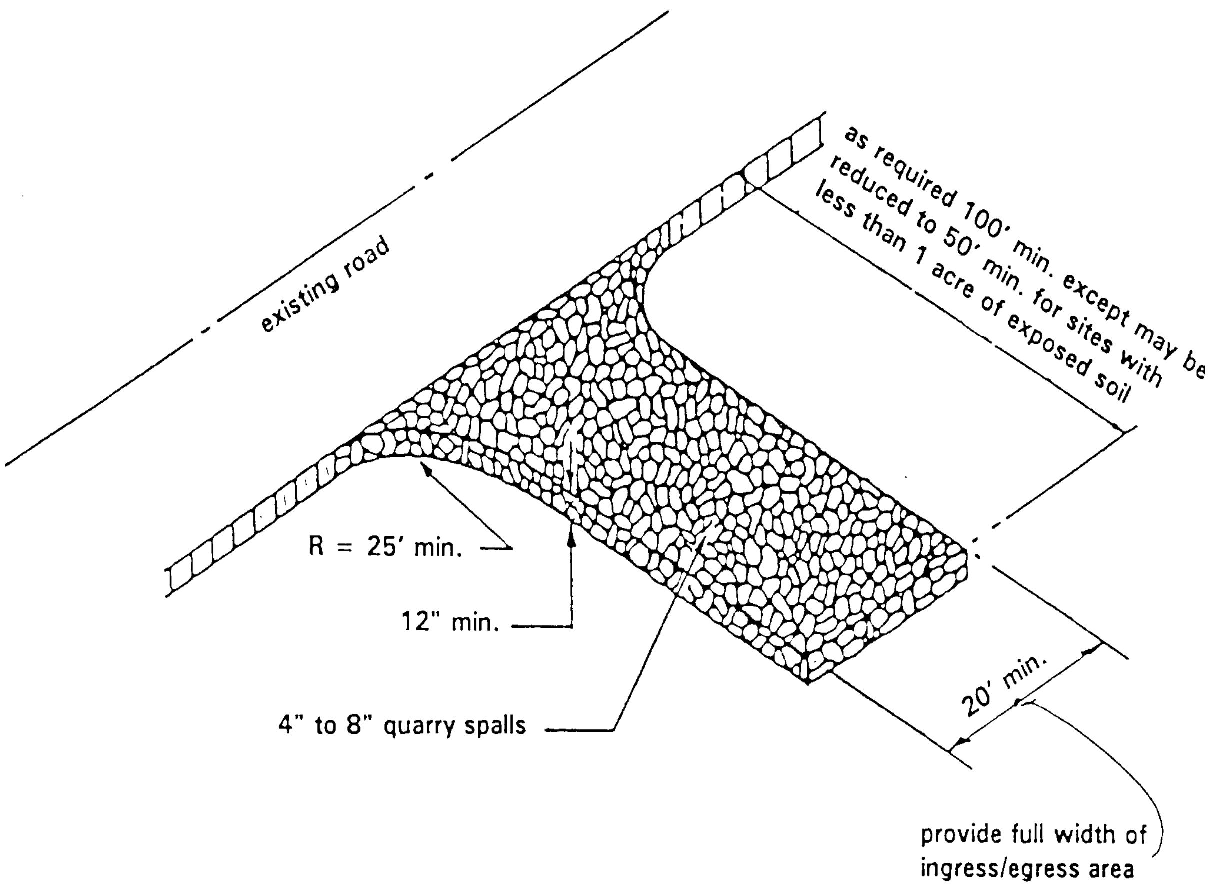
### 8-2.3.2 BMP E2.15 — Construction Road Stabilization

Code: (CRS)

#### *Definition*

The temporary stabilization with stone of access roads, parking areas, and other on-site vehicle transportation routes immediately after grading. This is done:

- 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.




**Stabilized Construction Entrance**

***Figure 8-2.4***

### *Conditions Where Practice Applies*

- Wherever rock-base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.

### *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.

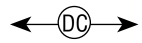
### *Design Criteria*

- A 6-inch (150 mm) course of 2- to 4-inch (50 to 100 mm) 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 (100 mm) course of asphalt treated base (ATB) may be used in lieu of the crushed rock.
- Where feasible, alternative routes should be made for construction traffic; one for use in dry conditions, 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.
- Installed inlets shall be protected to prevent sediment-laden water entering the drain sewer system (see BMP E3.30).
- 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.

### 8-2.3.3 BMP E2.20 — Dust Control

Code: DC Symbol: 


***Definition***

Reducing surface and air movement of dust during land disturbing, demolition, and construction activities.

***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.

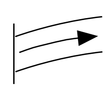
***Disadvantages/Problems***

- 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 was not one.

***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 district Construction Office to see which other dust palliatives may be used in the area.

### 8-2.3.4 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. Pipe slope drains are used 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 an effective method of conveying water safely down steep slopes.

### *Disadvantages/Problems*

- Care must be taken to correctly locate 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.

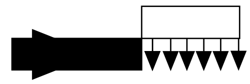
### *Design Criteria*

- The capacity for temporary drains shall be sufficient to handle a 10-year flow. This may be computed using the conveyance design method as dicussed in Chapter 3. Permanent pipe slope drains shall be sized as described in the WSDOT *Hydraulics Manual*.
- The entrance shall consist of a standard flared end section for culverts 12 inches (300 mm) and larger. The slope of the entrance shall be at least 3 percent.
- 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 (300 mm) higher at all points than the top of the inlet pipe.
- The area below the outlet must be stabilized with a riprap apron.
- If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

### *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.
- 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.

## 8-2.3.5 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. This converts 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.

### *Design Criteria*

- The grade of the channel for the last 20 feet (6 m) 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.
- A 6-inch (150 mm) high gravel berm placed across the level lip shall consist of washed crushed rock, 2 to 4 inch (50 to 100 mm) or $^{3}/_{4}$ inch (1.91 cm) to $1^{1}/_{2}$ inch (19 to 38 mm) size.
- The spreader length will be determined by estimating the 25-year flow and selecting the appropriate length from the following table:

| Q25, in CFS ($m^3$/sec) | | Min. Length, in Feet (m) |
|---|---|---|
| 0-0.1 | (0-0.028) | 15 (4.5) |
| 0.1-0.2 | (0.028-0.057) | 20 (6) |
| 0.2-0.3 | (0.057-0.085) | 30 (9) |
| 0.3-0.4 | (0.085-0.11) | 40 (12) |

- When used with a biofiltration swale, the spreader length will be equal to the width of the swale.
- The width of the spreader should be at least 6 feet (1.8 m).

- 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 periodically 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.

## 8-2.3.6 BMP E2.55 — Interceptor Dike and Swale

Code: (IDS) Symbol: ←(IDS)→

### *Definition*

A ridge of compacted soil or a swale with vegetative lining located at the top or base of a sloping disturbed area. This intercepts 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. 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.

### *Design Criteria*

- Interceptor dikes shall meet the following criteria:

| | |
|---|---|
| Top Width | 2 feet (600 mm) minimum. |
| Height | 18 inches (450 mm) minimum. Measured from upslope toe and at a compaction of 90 percent ASTM D698 standard proctor. |
| Side Slopes | 3:1 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 (90 m) |
| Slopes | 5-10% | = | 200 feet (60 m) |
| Slopes | 10-40% | = | 100 feet (30 m) |

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. |

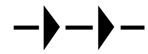
- Interceptor swales shall meet the following criteria:

| | |
|---|---|
| Bottom Width | 2 feet (600 mm) minimum; the bottom shall be level. |
| Depth | 1 foot (300 mm) minimum. |
| Side Slope | 3:1 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 Riprap 12 inches (300 mm) thick pressed into the bank and extending at least 8 inches (200 mm) vertical from the bottom. |
| Swale Spacing | |
| Slope of disturbed area: | <5% = 300 feet (90 m) |
| | 5-10% = 200 feet (60 m) |
| | 10-40% = 100 feet (30 m) |
| 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.

## 8-2.3.7 BMP E2.60 — Check Dams

Code: (CD) Symbol: 

### *Definition*

Small dams constructed across a swale or drainage ditch. This reduces the velocity of concentrated flows, reducing erosion of the swale or ditch.

### *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 (4 Ha) or less. No check dams may be placed in streams (unless approved by the State Department of Fish and Wildlife as appropriate). Other permits may also be necessary.

### *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 project completion.
- 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.

### *Design Criteria*

- Check dams can be constructed of either rock, pea-gravel filled bags or logs. Provide a deep sump immediately upstream.
- 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.

- 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 (100 to 150 mm) diameter logs. The logs shall be embedded into the soil at least 18 inches (450 mm).
- 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 periodically monitored for performance and sediment accumulation 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.

## *8-2.4 Sediment Retention*

### 8-2.4.1 BMP E3.10 — Filter Fence

Code: (FF) Symbol: *———*———*

#### *Definition*

A temporary sediment trap 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.

#### *Conditions Where Practice Applies*

- Below disturbed areas where runoff may occur in the form of sheet and rill erosion; wherever runoff has the potential to impact downstream resources.
- Perpendicular to minor swales or ditch lines for contributing drainage areas up to one acre in size.

#### *Advantages*

- Downstream riparian and in stream habitat will not be damaged by sediment deposits originating from the development.
- Able to install at nearly any site where erosion is a problem.

#### *Disadvantages/Problems*

- 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.

### *Design Criteria*

- Maximum slope steepness (perpendicular to fence) is 1.5:1.
- Maximum sheet flow path length to the fence is 100 feet (30.5 m) for slopes between 1.5:1 and 3:1, 150 feet (45.7 m) for slopes between 3:1 and 6:1, and 200 feet (61.0 m) for slopes less steep than 6:1.
- Maximum apparent opening size (AOS) for slit film filter fabric is 0.60 mm (#30 sieve). All other filter material shall have a maximum AOS of 0.30 mm (#50 sieve). The minimum AOS for all filter fabrics is 0.15 mm (#100 sieve).
- The minimum permitivity is 0.05 $sec^{-1}$.
- The minimum grab tensile strength in machine and cross machine directions shall be 200 lbs. (900 N) for fabric that is unsupported between posts and 100 lbs. (450 N) for fabric that is supported with a wire or polymeric mesh. The maximum grab failure strain in machine direction shall be 30 percent for fabric that is unsupported between posts. There is no strain requirement for fabric that is supported between posts.
- The filter fabric shall have a service life of six months. To achieve this, the minimum strength retained after 500 hours in a weatherometer must be 70 percent.
- Fence backup support, if used, shall consist of 14 gage steel wire with a mesh spacing of 2 inches (50 mm) or a prefabricated polymeric mesh with support capabilities equivalent to the wire fencing. The polymeric mesh must be as resistant to ultraviolet radiation as the fabric that it supports.
- 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, they can be formed by folding the fabric from each section over on itself several times and firmly attaching the folded seam to the fence post. Any joints must be able to with stand the expected loading on the fabric.
- Support posts shall be spaced a maximum of 8 feet (2.4 m) apart and driven securely into the ground a minimum of 24 inches (600 mm) where physically possible. Support posts shall be either wood or steel. Wood posts shall have minimum dimensions of 1.5 inches (35 mm) by 1.5 inches (35 mm). Steel posts shall consist of either size No. 6 or larger rebar or ASTM A 120 steel pipe with a minimum diameter of 0.75 inches (20 mm).
- The minimum height of the filter fabric above the ground line is 30 inches (75 mm).
- A trench shall be excavated approximately 4 inches (100 mm) wide and 6 inches (150 mm) deep along the line of posts and upslope from the fence line. A minimum of 6 inches (150 mm) of filter fabric must extend into the trench. After placing the fabric, the trench must be backfilled and the soil tamped. When wire or plastic mesh support is used, the mesh shall be buried in the trench a minimum of 3 inches (75 mm).

- The fabric shall be attached on the upslope side of the posts and support system with staples, wire, or in accordance with the manufacturer's recommendations. Silt fence backup support for the material in the form of a wire or plastic grid is optional, depending on the properties of the material selected. If wire or plastic backup grid is used, the grid material shall be fastened securely to the upslope of the posts with the fabric being upslope of the grid backup support.
- Filter fences should only be placed where they will be beneficial, along the downhill end of an exposed slope where erosion is a potential problem. The ends of the fence shall turn upslope (run parallel to the slope) for a distance great enough to allow 30 inches (750 mm) of ponding depth behind the fence line that is perpendicular to the slope. For exposed slopes immediately adjacent to sensitive receiving waters, two rows of filter fence may be required to provide additional protection.
- Filter fences shall be removed when the upslope area has been permanently stabilized. Retained sediment must be removed and properly disposed of, or mulched and seeded.

### *Maintenance*

- Inspect immediately after heavy rainfall, and regularly during prolonged rainfall. Repair as necessary.
- Sediment must be removed when it reaches approximately $^{1}/_{3}$ 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.

## 8-2.4.2 BMP E3.15 — Straw Bale Barrier

Code: (STB) Symbol:

### *Definition*

A temporary sediment barrier consisting of a row of entrenched and anchored straw bales. Straw bale barriers intercept and detain small amounts of sediment from disturbed areas to prevent sediment from leaving the site.

### *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 (1,000 $m^2$ per 30 m) of barrier length, the maximum slope length behind the barrier is 200 feet (61 m), 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 (0.8 Ha).
- Where effectiveness is required for less than three months.

### *Advantages*

- When properly used, straw bale barriers are an inexpensive method of sediment control.

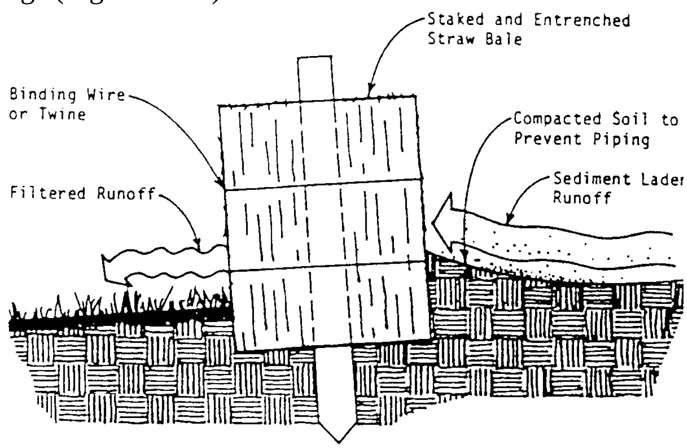
### *Disadvantages/Problems*

- 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.

### *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 8-2.5).




**Cross-Section of a Properly Installed Straw Bale Barrier**

***Figure 8-2.5***

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 (100 mm). 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 back-filled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to 4 inches (100 mm) against the uphill side of the barrier (Figure 8-2.5).

4. Each bale shall be securely anchored by at least two 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.
  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 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 after each runoff-producing rainfall and regularly 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 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 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.

### 8-2.4.3 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 clearing and grubbing on-site. Brush barriers intercept and retain sediment from disturbed areas.

#### Conditions Where Practice Applies

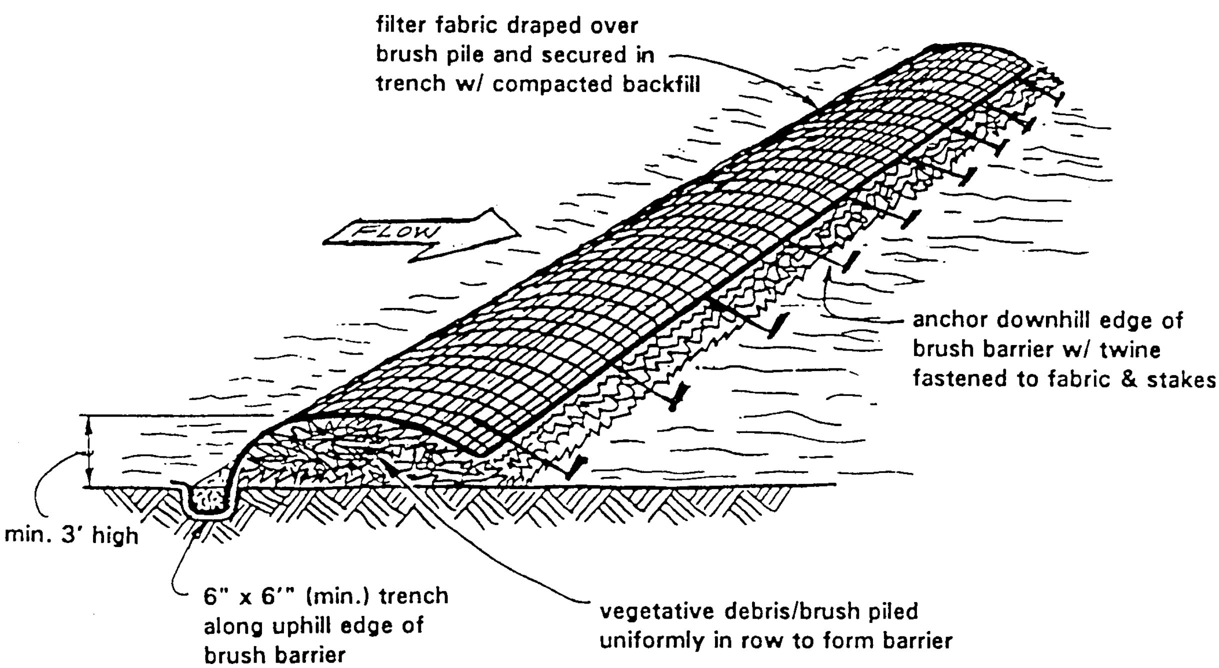
- Below disturbed areas of less than one quarter acre that are subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier.

#### Advantages

- Brush barriers can often be constructed using materials found on-site.

#### Design Criteria

- Height 3 feet (1 m) (minimum) to 5 feet (1.5 m) (maximum).
- Width 5 feet (1.5 m) at base (minimum) to 15 feet (4.5 m) (maximum).
- Filter fence anchored over the berm will enhance its filtration capacity.
- Further design details are illustrated in Figure 8-2.6.




**Brush Barrier**

*Figure 8-2.6*

### 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.

## 8-2.4.4 BMP E3.25 — Gravel Filter Berm

Code: (GFB) Symbol: GFB

### Definition

A gravel berm constructed on traffic areas within a construction site. Gravel filter berms retain sediment from traffic areas.

### Conditions Where Practice Applies

- Where a temporary measure is needed to retain sediment 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 to 3 inches (75 mm) in size, washed, well-graded gravel or crushed rock with less than 5 percent fines.
- Spacing of berms:

  Every 300 feet (90 m) on slopes less than 5 percent.

  Every 200 feet (60 m) on slopes between 5 and 10 percent.

  Every 100 feet (30 m) on slopes greater than 10 percent.
- Berm dimensions:

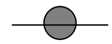
  1 foot (300 mm) high with 3:1 side slopes

  8 linear feet (2.4 m) per 1 cfs (0.028 $m^3$/sec) runoff based on the 10-year storm.

### Maintenance

- Regular inspection is required; sediment shall be removed and filter material replaced as needed.

## 8-2.4.5 BMP E3.30 — Storm Drain Inlet Protection

Code: IP Symbol: 

### *Definition*

A sediment filter or an excavated impounding area around a storm drain, drop inlet, or curb inlet. This prevents 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 (0.40 Ha)] flat area (less than 5 percent slope). 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 (0.014 $m^3$/sec)] are expected.

  c. Gravel and Wire Mesh Filter — Applicable where flows greater than 0.5 cfs (0.014 $m^3$/sec) are expected and construction traffic may occur over the inlet.

### *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.

### *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 (300 to 600 mm) in depth, with 2:1 side slopes.
- Installation procedure for filter fabric fence:

  a. Place 2-inch by 2-inch (50 by 50 mm) wooden stakes around the perimeter of the inlet a maximum of 3 feet (1 m) apart and drive them into the ground. The stakes must be at least 3 feet (1 m) long.

  b. Excavate a trench approximately 4 inches (100 mm) wide and 6 inches (150 mm) 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 6 inches of the fabric extends out and can be formed into the trench. Use heavy-duty wire staples at least $^1/_2$ inch (12 mm) in length.

d. Backfill the trench with $^3/_4$ inch (20 mm) 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 (300 mm) beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with $^1/_2$-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 (100 mm), 8 inches (200 mm), and 12 inches (300 mm) wide. The row of blocks should be at least 12 inches (300 mm), but no greater than 24 inches (600 mm) high.

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 $^3/_4$- to 3-inch (20 to 75 mm) 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 (300 mm) beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with $^1/_2$-inch (12 mm) 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 (450 mm) on all sides. Place 3-inch (75 mm) gravel over the filter fabric/wire mesh. The depth of the gravel should be at least 12 inches (300 mm) over the entire inlet opening.

## 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 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.

### 8-2.4.6 BMP E3.35 — Sediment Trap

Code: (ST) Symbol:

#### Definition

A small temporary ponding area, with a gravel outlet, formed by excavation and/or by constructing an earthen embankment. A sediment trap is used to collect and store sediment from sites cleared and/or graded during construction. The trap is a temporary measure (with a design life of approximately six 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 construction sites where the tributary drainage area is less than 3 acres (1.2 Ha).

#### 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

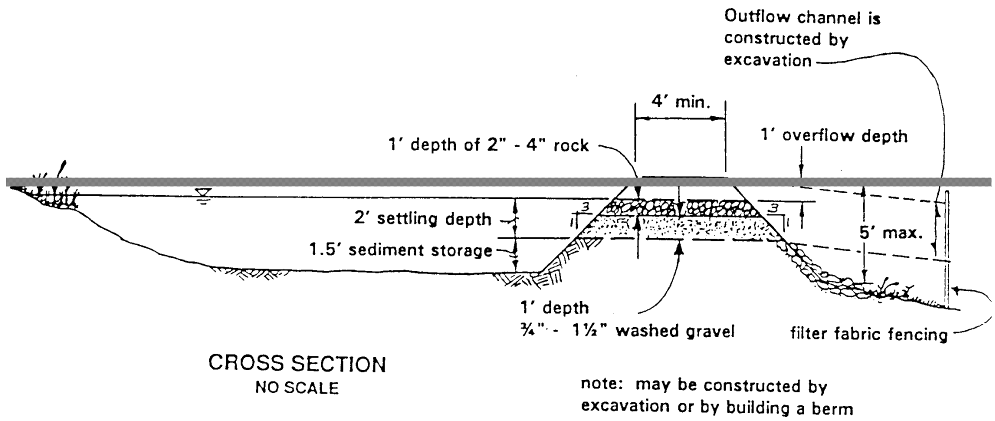
- Serves only limited areas.
- Sediment traps (and ponds, see BMP E3.40) are only practically effective in removing sediment down to about the medium silt size fraction. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated, emphasizing the need to control erosion to the maximum extent first.

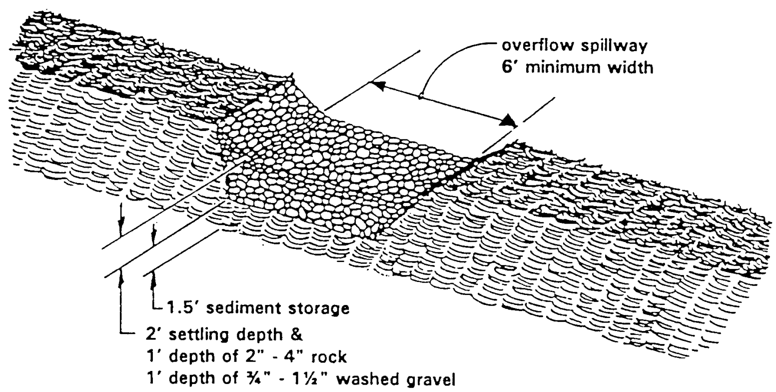
#### Design Criteria

The sediment trap may be formed completely by excavation or by construction of a compacted embankment. It shall have a 1.5 foot (0.45 m) 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 Figure 8-2.7 for details.
- The temporary sediment trap volume can be found by computing the detention volume required for the 2-year storm using one of the approved methods found in Chapter 3. Side slopes should not exceed 3:1. After

determining the necessary volume, size the trap by adding an additional $1^1/_2$ feet (450 mm) for sediment accumulation to the volume computed using the 2-year storm.




**Sediment Trap**

***Figure 8-2.7***

- To complete the design of the temporary sediment trap:
- 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 the surface area at the interface between the settling zone and sediment storage volume.
- Determine the bottom and top surface area of the sediment storage volume to be provided using $1^1/_2$ feet (450 mm) in depth for sediment storage and 3:1 side slope from the bottom of the trap. Note the trap bottom should be level.
- 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.

#### *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 (300 mm) in depth [assuming a $1^1/_2$ foot (450 m) sediment accumulation depth]. Regular inspections should be done and additional inspections made after each large runoff-producing storm.
- 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.

### 8-2.4.7 BMP E3.40 — Temporary Sediment Pond

Code: (SB)

#### *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. It is used to collect and store sediment from sites cleared and/or graded during construction or for extended periods of time before re-establishment of permanent vegetation and/or construction of structures. The basin is a temporary measure (with a design life less than one 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 (4 Ha).

#### *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.

#### *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. 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 (25-mm) diameter dewatering holes located at the top of the sediment storage volume on opposite sides of the riser pipe. 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 (1 m) in depth] plus a settling volume of not less than 2 feet (600 mm) 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 (600 mm) 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 (1.2 m).

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 3.

   $V_{sed}$ = the settling velocity of the design soil particle. The design particle chosen is medium silt (0.02 mm). This has a settling velocity ($V_{sed}$) of 0.00096 ft/sec ($2.9 \times 10^{-4}$ m/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. Note that choosing a $V_{sed}$ of 0.00096 ft/sec ($2.9 \times 10^{-4}$ m/sec) equates to a surface area (SA) of 1,250 square feet per cfs (4,100 $m^2$ per $m^3$/sec) of inflow.

b. Settling depth (SD) should not be less than 2 feet (600 mm) 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 (1 m) 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 maximum) as necessary to obtain the settling zone volume at 2-foot (600 mm) depth minimum or as determined above, 4-foot (1.2-m) maximum.

c. 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. 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 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.

## 8-3 Water Quality BMPs

### *8-3.1 BMP RB.05 — Biofiltration Swale*

#### *Definition*

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration swale is a sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to BMPs designed for that purpose.

#### *General Criteria*

1. The swale should have a length of 200 feet (61.0 m). The maximum bottom width is 10 feet (3.1 m). The depth of flow must not exceed 4 inches (100 mm) during the 6-month storm.
2. The channel slope should be at least 1 percent and no greater than 5 percent.
3. The swale can be sized as both a treatment facility for the 6-month storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located “on-line.”
4. The ideal cross-section of the swale should be a trapezoid. The side slopes should be no steeper than 3:1.
5. Roadside ditches should be regarded as significant potential biofiltration sites and should be utilized for this purpose whenever possible.

6. If flow is to be introduced through curb cuts, place pavement slightly above the biofilter elevation. Curb cuts should be at least 12 inches (300 mm) wide to prevent clogging.
7. Install low-flow biofiltration swales within ponds where sufficient land does not exist for both.
8. Biofilters must be vegetated in order to provide adequate treatment of runoff.
9. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses. Consult the district or headquarters Landscape Section for specific vegetation selection recommendations.
10. Biofilters should generally not receive construction-stage runoff. If they do, presettling of sediments should be provided (see BMPs E3.35 and E3.40). Such biofilters should be evaluated for the need to remove sediments and restore vegetation following construction.
11. If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

### Design Procedure

1. Determine the peak flow rate to the biofilter from the 6-month 24 hour design storm.
2. Determine the slope of the biofilter. This will be somewhat dependent on where the biofilter is placed. The slope should be at least 1 percent and shall be no steeper than 5 percent. When slopes less than 2 percent are used, the need for underdrainage must be evaluated.
3. Select a swale shape. Trapezoidal is the most desirable shape; however, rectangular and triangular shapes can be used. The remainder of the design process assumes that a trapezoidal shape has been selected.
4. Use Manning's Equation to estimate the bottom width of the biofilter. Manning's Equation for English units is as follows:

$$Q = (1.486\ A\ R^{0.667}\ S^{0.5}) / n$$

Where: Q = flow (cfs)

A = cross sectional area of flow (ft$^2$)

R = hydraulic radius of flow cross section (ft)

S = longitudinal slope of biofilter (ft/ft)

n = Manning's roughness coefficient = 0.20 for typical biofilter

For a trapezoid, this equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow the hydraulic radius can be set equal to the depth of flow. Using this assumption, the equation can be altered to:

$$b = ((0.135\ Q) / (y^{1.667}\ S^{0.5}))-zy$$

Where: y = depth of flow

z = the side slope of the biofilter in the form of z:1

Typically the depth of flow is selected to be 4 inches (100 mm). It can be set lower but doing so will increase the bottom width. Sometimes when the flowrate is very low the equation listed above will generate a negative value for b. Since it is not possible to have a negative bottom width, the bottom width should be set to 1 foot when this occurs.

Biofilters are limited to a maximum bottom width of 10 feet. If the required bottom width is greater than 10 feet, parallel biofilters should be used in conjunction with a device that splits the flow and directs the proper amount to each biofilter.

5. Calculate the cross sectional area of flow for the given channel using the calculated bottom width and the selected side slopes and depth.

6. Calculate the velocity of flow in the channel using:

$$V = Q / A$$

   If V is less than or equal to 1 ft/sec, the biofilter will function correctly with the selected bottom width. Proceed to design step 7.

   If V is greater than 1 ft/sec, the biofilter will not function correctly. Increase the bottom width, recalculate the depth using Manning's Equation and return to design step 5.

7. Select a location where a biofilter with the calculated width and a length of 200 feet (61 m) will fit. If a length of 200 feet (61 m) is not possible, the width of the biofilter must be increased so that the area of the biofilter is the same as if a 200 foot (61 m) length had been used.

8. Select a vegetation cover suitable for the site. Refer to the district or headquarters landscape architect or the headquarters horticulturist.

9. Determine the peak flow rate to the biofilter during the 100-year 24-hour storm. Using Manning's Equation, find the depth of flow (typically n = 0.04 during the 100-year flow). The depth of the channel shall be 1 foot (300 mm) deeper than the depth of flow.

### *Construction and Maintenance Criteria*

1. Groomed biofilters planted in grasses shall be mowed during the summer to promote growth and pollutant uptake.

2. Remove sediments during summer months when they build up to 4 inches (100 mm) at any spot, cover biofilter vegetation, or otherwise interfere with biofilter operation. If the removal equipment leaves bare spots, reseed those spots.

3. 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.

4. Clean curb cuts when soil and vegetation buildup interferes with flow introduction.

5. Remove litter to keep biofilters free of external pollution.

## 8-3.2 BMP RB.10T — Vegetative Filter Strip

### Definition

A vegetative filter strip is a facility that is designed to provide stormwater quality treatment of conventional pollutants but not nutrients. This BMP will not provide stormwater quantity control. The primary use of vegetative filter strips will be along rural roadways where sheet flow from the roadway will pass through the filter strip before entering a conveyance system or a quantity control facility. The vegetative filter strip is still in an interim phase of development. This BMP is acceptable for use on any project that meets the General Criteria listed below; however, the General Criteria may change in the near future as research projects and field tests involving this BMP are completed. Users of this manual that are not associated with WSDOT should contact Michelle Horn of the Department of Ecology's Water Quality Unit to verify the applicability of this BMP before using it in a project.

### General Criteria

1. The width of a filter strip shall be 10 feet (3 m) with a transverse slope between 1 percent and 15 percent.
2. Filter strips may be placed 3 to 4 feet (1 to 1.25 m) from the edge of pavement, to accommodate a vegetation free zone.
3. Once stormwater has been treated by a filter strip, it shall be collected and conveyed to a stormwater quantity BMP.
4. Vegetative filter strips must not receive concentrated flow discharges.
5. A maximum of two lanes can contribute to a filter strip.
6. The roadway ADT is less than 30,000.
7. Vegetative filter strips should not be used on roadways with longitudinal slopes greater than 5 percent because of the difficulty in maintaining the necessary sheet flow conditions.
8. Vegetative filter strips should be constructed after other portions of the project are completed.

### Design Procedure

Provide an area next to the roadway to use as a filter strip. The strip must run the length of the roadway to be treated and have a width of 10 feet (3 m) with a slope between 1 and 15 percent. The flow from the roadway must enter the filter strip as sheet flow.

### Construction and Maintenance Criteria

1. Construct filter strips after completion of the highway project.
2. Groomed filter strips planted in grasses shall be mowed during the summer to promote growth.
3. Inspect filter strips periodically, especially after periods of heavy runoff. Remove sediments and reseed as necessary.

4. Remove litter to keep filter strips free of external pollution and ensure sheet flow through the filter strip.

### 8-3.3 BMP RD.05 — Wet Pond

#### Definition

A wet pond is a facility that treats stormwater for water quality by utilizing a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration. A wet pond may also be designed to provide stormwater quantity control through the use of a "live storage" area above the permanent pool.

#### General Criteria

1. Wet ponds shall be multi-celled with at least two cells, and preferably three. The cells should be approximately equal in size. The first cell should be 3-feet deep in order to effectively trap coarser sediments and reduce turbulence which can resuspend sediments. It should be easily accessible for maintenance purposes. The berm dividing the pond into cells shall have a 5-foot (1.5-m) minimum top width, a top elevation set 1 foot lower than the design water surface, maximum 3:1 side slopes, and a quarry spall and gravel filter "window" between the cells.
2. All facilities shall be a minimum of 20 feet (6 m) from any structure, right of way line, and any vegetative buffer, and 100 feet (30 m) from any septic tank/drain field. All facilities shall be a minimum of 50 feet (15 m) from any steep (greater than 15 percent) slope unless a geotechnical report has indicated that the steep slope will be stable.
3. 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.
4. The pond bottom shall be level to facilitate sedimentation.
5. 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. Slopes should be no steeper than 4H:1V if they are to be mowed.
6. Pond walls may be retaining walls, provided 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.
7. For berm embankments of 6 feet (1.8 m) or less (including 1 foot (300 mm) freeboard), the minimum top width shall be 6 feet (1.8 m) or as recommended by the engineer.
8. The toe of the exterior slope of pond berm embankment must be no closer than 5 feet (1.5 m) from the right of way.
9. The berm embankment shall be constructed in accordance with Section 2-03.3(14)C Method C of WSDOT *Standard Specifications*.

10. A "key" must be excavated that is 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 (300 mm) of excavation into the till).
11. Anti-seepage collars must be placed on outflow pipes in berm embankments impounding water greater than 8 feet (2.5 m) in depth at the design water surface.
12. Exposed earth on the side slopes shall be sodded or seeded with the appropriate seed mixture as soon as is practicable. Establishment of protective vegetative cover shall be ensured with erosion protection and reseeded as necessary.
13. 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.
14. If a wet pond is used during construction, the pond should be cleaned before becoming a permanent erosion control fixture.
15. Detention facility design must take into consideration overflow. 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.
16. 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 should be a basic consideration in design and in determination of first cost.

## Design Procedure

1. Calculate the runoff hydrograph for the 6-month 24-hour design storm (see Chapter 3).
2. The wet pond shall be designed with a permanent pool volume equal to the runoff volume of the 6-month design storm. It is not necessary to vegetate the permanent pool, but establishment of a shallow marsh system can provide additional pollutant removal capabilities.
3. If the wet pond is not to be used for stormwater quantity control, then design an outlet such as a weir or an orifice that will pass the 100-year event through the pond. Place the invert of the outlet at the same elevation as the top of the dead storage volume. The flow leaving the wet pond will discharge either to a large receiving body or to a quantity control BMP.
4. If the wet pond is to be used for quantity control, estimate the volume needed above the dead storage volume. Base the estimate on the difference between the 100-year pre-project and 100-year post-project hydrographs.
5. Route the 2-year, 10-year, and 100-year post-project storms through the pond, one storm event at a time. An outlet device such as a weir or an orifice must be designed to match each release rate. WaterWorks can be used to design an orifice or analyze a given outlet structure.

6. Continue to alter the volume until the allowable release rates are not exceeded. After this is accomplished, the factor of safety must be applied (see Figure 2-6.2) and the design volume must be increased without increasing the depth to establish the final volume.
7. Identify an overflow route to be used in the event that the pond capacity is exceeded. This overflow route should be designed to meet Minimum Requirement No. 2 (Preservation of Natural Drainage Systems).

### Construction and Maintenance Criteria

1. Roads in and around the pond shall be constructed according to standard WSDOT practices and meet the following criteria:
   - Maximum Grade: 15 percent to control structure, 20 percent into pond.
   - Provide 40-foot (12 m) 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 (4.5 m) in width.
   - Manhole and catch basin lids must be at either edge of an access road or pad and be at least 3 feet (1 m) from a property line.
2. 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.
3. Standing water removed during the maintenance operation may require disposal at an approved discharge location.
4. Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be continually monitored in the basin. 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. Contact the district environmental staff for assistance.
5. Remove litter to keep the pond free of external pollution.
6. Check the pond for damage caused by erosion and restabilize areas where there is the potential for continued erosion.
7. Maintain pond shape and depth by removing accumulated sediments that exceed 10 percent of the designed pond depth.

## 8-3.4 BMP RD.06 — Nutrient Control Wet Pond

### Definition

This BMP is similar to BMP RD.05 (Wet Pond) but also includes a shallow marsh area which provides additional removal of nutrients. The shallow marsh area is contained within the permanent pool of water. Stormwater quantity control can also be provided through this BMP by adding a “live storage” area above the permanent pool. This BMP should only be used when discharging to a documented nutrient sensitive water body.

## General Criteria

1. Wet ponds shall be multi-celled with at least two cells, and preferably three. The cells should be approximately equal in size. The first cell should be easily accessible for maintenance purposes. The berm dividing the pond into cells shall have a 5-foot (1.5 m) 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.
2. A portion of the pond shall be constructed as a shallow marsh area. Planting wetland associated plants in the marsh area is not required but is beneficial and recommended.
3. All facilities shall be a minimum of 20 feet (6 m) from any structure, right-of-way line, and any vegetative buffer required by the local government, and 100 feet (30 m) from any septic tank/drainfield. All facilities shall be a minimum of 50 feet (15 m) from any steep (greater than 15 percent) slope unless a geotechnical report has indicated that the steep slope will be stable.
4. 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.
5. The pond bottom shall be level to facilitate sedimentation.
6. 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.
7. Pond walls may be retaining walls, provided 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.
8. For berm embankments of 6 feet (1.8 m) or less, (including 1 foot (300 mm) freeboard), the minimum top width shall be 6 feet (1.8 m) or as recommended by the engineer.
9. The toe of the exterior slope of pond berm embankment must be no closer than 5 feet (1.5 m) from the right-of-way.
10. The berm embankment shall be constructed in accordance with Section 2-03.3(14)C Method C of WSDOT Standard Specifications.
11. A “key” must be excavated that is 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 (300 mm) of excavation into the till).
12. Anti-seepage collars must be placed on outflow pipes in berm embankments impounding water greater than 8 feet (2.5 m) in depth at the design water surface.

13. Exposed earth on the side slopes shall be sodded or seeded with the appropriate seed mixture as soon as is practicable. Establishment of protective vegetative cover shall be ensured with jute mesh or other protection and reseeded as necessary.
14. 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.
15. If a nutrient control wet pond is used during construction, the pond should be cleaned before becoming a permanent erosion control fixture.
16. Detention facility design must take into consideration overflow. 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.
17. 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 should be a basic consideration in design and in determination of first cost.

### *Design Procedure*

1. Calculate the runoff hydrograph for the 6 month 24-hour design storm (See Chapter 3).
2. The nutrient control wet pond shall be designed with a permanent pool volume equal to the runoff volume of the 6-month design storm.
3. The pond surface area to depth relationship shall be such that 30 percent of the pond area has a depth of 0 to 2 feet (0 to 600 mm) and the remainder of the pond has a depth of 2 to 6 feet (600mm to 3.0 m).
4. If the wet pond is not to be used for stormwater quantity control, then design an outlet such as a weir or an orifice that will pass the 100-year event through the pond. Place the invert of the outlet at the same elevation as the top of the dead storage volume. The flow leaving the wet pond will discharge either to a large receiving body or to a quantity control BMP. The pond design is finished after this step is completed.
5. If the wet pond is to be used for quantity control, estimate the volume needed above the dead storage volume. Based the estimate on the difference between the 100-year pre-project and 100-year post-project conditions.
6. Route the 2-year, 10-year, and 100-year post-project storms through the pond, one storm event at a time. An outlet device such as a weir or an orifice must be designed to match each release rate. WaterWorks can be used to design an orifice or analyze a given outlet structure.
7. Continue to alter the pond volume until the allowable release rates are not exceeded. After this is accomplished, the factor of safety must be applied (see Figure 2-6.2) and the design volume must be increased without increasing the depth to establish the final volume.

8. Identify an overflow route to be used in the event that the pond capacity is exceeded. This overflow route should be designed to meet Minimum Requirement No. 2 (Preservation of Natural Drainage Systems).

### Construction and Maintenance Criteria

1. Roads in and around the pond shall be constructed according to standard WSDOT practices and meet the following criteria:
   - Maximum Grade: 15 percent to control structure, 20 percent into pond.
   - Provide 40-foot (12 m) 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 (4.5 m) in width.
   - Manhole and catch basin lids must be at either edge of an access road or pad and be at least 3 feet (1 m) from a property line.
2. 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.
3. If possible, standing water removed during the maintenance operation must be disposed of to a sanitary sewer at an approved discharge location.
4. Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be continually monitored in the basin. 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. Contact the regional environmental staff for assistance.
5. Remove litter to keep the dry pond free of external pollution.
6. Check the pond for damage caused by erosion and restabilize areas where there is the potential for continued erosion.
7. Maintain pond shape and depth by removing accumulated sediments that exceed 10 percent of the designed pond depth.

## 8-3.5 BMP RD.15 — Wet Vault/Tank

### Definition

Wet vaults and tanks are underground storage facilities that treat stormwater for water quality through the use of a permanent pool of water that acts as a settling basin. Wet vaults and tanks can also provide stormwater quantity control by adding a live storage volume above the permanent pool.

### General Criteria

1. Wet vaults/tanks cannot provide the equivalent level of treatment accomplished by wet ponds 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 should only be used when more desirable BMPs are not practicable.
2. Wet vaults/tanks shall be a minimum of 20 feet (6 m) from any structure, property line, NGPE, and any septic tank/drain field. All facilities shall be a minimum of 50 feet (15 m) from any steep slope, unless a geotechnical report has addressed the potential impact on a steep slope.
3. The length-to-width ratio at the design surface area shall be no less than 3:1.
4. The vault shall be divided into two cells using a baffle, with the first cell occupying about 25 percent of the area. The top of the baffle wall must be coincident with the depth of the permanent pool.
5. Design with maintenance in mind. Good maintenance will be crucial to successful use of a vault/tank. 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 cost.

### Design Procedure

1. Route the 6-month 24-hour design storm through the basin to develop a hydrograph.
2. The permanent pool for water quality treatment shall be sized to equal the total volume of the 6-month storm.
3. If the wet vault is to be used for quantity control, estimate the volume needed based on the difference between the 100-year pre-project and 100-year post-project hydrographs.
4. Route the 2-year, 10-year, and 100-year post-project storms through the vault, one storm event at a time. An outlet device such as a weir or an orifice must be designed to match each release rate. WaterWorks can be used to design an orifice or analyze a given outlet structure.
5. Continue to alter the volume until the allowable release rates are not exceeded. After this is accomplished, the factor of safety must be applied (see Figure 2-6.2) and the design volume must be increased without increasing the depth to establish the final volume.
6. An overflow outlet must be provided in the event that the vault/tank capacity is exceeded. This overflow outlet should discharge to the same location as the main outlet.

## Construction and Maintenance Criteria

### *Materials*

1. Vaults

   Minimum 3,000 psi (2.11 ¥ 106 kgs/sq meter) structural reinforced concrete. All construction joints must be provided with water stops.

2. 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.

### *Structural Stability*

1. 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. 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.

2. 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.

3. Buoyancy (Tanks)

   In moderately pervious soils where seasonal ground water may induce flotation, buoyancy tendencies must be balanced by ballasting with 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***

1. Vaults

   Provide one access cover per 50 feet (15 m) of length or width and at least one access cover with ladder to the bottom of the vault per cell. The minimum internal height shall be 7 feet (2 m) and the minimum width shall be 4 feet (1.2 m). The maximum depth to the vault invert shall be 20 feet (6 m).

2. Tanks

   The maximum depth to a tank invert shall be 20 feet (6 m). Spacing between access openings for tanks shall not exceed 100 feet (30 m). 36-inch (0.9 m) minimum diameter CMP riser-type manholes of the same gauge as the tank material may be used for access along the length of the tank and at the up-stream 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. All tank access openings must be readily accessible by maintenance vehicles.

   Debris and sediment should be removed when the accumulated depth is greater than 10 percent of the diameter of the tank/vault. For instance, a 72-inch (1.8 m) storage tank/vault would require cleaning when the depth of sediment reaches 7 inches (180 mm). Contact the Olympia Service Center Maintenance Office for assistance on proper disposal methods.

## 8-3.6 BMP RI.05 — Water Quality Infiltration Pond

### Definition

A water quality infiltration pond is a facility that provides water quality treatment by storing runoff from the 6-month 24-hour storm and infiltrating it into the soil. Treatment is accomplished through particle settling, biological uptake, and filtration. Runoff from larger storms must be routed to a quantity control BMP.

### General Criteria

1. The soil infiltration rate must be greater than 0.5 inches (12 mm) per hour and less than 2.5 inches (65 mm) per hour.
2. The pond shall infiltrate all of the runoff from the 6-month storm within 24-hours after precipitation ends.
3. There shall be at least 3 feet (1 m) of soil from the bottom of the pond to the highest ground water level and the highest impermeable layer.
4. A settling basin must precede the pond.
5. An emergency overflow weir must be provided.
6. Pond depths are generally from 2 to 6 feet (0.6 to 1.8 m).
7. 1 foot (300 mm) of freeboard above the highest design water level must be provided.
8. Side slopes should be no steeper than 3:1. Side slopes should be no steeper than 4:1 if they are to be mowed.

9. There shall be at least 20 feet (6 m) to any up slope structure foundation and 100 feet (30 m) to any down slope structure. There shall be at least 20 feet (6 m) to any Native Growth Protection Easement.
10. The slope of the floor of the infiltration pond shall be 3 percent or less.

### Design Procedure

1. Select a location. This will be based on the ability to convey flow to the location and the expected soil conditions of the location. The minimum setback distances must also be met.
2. Conduct a soil investigation and determine the infiltration rate. A minimum of one soils log shall be required for each 5,000 square feet (465 square m) of infiltration pond bottom area with no less than three soils logs per pond. Each soils log shall extend a minimum of 3 feet (1 m) in depth below the bottom of the proposed pond, 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. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.

   The soil investigation is required for two purposes:

   a. Collect soil samples so that the infiltration rate, f, can be determined.
   b. Determine the depth of the seasonal high water table and impermeable soil layers.

   The design infiltration rate, fd, will be equal to onehalf the infiltration rate found from the soil textural analysis.

   An alternate method for determining design infiltration rate will be to perform an insitu percolation test at each of the soils log location. The design infiltration rate will be equal to one half of the average measured rate.
3. Calculate the size of the of the settling basin. There are many acceptable ways to design a settling basin. The preferred method is to size a basin using the procedure in BMP E3.40 except that instead of using the peak flow rate from the 10-year storm the peak rate from the 6-month storm is used for the calculations.
4. Calculate the post project 6-month storm hydrograph (see Chapter 3).
5. Estimate a pond size based on the total volume of the runoff for the 6-month storm.
6. Route the hydrograph through the pond. An infiltration pond functions in the same way as a dry pond, except that the only outlet is through infiltration. The outlet flow can be calculated as:

   $$Q_{outlet} = f_d * A_s$$

   Where: $f_d$ = design infiltration rate

   $A_s$ = water surface area of the pond
7. Design a flow splitting device such that all flows larger than the peak flow from the 6-month storm are routed around the settling basin and the infiltration pond. Also provide an emergency overflow outlet for the infiltration pond that

routes any excess flow from the pond into the conveyance system for the larger storm flows.

## *Construction and Maintenance Criteria*

### *Construction*

1. The sequence of various phases of pond construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the pond with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated pond could serve as a temporary sediment trap in order to assist in erosion and sediment control during construction. However, ponds 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 pond with a heavy concentration of fine sediment. This could seriously impair the natural infiltration characteristics of the pond floor. Final grade of an infiltration pond shall not be attained until after its use as a sediment control pond is completed.
2. Specifications for pond construction should state the earliest point in construction progress when storm drainage may be directed to the ponds, 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.
3. Initial pond excavation should be carried to within 1 foot of the final elevation of the pond 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 pond floor. After the final grading is completed, the pond floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.
4. Establishing a healthy stand of vegetation on the pond 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 pond shall also be provided. Removal of accumulated sediment is a problem only at the pond floor. Little maintenance is normally required to maintain the infiltration capacity of side slope areas.

### *Maintenance*

1. When infiltration ponds 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. Once it is determined that the pond is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to an annual basis with additional inspections following the occurrence of a large storm [e.g., approximately 2 inches (50 mm) in 24 hours].

2. The pond should be designed with maintenance in mind. Access should be provided for vehicles to easily maintain the entrance area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.
3. Cleanout frequency of infiltration ponds will depend on whether they are vegetated or nonvegetated and will be a function of their storage capacity, recharge characteristics, volume of inflow, and sediment load.
4. Grass bottoms in infiltration ponds 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 pond 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 pond. Grass planted on pond side slopes will also prevent erosion.
5. Tilling may be necessary to restore the natural infiltration capacity by over-coming the effects of surface compaction, and to control weed growth on the pond floor.
6. 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 pond floor, and prevents invasive weed growth.
7. Seed mixtures should recommended by the district or headquarters landscape architect or the headquarters horticulturist.

## 8-4 Water Quantity BMPs

### *8-4.1 BMP RD.11 — Dry Pond*

#### *Definition*

A dry pond is a facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels. A water quality BMP must precede a dry pond.

#### *General Criteria*

1. Dry pond site selection should consider both the natural topography of the area and right of way boundaries. The planting and preservation of vegetation should be an integral part of the storage facility design.
2. Dry pond design must take into consideration overflow. 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.
3. 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. Slopes should be no steeper than 4H:1V if they are to be mowed.

4. Pond walls may be retaining walls, provided 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.
5. For berm embankments of 6 feet (1.8 m) or less, the minimum top width shall be 6 feet (1.8 m).
6. The toe of the exterior slope of pond embankment must be no closer than 5 feet (1.5 m) from the right of way line.
7. Pond berm embankment must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots and other organic debris.
8. 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 (300 mm) of excavation into the till).
9. The berm embankment shall be constructed in accordance with Section 2-03.3(14)C Method C of WSDOT *Standard Specifications*.
10. Anti-seepage collars must be placed on outflow pipes in berm embankments impounding water greater than 8 feet (2.5 m) in depth at the design water surface.
11. Exposed earth on the pond bottom and side slopes shall be sodded or seeded with the appropriate seed mixture as soon as is practicable. Establishment of protective vegetative cover shall be ensured with jute mesh or other protection and reseeded as necessary.
12. The dry pond must be cleaned before becoming a permanent BMP if it was used as a retention pond during the construction stage.
13. Design with maintenance in mind. Good maintenance will be crucial to successful use of the pond.

### Design Criteria

1. Calculate the pre-project and post project hydrographs for the 2-year, 10-year, and 100-year storms (see Chapter 3).
2. Estimate the initial pond size based on the difference between the 100-year pre-project and 100-year post-project hydographs.
3. Route the 2-year, 10-year, and 100-year post-project storms through the pond, one storm event at a time. An outlet device such as a weir or an orifice must be designed to match each release rate. WaterWorks can be used to design an orifice or analyze a given outlet structure.
4. Continue to alter the volume until the allowable release rates are not exceeded. After this is accomplished, the factor of safety must be applied (see Figure 2-6.2) and the design volume must be increased without increasing the depth to establish the final volume.

5. Identify an overflow route to be used in the event that the pond capacity is exceeded. This overflow route should be designed to meet Minimum Requirement No. 2 (Preservation of Natural Drainage Systems).

### *Construction and Maintenance Criteria*

1. Roads in and around the dry pond shall be constructed according to standard WSDOT practices and meet the following criteria:
   - Maximum Grade: 15 percent to control structure, 20 percent into pond.
   - Provide 40-foot (12-m) 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 (4.5 m) in width.
   - Manhole and catch basin lids must be at either edge of an access road or pad and be at least 3 feet (1 m) from a property line.
2. 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.
3. Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be continually monitored in the basin. 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.
4. Remove litter to keep the dry pond free of external pollution.
5. Check the pond for damage caused by erosion and restabilize areas where there is the potential for continued erosion.
6. Maintain pond shape and depth by removing accumulated sediments that exceed 10 percent of the designed pond depth.

## *8-4.2 BMP RD.20 — Dry Vault/Tank*

### *Definition*

A dry vault/tank is a facility that treats stormwater for water quantity control by detaining runoff and then releasing reduced flows at established standards. Dry vaults/tanks are not to be used for stormwater quality treatment purposes because of their limited pollution removal capabilities. Dry vaults/tanks must always be preceded by a BMP which has been sized to treat the 6-month storm. Because dry vault/tanks are underground, they are more difficult to inspect and maintain. Vaults/tanks shall be permitted for use only on small sites, and then only after it has been demonstrated that more desirable BMPs are not practicable.

### General Criteria

1. This BMP must be used in conjunction with a BMP that will fully treat runoff from the 6-month storm.
2. Dry vaults/tanks shall be a minimum of 20 feet (6 m) from any structure, right of way line, Native Growth Protection Easement (NGPE), and from any septic tank/drain field. All facilities shall be a minimum of 50 feet (15 m) from any steep slope. A geotechnical report must address the potential impact on a steep slope.
3. Design with maintenance in mind. Good maintenance will be crucial to successful use of a vault/tank. 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.

### Design Procedure

1. Calculate the existing condition and post project hydrographs for the 2-year, 10-year, and 100-year storms (see Chapter 3).
2. Estimate the initial pond size based on the difference between the 100-year pre-project and 100-year post-project hydrographs.
3. Route the 2-year, 10-year, and 100-year post-project storms through the vault, one storm event at a time. An outlet device such as a weir or an orifice must be designed to match each release rate. WaterWorks can be used to design an orifice or analyze a given outlet structure.
4. Continue to alter the volume until the allowable release rates are not exceeded. After this is accomplished, the factor of safety must be applied (see Figure 2-6.2) and the design volume must be increased without increasing the depth to establish the final volume.
5. An overflow outlet must be provided in the event that the vault/tank capacity is exceeded. This overflow outlet should discharge to the same location as the main outlet.

### Construction and Maintenance Criteria

#### *Materials*

1. Vaults

   Minimum 3,000 psi (2.11x106 kgs/sq meter) structural reinforced concrete. All construction joints must be provided with water stops.

2. 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.

***Structural Stability***

1. 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. 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.

2. 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.

3. Buoyancy (Tanks)

   In moderately pervious soils where seasonal ground water may induce flotation, buoyancy tendencies must be balanced by ballasting with 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***

1. Vaults

   Provide one access cover per 50 feet (15 m) of length or width and at least one access cover with ladder to the bottom of the vault per cell. The minimum internal height shall be 7 feet (2 m) and the minimum width shall be 4 feet (1.2 m). The maximum depth to the vault invert shall be 20 feet (6 m).

2. Tanks

   The maximum depth to a tank invert shall be 20 feet (6 m). Spacing between access openings for tanks shall not exceed 100 feet (30 m). 36-inch (1-m) minimum diameter CMP riser-type manholes of the same gauge as the tank material may be used for access along the length of the tank and at the up-stream 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. All tank access openings must be readily accessible by maintenance vehicles.

Debris and sediment should be removed when the accumulated depth is greater than 10 percent of the diameter of the tank/vault. For instance, a 72-inch (1.8-m) storage tank/vault would require cleaning when the depth of sediment reaches 7 inches (180 mm). Contact the Olympia Service Center Maintenance Office for assistance on proper disposal methods.

## 8-4.3 BMP RI.06 — Infiltration Pond

### Definition

An infiltration pond is a facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

### General Criteria

1. The soil infiltration rate shall be at least 6 inches (150 mm) per hour.
2. The pond shall be able to infiltrate the 10-year storm out of the pond within 24 hours after precipitation has ended and the 100-year storm within 48 hours after precipitation has ended.
3. There shall be at least 3 feet (1 m) of soil from the bottom of the pond to the highest ground water level and the highest impermeable layer.
4. Pond depths are generally from 2 to 6 feet (0.6 to 1.8 m).
5. There shall be at least 20 feet (6 m) to any up slope structure foundation and 100 feet (30 m) to any down slope structure. There shall be at least 20 feet (6 m) to any NGPE.
6. The slope of the floor of the infiltration pond shall be 3 percent or less.

### Design Procedure

1. Select a location. This will be based on the ability to convey flow to the location and the expected soil conditions of the location. The minimum setback distances must also be met.
2. Conduct a soil investigation and determine the infiltration rate. A minimum of one soils log shall be required for each 5,000 square feet (465 square m) of infiltration pond bottom area with no less than three soils logs per pond. Each soils log shall extend a minimum of 3 feet (1 m) in depth below the bottom of the proposed pond, 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. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.

   The soil investigation is required for two purposes:

   a. Collect soil samples so that the infiltration rate, f, can be determined.
   b. Determine the depth of the seasonal high water table and impermeable soil layers.

   The design infiltration rate, $f_d$, will be equal to one half the infiltration rate found from the soil textural analysis.

An alternate method for determining design infiltration rate will be to perform an in-situ percolation test at each of the soils log location. The design infiltration rate will be equal to one half of the average measured rate.

3. Calculate the postproject 100-year storm hydrograph (see Chapter 3).
4. Estimate a pond size based on the total volume of the runoff for the 100-year storm.
5. Route the hydrograph through the pond. An infiltration pond functions in the same way as a dry pond, except that the only outlet is through infiltration. The outlet flow can be calculated as:

$$Q_{outlet} = f_d * A_s$$

Where: $f_d$ = design infiltration rate

$A_s$ = water surface area of the pond

6. Rearrange the pond configuration until the volume of the pond is not exceeded during the 100-year design storm. The pond must drain the 100-year design storm within 48 hours after the precipitation has ended.
7. Identify an overflow route to be used in the event that the pond capacity is exceeded. This overflow route should be designed to meet Minimum Requirement No. 2 (Preservation of Natural Drainage Systems).
8. The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas shall be stabilized and planted in accordance with Minimum Requirement No. 1 (Erosion and Sediment Control).

## *Construction and Maintenance Criteria*

### *Construction*

1. The sequence of various phases of pond construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the pond with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated pond could serve as a temporary sediment trap in order to assist in erosion and sediment control during construction. However, ponds 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 pond with a heavy concentration of fine sediment. This could seriously impair the natural infiltration characteristics of the pond floor. Final grade of an infiltration pond shall not be attained until after its use as a sediment control pond is completed.
2. Specifications for pond construction should state the earliest point in construction progress when storm drainage may be directed to the ponds, 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.
3. Initial pond excavation should be carried to within 1 foot of the final elevation of the pond 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 pond floor. After the final grading is completed, the pond floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

4. Establishing a healthy stand of vegetation on the pond 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 pond shall also be provided. Removal of accumulated sediment is a problem only at the pond floor. Little maintenance is normally required to maintain the infiltration capacity of side slope areas.

***Maintenance***

1. When infiltration ponds 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. Once it is determined that the pond is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to an annual basis with additional inspections following the occurrence of a large storm [e.g., approximately 2 inches (50 mm) in 24 hours].
2. The pond should be designed with maintenance in mind. Access should be provided for vehicles to easily maintain the entrance area and not disturb vegetation, or resuspend sediment any more than is absolutely necessary.
3. Cleanout frequency of infiltration ponds will depend on whether they are vegetated or nonvegetated and will be a function of their storage capacity, recharge characteristics, volume of inflow, and sediment load.
4. Grass bottoms in infiltration ponds 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 pond 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 pond. Grass planted on pond side slopes will also prevent erosion.
5. Tilling may be necessary to restore the natural infiltration capacity by over-coming the effects of surface compaction, and to control weed growth on the pond floor.
6. 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 pond floor, and prevents invasive weed growth.
7. Seed mixtures should recommended by the district or headquarters landscape architect or the headquarters horticulturist.

| | | |
|---|---|---|
| AOS | = | Apparent Opening Size |
| APWA | = | American Public Works Association |
| BMP | = | Best Management Practice |
| DOE | = | Department of Ecology |
| EPA | = | Environmental Protection Agency |
| HPA | = | Hydraulic Project Approval |
| IPM | = | Integrated Pest Management |
| NGPE | = | Native Growth Protection Easement |
| SA | = | Surface Area |
| SBUH | = | Santa Barbara Urban Hydrograph |
| SCS | = | Soil Conservation Service |
| SD | = | Settling Depth |
| SSP | = | Stormwater Site Plan |
| TESC | = | Temporary Erosion and Sediment Control |
| TSS | = | Total Suspended Solids |
| WAC | = | Washington Administrative Code |
| WSDOT | = | Washinton State Department of Transportation |

*P3:HRM1*

# Conversion Factors

1 inch = 25.4 millimeters

1 foot = 0.3048 meters
1 yard = 0.9144 meters

1 mile = 1609 meters
1 mile = 1.609 kilometers

1 acre = 0.4047 hectare (Ha)
1 acre = 4047 square meters

1 square foot = 0.0929 sq meters
1 square yard = 0.8361 sq meters

1 cubic foot = 0.02832 cubic meters
1 cubic foot = 7.481 gallons

1 cubic yard = 0.7645 cubic meters
1 cubic yard = 27 cubic feet
1 cubic yard = 202 gallons

1 gallon = 3.785 liters
1 cubic meter = 1000 liters

1 pound = 0.4535 kilograms
1 pound/sq inch = 6.89 kilopascals

1 short ton = 2000 pounds
1 short ton = 907.18 kilograms
1 short ton = 0.9078 metric tons

1 metric ton = 2205 pounds
1 metric ton = 1000 kilograms

*P3:HRM1*

**Adjacent Steep Slope** — A slope with a gradient of 15 percent or steeper within 500 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.

**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.

**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 1 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).

**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.

**Best Management Practice (BMP)** — Physical, structural, and/or managerial practices that, when used singly or in combination, reduce the downstream quality and quantity impacts of stormwater.

**Biofiltration** — The simultaneous process of filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater that takes place when runoff flows over and through vegetated areas.

**Biofiltration Swale** — A sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to BMPs designed for that purpose.

**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.

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

**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.

**CN** — Soil Conservation Service's Curve Number. This number describes the runoff characteristics of a particular type of soil.

**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.

**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.

**Clay Lens** — A naturally occurring, localized area of clay which acts as an impermeable layer to runoff infiltration.

**Closed Depression** — An area which is low-lying 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.

**Constructed Wetland** — A wetland that is created on a site that previously was not a wetland. This wetland is designed specifically to remove pollutants from stormwater runoff.

**Conventional Pollutants** — Contaminants (other than nutrients) such as sediment, oil, and vehicle fluids.

**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.

**Created Wetland** — A wetland that is created on a site that previously was not a wetland. This wetland is created to replace wetlands that were unavoidably destroyed during design and construction of a project. This wetland cannot be used for treatment of stormwater runoff.

**Dead Storage** — The permanent pool volume located below the out structure of a storage device. Dead storage provides water quality treatment but does not provide water quantity treatment.

**Depression Storage** — The amount of precipitation that is trapped in depressions on the surface of the ground.

**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.

**Detention** — The storage and subsequent release of excess stormwater runoff from a site.

**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).

**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.

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

**Drainage Basin** — A geographic and hydrologic sub-unit 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 Divide** — 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.

**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, Soil** — The removal of water from a soil.

**Dry Pond** — A facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels.

**Dry Vault/Tank** — A facility that treats stormwater for water quantity control by detaining runoff in underground storage units and then releases reduced flows at established standards.

**Emergency Spillway** — A channel used to safely convey flood discharges in excess of the capacity of the principal outlet.

**Energy Dissipater** — 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.

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

**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.

**Erosion and Sediment Control** — Any temporary or permanent measures taken to reduce erosion, control siltation and sedimentation, and ensure that sediment-laden water does not leave a 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.

**Existing Site Conditions** — The conditions (ground cover, slope, drainage patterns) of a site as they existed on the first day that the project entered the design phase. Projects which drain into a sensitive area designated by a federal, state, or local agency may be required to use undisturbed forest conditions for the purposes of calculating runoff characteristics instead of using existing site conditions.

**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.

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

**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 flood plains which are reasonably required to carry and discharge the base flood flow. The portions of the adjoining flood plains 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.

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

**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 (wetlands)** — 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, flood flow alteration, ground water recharge and discharge, water quality improvement, and soil stabilization.

**Gabion** — A rectangular or cylindrical wire mesh cage filled with rock and used as a protecting agent, revetment, etc., against erosion. Soft gabions, often used in stream bank stabilization, are made of geotextiles filled with dirt, in between which cuttings are placed.

**Gage** — Device for registering precipitation, water level, discharge, velocity, pressure, temperature, etc.

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

**Gauge** — A measure of the thickness of metal; e.g., diameter of wire, wall thickness of steel pipe.

**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.

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

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

**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.

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

**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 precipitation versus time.

**Impervious Surface** — A hard surface area which either prevents or retards the entry of water into the soil. Common impervious surfaces include roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled surfaces.

**Infiltration** — 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.

**Infiltration Pond** — A facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

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

**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.

**Land Disturbing Activity** — 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.

**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.

**Level Spreader** — A temporary BMP used to spread stormwater runoff uniformly over the ground surface as sheet flow. The purpose of level spreaders are to prevent concentrated, erosive flows from occurring. Level spreaders will commonly be used at the upsteam end of wider biofilters to ensure sheet flow into the biofilter.

**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.

**Major Storm** — A precipitation event that is larger than the typically largest rainfall for a year.

**Manning's Equation** — An equation used to predict the velocity of water flow in an open channel or pipelines:

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

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 of the channel lining.

**Mass Wasting** — The movement of large volumes of earth material downslope.

**Mean Depth** — 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.

**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:

1. Avoiding the impact altogether by not taking a certain action or part of an action;
2. 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;
3. Rectifying the impact by repairing, rehabilitating or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
5. Compensation for the impact by replacing, enhancing, or providing substitute resources or environments.

**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.

**NGVD** — National Geodetic Vertical Datum

**National Pollutant Discharge Elimination System (NPDES)** — The part of the federal Clean Water Act, which requires point source discharges 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** — The location of those channels, swales, and other nonmanmade 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** — Includes 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.

**New Impervious Area** — The impervious area that is being created by the project.

**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.

**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 flow.

**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.

**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.

**Permeability Rate** — The rate at which water will move through a saturated soil.

**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.

**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.

**Practicable** — Available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes.

**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.

**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.

**Rare, Threatened, or Endangered Species** — Plant or animal species that are regionally 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.

**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.

**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.

**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).

**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.

**SBUH** — Santa Barbara Urban Hydrograph Method. An event-based hydrographic method of analysis used to determine stormwater runoff from a site.

**SCS** — Soil Conservation Service, U.S. Department of Agriculture.

**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.

**Settleable Solids** — Those suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.

**Sheetflow** — Runoff which flows over the ground surface as a thin, even layer, not concentrated in a channel.

**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.

**Soil Group** — 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 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.

**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.

**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.

**Steep Slope** — Slopes of 40 percent gradient or steeper.

**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.

**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 Quality** — A term used to describe the chemical, physical, and biological characteristics of stormwater.

**Stormwater Quantity** — A term used to describe the volume characteristics of stormwater.

**Stormwater Site Plan** — A plan which shows the measures that will be taken during and after project construction to provide erosion and sediment control and stormwater control.

**Stream Gaging** — The quantitative determination of stream flow using gages, current meters, weirs, or other measuring instruments at selected locations. See gaging station.

**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.

**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.

**Subgrade** — A layer of stone or soil used as the underlying base for a BMP.

**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.

**TESC** — Temporary Erosion and Sediment Control (Plan).

**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 existing ground slope; or 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 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.

**Total Suspended Solids** — The entire amount of organic and inorganic particles dispersed in water.

**Travel Time** — The estimated time for surface water to flow between two points of interest.

**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.

**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.

**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.

**Vactor Waste** — The waste material that is found in the bottom of a catch basin.

**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.

**Vegetative Filter Strip** — A facility that is designed to provide stormwater quality treatment of conventional pollutants but not nutrients through the process of biofiltration.

**Water Quality BMP** — A BMP specifically designed for pollutant removal.

**Water Quality Design Storm** — The 6-month recurrence interval 24-hour duration storm event.

**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 Quantity BMP** — A BMP specifically designed to reduce the peak rate of stormwater runoff.

**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.

**Wet Pond** — A facility that treats stormwater for water quality by utilizing a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration.

**Wet Vaults/Tanks** — Underground storage facilities that treat stormwater for water quality through the use of a permanent pool of water that acts as a settling basin.

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