Stormwater Management

FOR EASTERN WASHINGTON

DRAFT

Stormwater Management Manual for Eastern Washington

Foreword, Chapter 1 – Introduction, Glossary
Chapter 2 – Core Elements for New Development and Redevelopment
Chapter 3 – Preparation of Stormwater Site Plans
Chapter 4 – Hydrologic Analysis and Design

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

September 2002
Publication Number 02-10-040A

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Water Quality Program

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Foreword

Objective of the Manual

Urban development causes significant changes in patterns of stormwater flow from land into receiving waters. Water quality can be affected when runoff carries sediment or other pollutants into streams, wetlands, lakes, and marine waters or into ground water. Stormwater management can help to reduce these effects. Stormwater management involves careful application of site design principles; construction techniques and source controls to prevent sediment and other pollutants from entering surface or ground water; treatment of runoff to reduce pollutants; and flow controls to reduce the impact of altered hydrology.

The objective of this Manual is to provide a commonly accepted set of technical standards and guidance on measures that will manage the quantity and quality of stormwater produced by new development and redevelopment in eastern Washington. The Department of Ecology believes that when the standards and recommendations of this Manual are properly applied, stormwater runoff should generally comply with water quality standards and protect beneficial uses of the receiving waters. Ecology recognizes that individual circumstances vary greatly, and in some instances compliance with the Manual may not ensure compliance with water quality standards.

Background and Development of the Stormwater Management Manual for Eastern Washington

Many guidance manuals for stormwater have been written to address national, regional and local characteristics and management needs. In the state of Washington, several guidance manuals have been prepared, used, and updated to address regional and local requirements. The Washington State Department of Ecology published the Stormwater Management Manual for Western Washington (SWMMWW) in August 2001 as an update to a predecessor manual prepared in 1992. Ecology initially proposed that the Manual could be updated to cover the entire State of Washington. In response to that proposal, representatives of eastern Washington requested that Ecology create a separate Stormwater Management Manual (SWMM) for the eastern portion of the state. Based upon these requests and upon recognition of the significantly different hydrology and geology of eastern Washington, Ecology agreed to create a separate Manual.

Discussions continued at various conferences, meetings and forums to determine the best method to accomplish this effort. A chartering meeting was held in June 2001 to formalize the structure and process for preparing the Manual for eastern Washington. David Evans & Associates, supported by EnviroIssues for meeting facilitation, was hired as a consultant to support the effort. The day long chartering meeting was attended by more than 70 representatives of 17 cities, 11 counties and five Federal and State agencies with interests in stormwater management in eastern Washington.

The chartering meeting established a ten-person Steering Committee with several alternate members to lead the overall effort; it also created two Subcommittees: one for leading the preparation of the Technical Stormwater Manual, and another for leading the preparation of a Model Municipal Stormwater Program. Ecology agreed to fund the hiring of a consultant team to support the development and preparation of the documents and to assist the Steering Committee and Subcommittees with meeting coordination, public involvement and related project tasks. A Request for Qualifications was prepared and submittals were received by four consultant teams in October 2001; the team lead by Tetra Tech/KCM of Spokane was selected.

A project kick-off meeting was held on November 7, 2001 with members of the Steering Committee, Ecology, and the consultant team. The scope of work for the project and a proposed production schedule were prepared; a corresponding budget was prepared and the work began. A stakeholder workshop was held on November 29, 2001 to inform interested parties about the project efforts, the regulatory requirements, the schedule for meetings, and the document production format. After the introductory sessions, concurrent meetings of the Subcommittees were held to begin the development of the Technical Manual and the Model Municipal Stormwater Program. At least once per month (and sometimes twice per month) meetings were held in 2002 to review drafts and updates for each chapter of each document. Periodic presentations were made to address special issues such as: design storm hydrology, subsurface infiltration rates, cost estimates for facilities and stormwater management program needs. These efforts resulted in draft documents submitted for public review beginning in September 2002.

Acknowledgement of Eastern Washington Stormwater Management Steering Committee and Manual Subcommittee Members

Ecology would like to thank the members of the Eastern Washington Stormwater Management Steering Committee for their valuable commitment of time and leadership in leading the process to develop this Manual and also the Model Municipal Stormwater Program for Eastern Washington.

Eastern Washington Stormwater Management Steering Committee	
Ross Dunfee *Steering Committee Chair*	Benton County
Nancy Aldrich *Manual Subcommittee Vice-Chair*	City of Richland
Gary Beeman *Steering Committee Vice-Chair*	WSDOT
Lloyd Brewer *NPDES II Subcommittee Vice-Chair*	City of Spokane – Environmental Programs
Michelle Brich Jack Lynch *(alternate)*	Home Builders Association of Tri-Cities
John Knutson *NPDES II Subcommittee Chair*	Yakima County Public Works
Don McGahuey	City of Wenatchee
Ed Molash *(alternate)*	WSDOT
Walt Olsen *(alternate)*	County Road Administration Board
Jim Seitz *(alternate)*	Association of Washington Cities
Tom Tebb	Department of Ecology – Central Region
Dwane Van Epps	City of Chelan
Steve Worley *Manual Subcommittee Chair*	Spokane County Public Works – Stormwater Utility

Ecology would also like to thank the members of the Eastern Washington Stormwater Management Manual Subcommittee for their valuable commitment of time and energy in helping develop, review and shape the contents of this document.

Eastern Washington Stormwater Management Manual Subcommittee Members

Nancy Aldrich, City of Richland, *Subcommittee Vice-Chair*
Tony Barrett, Washington State Department of Ecology
Gary Beeman, Washington State Department of Transportation
Michele Brich, Home Builders Association of Tri-Cities
Doug Busko, David Evans and Associates
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Steve Hansen, City of Spokane
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John Heinley, Washington State Department of Transportation
Mike Hepp, Washington State Department of Ecology
John Hohman, Spokane County
Steve King, RH2 Engineering; City of Wenatchee
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Steve Plummer, City of Kennewick
Mel Schaefer, MGS Engineering Consultants
Mary Shaleen-Hansen, Washington State Department of Ecology
Jim St. John, David Evans and Associates
Steve Worley, Spokane County, SW Utility, *Subcommittee Chair*

Organization of this Manual

Chapter 1: Introduction
The first chapter explains the need for a technical stormwater management manual; what the Manual is; and how the Manual is intended to be used. It provides the regulatory framework for the Manual.

Chapter 2: Core Elements for New Development and Redevelopment
The second chapter describes the components of a successful stormwater management program. It provides the technical basis for eight specific elements that are required for most projects and describes the conditions under which one or more elements may or may not apply to a particular project.

Chapter 3: Preparation of Stormwater Site Plans
This third chapter provides guidance for preparing the individual site plans upon which each project activity's success in managing stormwater will depend.

Chapter 4: Hydrologic Analysis and Design
This fourth chapter identifies and describes the recommended methodologies for sizing and designing flow control and water quality treatment facilities.

Chapter 5: Detention, Retention and Infiltration Design
This fifth chapter provides specific design information for flow control facilities including detention, retention and infiltration systems.

Chapter 6: Water Quality Facility Design
This sixth chapter provides specific design information for runoff treatment systems, including infiltration treatment facilities and pre-treatment facilities required for UIC rule-authorized subsurface infiltration systems such as drywells.

Chapter 7: Construction Stormwater Pollution Prevention
This seventh chapter identifies and describes best-management practices for preventing pollution, particularly from erosion and sediment runoff, during the construction phase of a project.

Chapter 8: Source Control
The final chapter identifies and describes best-management practices for preventing contamination of stormwater runoff.

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Chapter 1 - Introduction

1.1 Purpose and Scope

The purpose of this Manual is to provide guidance on measures necessary to control the quantity and quality of stormwater runoff from new development and redevelopment projects in order to achieve compliance with State water quality standards and to contribute to the protection of the beneficial uses of the receiving waters. The State water quality standards include: Chapter 173-200 WAC, Water Quality Standards for Ground Waters of the State of Washington; Chapter 173-201A, Water Quality Standards for Surface Waters of the State of Washington; and Chapter 173-204, Sediment Management Standards.

The objective of the Manual is to provide a commonly accepted set of technical standards and guidance for stormwater management. These stormwater management practices, if properly applied at a project site, should protect water quality in the receiving waters. Improperly managed stormwater runoff is one of the principal sources of water quality and habitat degradation in urban areas. A number of existing laws and regulations require that project proponents properly manage stormwater runoff to avoid adverse impacts to water quality and aquatic resources. This Manual is intended to provide technically sound and realistic guidance on how to properly manage stormwater runoff from individual project sites.

The Stormwater Management Manual for Eastern Washington is not a regulation. The Manual does not have any independent regulatory authority and it does not establish new environmental regulatory requirements. The Manual is a guidance document, or tool, which provides local governments, State and Federal agencies, developers and project proponents with stormwater management practices that, if implemented correctly, should result in compliance with existing regulatory requirements for stormwater – including compliance with the federal Clean Water Act and the State Water Pollution Control Act. In cases where ordinances and rules established by local governments – and permits and other authorizations issued by local, State, and Federal authorities – refer to this Manual project proponents should use the Manual or an approved equivalent for specific guidance on how to comply with those ordinances, rules or permit conditions.

This Manual identifies eight Core Elements for managing stormwater runoff from new development and redevelopment projects of all sizes. The Manual also provides guidance for preparation and implementation of stormwater site plans. The requirements of the Core Elements are generally satisfied by the application of Best Management Practices (BMPs) from Chapters 5 through 8 of this Manual. Projects that follow this approach will apply reasonable, technology-based BMPs and water quality-based BMPs to reduce the adverse impacts of stormwater.

This Manual is applicable to all types of land development including residential, commercial and industrial development and roads. A Manual with a more specific focus – such as a Highway Runoff Manual or a stormwater manual adopted by a local jurisdiction – that is equivalent to this Manual may provide more appropriate guidance to the project proponent.

Federal, State, and local permitting authorities with jurisdiction can require more stringent measures that are deemed necessary to meet locally established goals, State water quality standards, or other established natural resource or drainage objectives.

This Manual can also be helpful in identifying options for retrofitting BMPs to existing development. Retrofitting stormwater BMPs into existing developed areas will be necessary in many cases to meet federal Clean Water Act and state Water Pollution Control Act (Chapter 90.48 RCW) requirements. In retrofit situations there frequently are site constraints that make the strict application of these BMPs difficult. In these instances, the BMPs presented here can be modified, using best professional judgement, to provide reasonable improvements in stormwater management.

This Manual is applicable to all of eastern Washington, including the area bounded on the west by the Cascade Mountains crest; on the north by the Canadian border; on the east by the Idaho border; and on the south by the Oregon border. At the southern end of Washington's Cascade Mountain range where the crest does not follow county borders this Manual is applicable to all of Yakima and Klickitat Counties.

Following this Manual is not the only way to properly manage stormwater runoff, but the Manual is intended to provide project proponents, regulatory agencies and others with technically sound stormwater management practices which are presumed to protect water quality and instream habitat – and meet the stated environmental objectives of the regulations described in this chapter. Project proponents always have the option of not following the stormwater management practices in this Manual. However, if a project proponent chooses not to follow the practices in the Manual then it is up to the project proponent to individually demonstrate that the project will not adversely impact water quality by collecting appropriate supporting data to demonstrate that the alternative approach is equally or more protective of water quality and instream habitat than the BMPs in the Manual. Figure 1.A graphically depicts the relationship between the **presumptive approach** (the use of this Manual) and the **demonstration approach** for achieving the environmental objectives of the standards.

Figure 1.A – Relation between environmental science and standards in stormwater regulations. Both the presumptive and demonstration approaches are based on using best available science to achieve compliance with standards. See the glossary for definitions.

STANDARDS

Water Pollution Control Act

(Chapter 90.48 RCW)

Discharges to state waters shall not cause pollution, which is defined as an alteration of the physical, chemical or biological properties of State waters which would impair beneficial uses. Requires the use of AKART and BMPs approved by Ecology.

Federal Clean Water Act

Restore and maintain the chemical, physical, and biological integrity of the Nation's waters.

- State water quality standards
- Federal technology-based treatment requirements (BAT, BCT, MEP)
- NPDES permits
- 303(d) impaired water body list and TMDLs/water clean-up plans

Others

Endangered Species Act

- Properly functioning conditions

Hydraulics Code (HPA)

Safe Drinking Water Act (UIC)

Presumptive Approach

The Stormwater Management Manual for Eastern Washington provides a default set of stormwater practices based on current science which satisfy State and Federal stormwater requirements.

Considerations:

- More predictable, practices are approved across jurisdictions
- Costly studies, etc. are not required as they may be under the demonstration approach

Demonstration Approach

Project sponsor and approval agency individually review and condition proposed projects to meet federal and state stormwater standards based on current science.

Considerations:

- Lacks predictability and can be very time consuming
- For large, complex projects may reduce costs and/or improve environmental protection

Hydrology

- When native vegetation is removed and replaced with impervious surfaces (roads or buildings) there is an increase in stormwater runoff and a decrease in summer base flows.
- Increased flows lead to increased flooding and stream bank and stream bed erosion.
- Unless mitigated, adverse high flow impacts occur at even low levels of urban development: 4% to 10% total impervious area or about one house per five acres.
- Transportation infrastructure represents between 50% and 75% of the impervious surface area within any single watershed.

Water Quality

- More than a third of the State's urban streams, creeks and embayments are impaired due to stormwater runoff.
- Stormwater runoff from construction activities can contain large amounts of sediments and suspended solids which are harmful to fish and other aquatic life.
- Untreated stormwater from roads and urban areas can adversely impact water quality due to sediments, toxic metals, pesticides, herbicides, oils and greases, and possible human pathogens including fecal coliform bacteria.
- Untreated stormwater runoff from roads and urban areas can be toxic to aquatic life including fish.

SCIENCE

The Manual is limited in scope for addressing environmental problems caused by urbanization. The Manual does not include site development standards or limit where development should be allowed. Project by project management of stormwater runoff from new development and redevelopment alone will not correct existing water quality and instream habitat problems. The engineered stormwater treatment and flow control systems recommended in this Manual can reduce the impacts of development to water quality and instream habitat, but such systems cannot remove sufficient pollutants to replicate the pre-development water quality, nor can they replicate the natural functions of the watershed that existed before development.

1.2 Effects of Urbanization

Managing stormwater may not seem necessary in arid and semi-arid regions where rainfall is generally a welcome event. However, the quality and habitat function of receiving waters in arid and semi-arid climates are affected by pollutants carried by stormwater runoff and by the changes in the patterns of runoff from the land following development. Hydrologic and water quality changes caused by urbanization can result in irreversible changes to the biological systems that were supported by the natural hydrologic system.

1.2.1 Hydrologic Changes

Just as the landscape of eastern Washington includes prairies, pine forests, the shrub-steppe, channeled scablands, and vast areas of irrigated and dry land agriculture, the hydrology of streams in eastern Washington varies tremendously. Average annual precipitation varies from 6 to more than 60_inches. Streambed material varies from basalt rock to highly erodible loess soils. Many streams flow only during the relatively wet winter and spring seasons or only during a runoff-producing rainstorm or snowmelt event.

Regardless of the hydrologic and geologic setting, streams can be impacted by urbanization of their watersheds. As development occurs, land is cleared and impervious surfaces such as roads, parking lots, rooftops, and sidewalks are added. Roads are cut through slopes and low spots are filled. The natural soil structure is lost due to grading and compaction during construction. Drainage patterns are irrevocably altered. Maintained landscapes that have much higher runoff characteristics often replace the natural vegetation. The accumulation of these changes may affect the natural hydrology by:

- Increasing the peak volumetric flow rates of runoff;
- Increasing the total volume of runoff;
- Decreasing the time it takes for runoff to reach a natural receiving water;
- Increasing stream velocities;

- Reducing groundwater recharge;
- Increasing the frequency and duration of high stream flows;
- Increasing inundation of wetlands during and after wet weather; and
- Reducing stream flows and wetland water levels during the dry season.

Figure 1.B illustrates some of these hydrologic changes. As a consequence of these changes in hydrology, stream channels may experience both increased flooding and reduced base flows; natural riffles, pools, gravel bars, and other areas are altered or destroyed. Increased channel erosion, loss of hydraulic complexity, degradation of habitat, and changes in the composition of species present in receiving waters may follow.

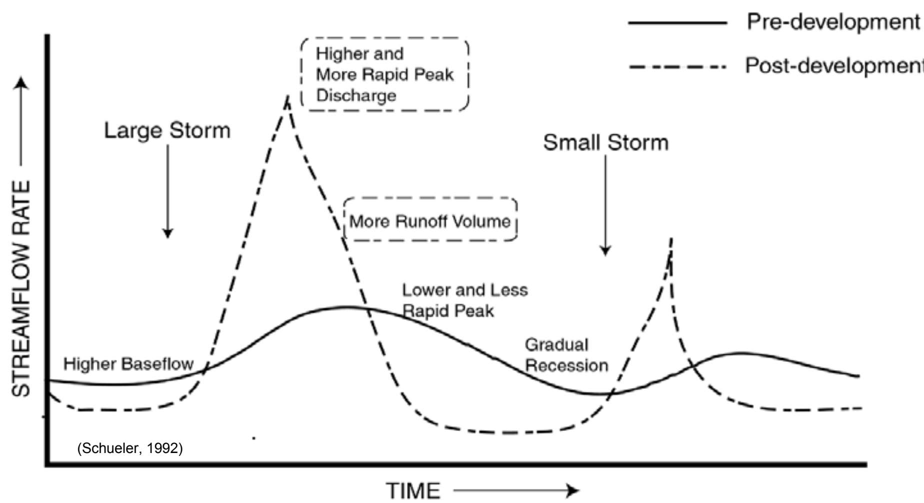

Figure 1.B – Changes in hydrology following development

These changes do not result from any one project; they are the cumulative effect of all of the development in a watershed. Therefore most new development must control flows. This Manual provides guidance on stormwater management practices for controlling excess runoff volume from individual sites through Flow Control Best Management Practices (BMPs). Section 1.4.4 of this chapter provides the background of developing these BMPs; Core Element #6 in Chapter 2 defines the requirements for applying these BMPs; and Chapters 4 and 5 of this Manual describe the design procedures for implementing these BMPs.

1.2.2 Water Quality Changes

Urbanization also causes increases in the types and quantities of pollutants in receiving waters. Runoff from urban areas has been shown to contain many different types of pollutants, depending on the nature of the activities in those areas. The runoff from roads and highways is contaminated with pollutants from vehicles; typical pollutants in road runoff include oil and grease, polynuclear aromatic hydrocarbons (PAHs), lead, zinc, copper, cadmium, sediments (soil particles) and road salts. Runoff from industrial areas typically contains even more types of heavy metals, sediments, and a broad range of man-made organic pollutants, including phthalates, PAHs and other petroleum hydrocarbons. Residential areas contribute the same road-based pollutants to runoff, as well as herbicides, pesticides, nutrients (from fertilizers and animal wastes), bacteria and viruses (from animal wastes). The pollutants in urban runoff can be dissolved in the water column or can be attached to solid particles that settle in streambeds, lakes, or wetlands. All of these contaminants can impair the beneficial uses of the receiving waters.

Table 1.1 shows typical concentrations of a limited number of pollutants found in urban stormwater runoff. The pollutant concentrations in stormwater runoff from arid watersheds tend to be higher than that of humid watersheds, since rain events are infrequent and pollutants have more time to accumulate on impervious surfaces. Pervious areas in arid and semi-arid regions also tend to produce higher sediment and organic carbon concentrations because the sparse vegetative cover does little to prevent soil erosion in uplands and along channels when it does rain.

Table 1.1 – Mean concentrations of selected pollutants in urban stormwater runoff across the United States and in arid and semi-arid regions.

Source: several studies summarized in Watershed Protection Techniques, Vol. 3 No. 3, March 2000.

Location	Total Suspended Solids (mg/L)	Total Copper (ug/L)	Total Zinc (ug/L)	Total Lead (ug/L)	Total Phosphorus (ug/L)
National Average	78	14	162	68	320
Phoenix, AZ	227	47	204	72	410
Boise, ID	116	34	342	46	750
Denver, CO	384	60	350	250	800
San Jose, CA	258	58	500	105	830
Dallas, TX	663	40	540	330	780

Table 1.2 shows typical concentrations of a limited number of pollutants from stormwater runoff generated by different land uses. For copper and zinc, these concentrations range from 40% to more than ten times the acute fresh water quality standard concentrations for a receiving water with a hardness of 48 mg/L as $CaCO_3$; only open land use results in pollutant concentrations below the standards. While instream dilution of the higher concentrations from any single project might prevent impairment of the beneficial uses of the receiving water, capacity does not exist in most urban streams to dilute the discharges from all of the sources in the watershed, and the cumulative effect of all of the discharges in the watershed is much more likely to impair the beneficial uses of the receiving water.

Table 1.2 – Mean concentrations of selected pollutants in stormwater runoff from different land uses in the State of Oregon.

Note: In-pipe industry means the samples were taken in stormwater pipes. Instream industry means the samples were taken in streams flowing through industrial areas. Samples for all other categories were taken from within stormwater pipes.
Source: Strecker et al*, 1997.*

Land Use	Total Suspended Solids (mg/L)	Total Copper (ug/L)	Total Zinc (ug/L)	Total Lead (ug/L)	Total Phosphorus (ug/L)
In-pipe industry	194	53	629	---	633
Instream industry	102	24	274	---	509
Transportation	169	35	236	---	376
Commercial	92	32	168	---	391
Residential	64	14	108	---	365
Open	58	4	25	---	166

Table 1.3 shows typical concentrations of a limited number of pollutants in highway runoff. These pollutants were detected in 46% to 100% of the samples collected for 102 sites with AADT =<30,000 and 93.5% to 100% of the samples collected for 231 sites with AADT >30,000. The mean concentrations of copper, lead, and zinc rage from 42% to more than 4.5 times the acute water quality standards.

Table 1.3 – Mean concentrations of selected pollutants in highway stormwater runoff in the State of California.

Source: California Department of Transportation, 2002.

Annual Average Daily Traffic (AADT)	Total Suspended Solids (mg/L)	Total Cadmium (ug/L)	Total Copper (ug/L)	Total Lead (ug/L)	Total Zinc (ug/L)
Less than or equal to 30,000	160	0.32	16	12	90
Greater than 30,000	160	0.89	39	64	260

Regardless of the eventual land use conversion, the sediment load produced by a construction site can increase turbidity in the receiving water. Fine sediments can be deposited over the natural sediments of the receiving water and degrade fish spawning areas and instream habitat for other aquatic life.

Urbanization may also cause changes in water temperature. Stormwater heated from impervious surfaces and exposed treatment and detention ponds may be discharged to streams with less riparian vegetation for shade. Urbanization also reduces recharge of groundwater, a source of cool water contributions to stream flows.

This Manual provides guidance on runoff treatment practices for reducing the impacts of pollutant-laden stormwater from individual sites through

Source Control, Construction Stormwater Pollution Prevention, and Water Quality Treatment Best Management Practices (BMPs). Section 1.4.2 of this chapter provides the background of developing Source Control BMPs; Chapter 8 of this Manual describes the procedures for implementing these BMPs. Section 1.4.3 of this chapter provides the background of developing Water Quality Treatment BMPs; Core Element #5 in Chapter 2 defines the requirements for applying these BMPs; and Chapters 4 and 6 of this Manual describe the design procedures for implementing these BMPs. Core Element #2 in Chapter 2 and all of Chapter 7 are devoted to Construction Stormwater Pollution Prevention.

1.3 Relationship of this Manual to Federal, State, and Local Regulatory Requirements

This Manual is one tool in the efforts to manage and reduce the impacts of urban stormwater discharges. Ecology considers the Manual to include all known, available and reasonable methods of prevention and treatment (AKART) for properly managing stormwater discharges on a site-by-site basis. At the date of publication of this Manual, the following regulatory programs and permits exist that may directly or indirectly require a project proponent to properly manage stormwater.

1.3.1 NPDES and State Waste Discharge Stormwater Permits for Municipalities

In Washington State, the Cities of Seattle and Tacoma; King, Pierce, Snohomish, and Clark Counties; and the Washington State Department of Transportation facilities within those jurisdictions have been subject to U.S. Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Phase I Stormwater Regulations (40 CFR Part 122). EPA adopted NPDES Phase II stormwater regulations in December 1999. Those rules identify additional municipalities that are subject to NPDES municipal stormwater permitting requirements. An initial statewide estimate is that 76 cities and eight counties in Washington will be subject to the requirements, and another 16 or more additional municipalities may be subject to the requirements, depending upon an analysis that Ecology must perform. In eastern Washington there are no Phase I communities; however there are four counties and between ten and fifteen cities that are subject to EPA's Phase II stormwater rules. Federal regulations require that Phase II permits be issued by December 2002 and that designated Phase II communities submit an application for permit coverage by March 2003.

The EPA NPDES regulations specify minimum measures for municipal stormwater programs for compliance with the Phase II rules. One of those measures is the adoption of a program for "post-construction stormwater management in new development and redevelopment." Another is a program for "construction site stormwater runoff control." This Manual provides technical guidance for projects to comply with municipal stormwater requirements in these two areas. For additional information on the Phase II Municipal permit and the minimum control measures, see Ecology's Publication Number 02-10-041 "NPDES Phase II Model Municipal Stormwater Program for Eastern Washington."

> **Note to reviewers:** *The draft public comment version of the Model Program document is being distributed together with the draft public comment version of this Manual. If you ordered a print version of the Manual, you also received the Model Program. If you downloaded the Manual from Ecology's website, it is available at the same http address.*

1.3.2 Industrial Stormwater General Permit (i.e. NPDES and State Waste Discharge Baseline General Permit for Stormwater Discharges Associated With Industrial Activities)

Businesses subject to the Industrial Stormwater General Permit have to prepare and implement a Stormwater Pollution Prevention Plan in accordance with the terms of that permit. The general permit, which was reissued August 2002, requires a description and implementation of operational source control BMPs and structural source control BMPs as applicable to their industrial activity. Additionally, application of erosion and sediment control BMPs, flow control BMPs and treatment BMPs from the Stormwater Management Manual (SWMM) and other published guidance is required if necessary to address an erosion, flow, or pollution problem.

The Industrial Stormwater General Permit requires selection of BMPs from: "the most recent published edition of the SWMM, or other equivalent manuals, that are available when selecting BMPs for their facility." This Manual will be the applicable SWMM for eastern Washington.

1.3.3 Construction Stormwater General Permit (i.e. NPDES and State Waste Discharge General Permit for Stormwater Discharges Associated With Construction Activity)

Operators of construction activities are required to seek coverage under the Construction Stormwater General Permit if the activity results in the disturbance of five acres or greater (including clearing, grading and excavation activities) and also has a discharge of stormwater to a surface water and/or storm drain.

Beginning March 10, 2003, the U.S. Environmental Protection Agency's Phase II Rule (Federal Register, Vol.64, No. 235, pages 68722-68852) requires operators of "Small Construction" activities disturbing greater than one acre of land to obtain an NPDES permit before discharging stormwater to a surface water or storm drain.

The Construction Stormwater General Permit requires the development and implementation of a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP must detail the various Best Management Practices (BMP) that will be used during construction to prevent erosion and sedimentation that could impact downstream water quality. The permit requires that BMPs be selected from the most recent edition of the appropriate regional or local Stormwater Management Manual (SWMM) that has been available at least 120 days prior to the BMP selection. This Manual will be the applicable SWMM for eastern Washington.

1.3.4 Underground Injection Control Authorizations

One of the provisions of the Safe Drinking Water Act is to protect Underground Sources of Drinking Water (USDW). The Underground Injection Control (UIC) Program was established to protect USDW by regulating the discharges of fluids into the subsurface by underground injection wells. In 1984 Ecology adopted Chapter 173-218 WAC to implement the program.

Subsurface infiltration systems, such as drywells, are classified as Class V injection wells in the EPA's federal UIC program. The two requirements of the UIC program are:

- A non-endangerment performance standard must be met, prohibiting discharges that allow movement of fluids containing contaminants into underground sources of drinking water, and
- All well owners must provide inventory information by registering the wells.

Under the Federal UIC regulations, the definition of an underground injection well is a bored, drilled, or driven shaft whose depth is greater than the largest surface dimension; or a dug hole whose depth is greater than the largest surface dimension; or an improved sinkhole; or a subsurface fluid distribution system which includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of a UIC well or a subsurface infiltration system are drywells, drain fields, catch basins, pipe or french drains and other similar devices that discharge to ground.

Note to reviewers: *Ecology is proposing to revise the existing UIC rule. The proposed changes to the rule will include rule authorization for properly managed stormwater from defined sources to be discharged to subsurface infiltration systems. Proper management would be based on following applicable best management practices as described in Ecology's current regional stormwater manuals or an approved equivalent manual. This Manual will be the applicable manual for eastern Washington. For more information about the rule revision contact Mary Shaleen-Hansen at* maha461@ecy.wa.gov *or* (360) 407-6143.

1.3.5 Endangered Species Act

Project proponents planning to discharge stormwater into bodies of water that provide habitat for threatened or endangered species are expected to properly manage their stormwater. The intent of this Manual is to meet the requirements of the Endangered Species Act as well as the requirements of the Clean Water Act for properly managing stormwater in order to prevent degradation of water quality and physical habitat in receiving waters in eastern Washington.

1.3.6 Section 401 Water Quality Certifications

For projects that require a fill or dredge permit under Section 404 of the Clean Water Act, Ecology must certify to the U.S. Army Corps of Engineers that the proposed project will not violate water quality standards, including state sediment standards. In order to make such a determination, Ecology may do a more specific review of the potential impacts of a stormwater discharge from the construction phase of the project and from the completed project. As a result of that review, Ecology may condition its certification to require:

- Application of the Core Elements and BMPs in this Manual; or
- Application of more stringent requirements.

1.3.7 Hydraulic Project Approvals (HPAs)

Under Chapter 77.55 RCW, the Hydraulics Act, the Washington State Department of Fish and Wildlife has the authority to require actions when stormwater discharges related to a project would change the natural flow or bed of State waters. The implementing mechanism is the issuance of a Hydraulics Project Approval (HPA) permit. In exercising this authority, Fish and Wildlife may require:

- Compliance with the provisions of this Manual; or
- Application of more stringent requirements that are determined to be necessary to meet their statutory obligations to protect fish and wildlife.

1.3.8 Aquatic Lands Use Authorizations

As the steward of public aquatic lands, the Department of Natural Resources (DNR) may require a stormwater outfall to have a valid use authorization and to avoid or mitigate impacts to natural resources. Through its use authorizations, which are issued under authority of Chapter 79.90 through 96, and in accordance with Chapter 332-30 WAC, DNR may require:

- Compliance with the provisions of this Manual; or
- Application of more stringent requirements that are determined to be necessary to meet their statutory obligations to protect the quality of the State's aquatic lands.

1.3.9 Requirements Identified through Watershed/Basin Planning or Total Maximum Daily Loads

A number of the requirements of this Manual can be superseded by the adoption of ordinances and rules to implement the recommendations of watershed plans or basin plans. Local governments may initiate their own watershed or basin planning processes to identify more stringent or alternative requirements. They may choose to develop a watershed plan in accordance with the Watershed Management Act (Chapter 90.82 RCW) that includes water quality and habitat elements. They may also choose to develop a basin plan in accordance with Chapter 400-12 WAC. As long as the actions or requirements identified in those plans and implemented through local or State ordinances or rules comply with applicable state and Federal regulations (e.g., the Clean Water Act and the Endangered Species Act), they can supersede the requirements in this Manual. The determination of whether such local requirements comply with Federal and State statutes must be made by the regulatory agency or agencies responsible for implementing those regulations.

Any requirement of this Manual may also be superseded or added to through the adoption of actions and requirements identified in a Total Maximum Daily Load (TMDL) that is approved by the EPA. However, it is likely that many TMDLs will require use of the BMPs in this Manual.

1.3.10 Other Local Government Requirements

Local governments have the option of applying more stringent requirements than those in this Manual. They are not required to base those more stringent requirements on a watershed/basin plan or their obligations under a TMDL. Project proponents should always check with the local governmental agency with jurisdiction to determine the stormwater requirements that apply to their project.

1.4 Best Management Practices for Stormwater Management

1.4.1 Best Management Practices (BMPs)

The method by which the Manual controls the adverse impacts of development and redevelopment is through the application of Best Management Practices (BMPs). The BMPs included in this Manual have been approved by Ecology; as new technologies are evaluated and approved, additional BMPs will be published as updates to this Manual.

BMPs are defined as schedules of activities, prohibitions of practices, structural facilities, maintenance procedures, and/or managerial practices that when used singly or in combination prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State. The basic types of BMPs are source control, water quality treatment, and flow control. BMPs that involve construction of engineered structures are often referred to as facilities in this Manual.

The primary purpose of using BMPs is to protect the beneficial uses of water resources (1) through prevention of contamination, (2) through the reduction of pollutant concentrations and loads, and/or (3) through reduction of discharge flow rates that cause stream channel erosion. If it is found that beneficial uses are still threatened or impaired following the implementation of BMPs advocated in this Manual, then additional controls may be required.

1.4.2 Source Control BMPs

Source Control BMPs prevent pollution or other adverse effects of stormwater from occurring. Most of these BMPs are common-sense "good housekeeping" measures and are targeted for various pollutant-generating activities and sources. Source Control BMPs may be either operational or structural; examples include methods as varied as sweeping, using mulches and covers on disturbed soil, putting roofs over outside storage areas, and constructing berms around potential pollutant source areas to prevent both stormwater run-on and pollutant runoff.

It is generally more cost effective to use source controls to prevent pollutants from entering runoff, than to treat runoff to remove pollutants. However, since source controls cannot prevent all impacts, some combination of measures will always be needed.

1.4.3 Water Quality Treatment BMPs

Water Quality Treatment BMPs include facilities that remove pollutants from stormwater by filtration, biological uptake, adsorption, and/or gravity settling of particulate pollutants. The need for a project to provide runoff treatment facilities depends on (1) the type and amount of pollutants expected to be generated by the completed project and (2) the vulnerability of the receiving waters to the pollutants of concern. A combination of BMPs may be required to protect the receiving waters.

Water Quality Treatment BMPs can accomplish significant levels of pollutant load reductions if properly selected, designed, operated and maintained. Some Water Quality Treatment BMPs are targeted for removal of a specific type of pollutant; others are effective at removing several classes of pollutants. Some BMPs may be appropriate only for certain climates or under other conditions.

It is not generally practical to treat 100% of the annual stormwater runoff volume generated by a project site. Some of the design specifications for Water Quality Treatment BMPs in this Manual are established such that the BMPs are presumed to treat at least 90% of the total average annual runoff volume; this amount is considered to be a reasonable goal for capturing as many contaminants as practicable. Other BMP design specifications are based on treating the "first flush" of each storm event:

stormwater produced by first rainstorm following a dry period during which pollutants have accumulated on impervious surfaces is commonly believed to carry a majority of the pollutants in urban runoff.

1.4.4 Flow Control BMPs

Flow Control BMPs may control the rate, frequency, and/or flow duration of stormwater surface runoff. The need for a project to provide a flow control facility depends on whether a development site discharges to a stream system or wetland either directly or indirectly and whether the cumulative projected development impacts in the watershed of the receiving waters are likely to cause unnatural erosion of the stream channel. Stream channel erosion control can be accomplished by constructing BMPs that detain runoff flows and also by physical stabilization of eroding stream banks. Both types of measures may be necessary in urban streams, but only the former is covered in this Manual.

Excess stormwater runoff volumes are generally managed by construction and operation of infiltration, evaporation, or detention facilities. On-site infiltration is the preferred means of disposing of stormwater runoff but is feasible only where more porous soils are available and the water table is not too near to the land surface. With the lower amounts of runoff in the arid and semi-arid climate of eastern Washington, infiltration is feasible in many areas of new development.

For projects with discharges to surface waters, detention ponds are designed and operated to meet established flow control requirements. The concept of detention is to collect runoff from a developed area and release it at a slower rate than it enters the collection system. The reduced release rate requires temporary storage of the excess amounts in a pond with release occurring over a few hours or days. The volume of storage needed is dependent on (1) the size of the drainage area; (2) the extent of disturbance of the natural vegetation, topography, and soils and creation of effective impervious surfaces – surfaces that drain to a stormwater collection system; and (3) how rapidly the water is allowed to leave the detention pond, i.e., the target release rates.

Historic flow control measures have focused on controlling runoff by matching the pre- and post-development peak flow rates for the certain recurrence intervals. This level of control does not adequately address the increased duration at which those high flows occur because the volume of water from the post-developed condition is increased as compared to the pre-developed condition. The approach of only matching the peak flow rates fails to protect stream habitats from increased erosional energy.

To protect stream channels from increased erosion, it is necessary to control the durations over which a stream channel experiences geomorphically significant flows such that the energy imparted to the stream channel does not increase significantly. Geomorphically significant flows are those that are capable of moving sediments; for most streams, these flows are within the 1.5- to 2-year range of recurrence intervals. If the 2-year peak runoff rate is met, the stream experiences that flow rate for the longer period necessary to release the increased volume of runoff in the post-developed condition. In the absence of a continuous runoff model a full duration standard cannot be achieved, but a partial duration standard can be implemented by releasing the post-developed 2-year volume at half of the pre-developed 2-year peak flow rate, thus reducing the total erosional energy to somewhat nearer to that of the pre-developed condition. This target will translate into lower release rates and larger detention ponds. The size of the facility can be reduced by reducing the extent to which a site is disturbed.

Another important consideration in establishing flow control standards in eastern Washington is whether the intense summer thunderstorms or gentler, more prolonged winter/spring storms and snowmelt, or both, are more geomorphically important for maintaining in-stream habitat quality in streams of eastern Washington. The answer to this question may vary from region to region, with streams in the Central Basin being dependent on the high, flashy flows that follow intense summer thunderstorms and streams in the mountainous regions being more sensitive to increased and prolonged winter/spring flows.

For discharges to wetlands, the objective of flow control is to not alter the natural hydroperiod. This means that flows from a development should be controlled such that the wetland is within certain elevations at different times of the year and that short-term elevation changes are within prescribed limits. If the amount of surface water runoff draining to a wetland is increased because of land conversion from forested to impervious areas, it may be necessary to bypass some water around the wetland in the wet season. (Bypassed stormwater must still meet flow control and treatment requirements applicable to the receiving water.) If however, the wetland was fed by local ground water elevations during the dry season, the impervious surface additions and the bypassing practice may cause variations from the dry season elevations. Accurate estimates of what should be done to maintain the natural hydroperiod require data collection prior to the development activity and the use of a continuous runoff model, neither of which is available for most cases in eastern Washington. Even if the data and modeling approach are sufficient, it will be a challenge to simulate pre-development hydrology after significant development has occurred.

1.4.5 New and Emerging BMPs

Ecology encourages the development and implementation of new approaches to managing stormwater. This Manual is intended to be a living document, and project proponents should check Ecology's website for additional BMPs that have been approved since the publication of this Manual. More information is provided in Chapter 6 of this Manual about the new Statewide protocol for testing new and emerging stormwater management technologies.

1.5 How to Apply this Manual

The users of this Manual will be engineers, planners, private industry, environmental scientists, plan reviewers and inspectors at the local, State, and Federal government levels. Ecology may approve other stormwater management manuals developed by local jurisdictions, the Washington State Department of Transportation or other entities as being equivalent to this Manual. Local government officials may adopt and apply the requirements of this Manual directly or adopt and apply the requirements of an equivalent manual (see Section 1.5.2, Alternative Technical Manuals, below). Local government staff may use this Manual or an equivalent manual as a reference for reviewing stormwater site plans; checking source control, runoff treatment and flow control facility designs; and for providing technical advice in general. Private industry may use the Manual for information on how to develop and implement stormwater site plans and as a reference for technical specifications of Best Management Practices (BMPs).

The Manual itself has no independent regulatory authority. The Core Elements and technical guidance in the Manual only become required through:

- Ordinances and rules established by local governments; and
- Permits and other authorizations issued by local, State, and Federal authorities.

Local jurisdictions may adopt and apply the Core Elements, thresholds, definitions, BMP selection processes, and BMP design criteria of this Manual or an equivalent manual. Staff at local governments and agencies with permitting jurisdiction may use this Manual in reviewing Stormwater Site Plans, checking BMP designs, and providing technical advice to project proponents.

Federal, State, and local permits may refer to this Manual or the BMPs contained in this Manual. In those cases, affected permit-holders or applicants should use this Manual for specific guidance on how to comply with permit conditions.

<u>Project proponents should start by reading Chapter 2 of this Manual</u>. Chapter 2 explains the requirements of the Core Elements and defines how the Core Elements should be applied to individual projects and to particular levels of development.

For several of the Core Elements, thresholds are identified. These are levels (e.g. project size) at which an action becomes required for that project. The thresholds presented in Chapter 2 of this Manual are *technical thresholds*. However, *regulatory thresholds* may be established in ordinances, rules, permits or other authorizations; these thresholds are not included in this Manual but may modify certain thresholds that need to be met for a given project to be required to comply with one or more Core Elements.

1.5.1 Stormwater Technical Manual

This Manual serves as a single technical stormwater manual for the eastern Washington region. It provides uniform stormwater management standards and is a central repository for BMPs. Ecology will maintain the region's technical stormwater manual for new development and redevelopment and will update, revise and republish this Manual as appropriate.

1.5.2 Alternative Technical Manuals

Cities, counties, and other agencies may choose to develop alternative technical manuals. Those agencies and jurisdictions subject to State and Federal regulatory programs that refer to this Manual are directed to submit their manuals to Ecology. The submittal is to include an outline of significant differences between the manuals and demonstrate how the alternative manual is substantively equivalent to this Manual. Ecology will work with jurisdictions to ensure that all alternative manuals meet or exceed the standards in this Manual. Where Ecology is uncertain that a local government or agency requirement provides equivalent or better protection, it may provisionally approve the requirement. The provisions would require the local government or agency to implement an approved monitoring effort to assess the performance of the local requirement. Jurisdictions choosing to develop an alternative manual are directed to adopt this Manual in the interim.

Glossary

The following terms are provided for reference and use with this Manual. They shall be superseded by any other definitions for these terms adopted by ordinance, unless they are defined in a Washington State WAC or RCW.

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

Adaptive management The modification of management practices to address changing conditions and new knowledge. Adaptive management is an approach that incorporates monitoring and research to allow projects and activities, including projects designed to produce environmental benefits, to go forward in the face of some uncertainty regarding consequences. The key provision of adaptive management is the responsibility to change adaptively in response to new understanding or information after an action is initiated.

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.

AKART All Known, Available, and Reasonable methods of prevention, control, and Treatment. The most current methodology that can be reasonably required for preventing, controlling, or abating the pollutants associated with a discharge. The concept of AKART applies to both point and nonpoint sources of pollution. Best Management Practices (BMPs) typically applied to nonpoint source pollution controls are considered a subset of the AKART requirement. The Stormwater Management Manual for Easter Washington may be used as a guideline, to the extent appropriate, for developing best management practices to apply AKART for storm water discharges. AKART and BAT are roughly equivalent State and Federal terms for the same concept.

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

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

Applicable BMPs As used in Chapters 2 and 8, applicable BMPs are those source control BMPs that are expected to be required by local governments at new development and redevelopment sites. Applicable BMPs will also be required if they are incorporated into NPDES permits, or they are included by local governments in a stormwater program for existing facilities.

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

Arterial A road or street primarily for through traffic. A major arterial connects an Interstate Highway to cities and counties. A minor arterial connects major arterials to collectors. A collector connects an arterial to a neighborhood. A collector is not an arterial. A local access road connects individual homes to a collector.

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 occur on average every 1.5 to 2 years and controls the shape and form of natural channels.

BAT Best Available Technology. The most current technology available for controlling releases of pollutants to the environment. Major dischargers are required to use BAT unless it can be demonstrated that it is unfeasible for energy, environmental, or economic reasons. BAT and AKART are roughly equivalent Federal and State terms for the same concept.

BCT Best available Control Technology. All technologies and/or methods currently available for preventing releases of hazardous substances and demonstrated to work under similar site circumstances or through pilot studies, and applicable to the site at reasonable cost.

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

Beneficial uses Those water uses identified in state water quality standards that must be achieved and maintained as required under the Federal Clean Water Act. "Beneficial use" and "designated use" are often used interchangeably.

Berm A constructed barrier of compacted earth, rock, or gravel. In a stormwater facility, a berm may serve as a vertical divider typically built up from the bottom.

Best available science The technical provisions in the Stormwater Management Manual for Eastern Washington represent common provisions for the protection of waters of the State from adverse impacts of urban stormwater. Implementation of these provisions is necessary to minimize project specific and cumulative impacts to waters of the State. This Manual reflects the best available science and practices related to protection of water quality. The Manual will incorporate new information as it becomes available, and to allow for alternative practices that provide equal or greater protection for waters of the State.

Best Management Practices (BMPs) The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices approved by Ecology that, when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

Catch basin 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.

Catchment Surface drainage area.

Cation exchange capacity (CEC) The amount of exchangeable cations that a soil can adsorb at pH 7.0.

Channel, constructed Reconstructed natural channels or other channels or ditches constructed to convey surface water.

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

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

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

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

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

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

Compaction The densification, settlement, or packing of soil in such a way that permeability of the soil is reduced. Compaction effectively shifts the performance of a hydrologic group to a lower permeability hydrologic group. For example, a group B hydrologic soil can be compacted and be effectively converted to a group C hydrologic soil in the way it performs in regard to runoff. Compaction may also refer to the densification of a fill by mechanical means.

Contractor Erosion and Spill Control Lead (CESCL) — The employee designated as the responsible representative in charge of erosion and spill control. The CESCL shall be qualified in construction site erosion and sediment control regulatory requirements and BMPs and shall have thorough knowledge and understanding of the Construction Stormwater Pollution Prevention Plan (SWPPP) for the project site.

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.

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

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. Facilities designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

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

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

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

Development — Means new development, redevelopment, or both. See definitions for each.

Discharge	Runoff leaving a new development or redevelopment via overland flow, built conveyance systems, or infiltration facilities. A hydraulic 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.
Dispersion	Release of surface and stormwater runoff from a drainage facility system such that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.
Ditch	A long narrow excavation dug in the earth for drainage with its top width less than 10 feet at design flow.
Divide, Drainage	The boundary between one drainage basin and another.
Drain	A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or ground water.
Drywell	A well completed above the water table so that its bottom and sides are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface and are commonly used for stormwater management in eastern Washington. See also UIC.
Effective impervious surface	Those impervious surfaces that are connected via sheet flow or a conveyance system to a drainage system. Most impervious areas are effective.
Emerging technology	Treatment technologies that have not been evaluated with approved protocols, but for which preliminary data indicate that they may provide a necessary function(s) in a stormwater treatment system. Emerging technologies need additional evaluation to define design criteria to achieve, or to contribute to achieving, state performance goals, and to define the limits of their use.
Erodible or leachable materials	Substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils that are stockpiled; uncovered process wastes; manure; fertilizers; oily substances; ashes; kiln dust; and garbage dumpster leakage.
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.
Erosion and sedimentation control (ESC)	Any temporary or permanent measures taken to reduce erosion; control siltation and sedimentation; and ensure that sediment-laden water does not leave the site.

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

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

Excavation The mechanical removal of earth material.

Exception Relief from the application of a Core Element to a project.

Existing condition The impervious surfaces, drainage systems, land cover, native vegetation and soils that exist at the site with approved permits and engineering plans when required. If sites have impervious areas and drainage systems that were built without approved permits, then the existing condition is defined as those that existed prior to the adoption of this Manual. These conditions can be verified by record aerial photography, or other methods.

Flood An overflow or inundation that comes from a river or any other source, including (but not limited to) streams, tides, wave action, storm drains, or excess rainfall. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.

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

Flow duration The aggregate time that peak flows are at or above a particular flow rate of interest. For example, the amount of time that peak flows are at or above 50% of the 2-year peak flow rate for a period of record.

Flow frequency The inverse of the probability that the flow will be equaled or exceeded in any given year (the exceedance probability). For example, if the exceedance probability is 0.01 or 1 in 100, that flow is referred to as the 100-year flow.

Flow path The route that stormwater runoff follows between two points of interest.

Forest practice Any activity conducted on or directly pertaining to forest land and relating to growing, harvesting, or processing timber, including but not limited to: road and trail construction; harvesting, final and intermediate; precommercial thinning; reforestation; fertilization; prevention and suppression of diseases and insects; salvage of trees; and brush control.

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 and/or affect soil infiltration capacity.

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

Groundwater — Water in a saturated zone or stratum beneath the land surface or beneath a surface water body.

Groundwater recharge — Inflow to a groundwater reservoir or aquifer.

Groundwater 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.

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

Highway — A main public road connecting towns and cities.

Horton overland flow — A runoff process whereby the rainfall rate exceeds the infiltration rate, so that the precipitation that does not infiltrate flows downhill over the soil surface.

HSPF — Hydrological Simulation Program-Fortran. A continuous simulation hydrologic model that transforms an uninterrupted rainfall record into a concurrent series of runoff or flow data by means of a set of mathematical algorithms which represent the rainfall-runoff process at some conceptual level.

Hydrograph — A graph of runoff rate, inflow rate, discharge rate, or another characteristic of a body of water during a specific period of time.

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

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

Type A: Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.
Type B: Moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
Type C: Moderately high runoff potential. Soils having slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
Type D: High runoff potential. Soils having very slow infiltration rates when thoroughly wetted, and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan, till, or clay layer at or near the surface, soils with a compacted subgrade at or near the surface, and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission (Novotney and Olem, 1994).

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 or table of percentages of total precipitation for a series of time steps representing the total time in which precipitation occurs.

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

Impaired waters — Water bodies not fully supporting their beneficial uses.

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

Open, uncovered retention/detention facilities shall not be considered as impervious surfaces for the purposes of determining whether the thresholds for application of Core Elements are exceeded. Open, uncovered retention or detention facilities shall be considered impervious surfaces for purposes of runoff modeling.

Industrial activities Material handling, transportation, or storage; manufacturing; maintenance; treatment; or disposal. Areas with industrial activities include plant yards, access roads and rail lines used by carriers of raw materials, manufactured products, waste material, or by-products; material handling sites; refuse sites; sites used for the application or disposal of process waste waters; sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater.

Ineffective impervious surface Impervious surfaces on residential development sites where the runoff is not concentrated and is dispersed via sheet flow off the pavement and then through at least one hundred feet of native vegetation before flowing into a drainage system. An example is a tennis court in the middle of a park.

Infiltration The downward movement of water from the land 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 rate The rate, usually expressed in inches per hour, at which water percolates, or moves downward through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

Interflow That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface for example, in a roadside ditch, wetland, spring or seep. Interflow is a function of the soil system depth, permeability, and water-holding capacity.

Intermittent stream or intermittent channel A stream or portion of a stream that flows only in direct response to precipitation. Intermittent streams receive little or no water from springs and no long-continued supply from melting snow or other sources and are dry for a large part of the year.

Irrigation ditch	That portion of a designed and constructed conveyance system that serves the purpose of transporting irrigation water from its supply source to its place of use; this may include natural water courses or channels incorporated in the system design, but does not include the area adjacent to the water course or channel.
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 movement of earth, or a change in the existing soil cover (both vegetative and non-vegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to clearing, grading, filling, and excavation. Compaction that is associated with stabilization of structures and road construction shall also be considered a land disturbing activity. Vegetation maintenance practices are not considered land-disturbing activity.
Leachable materials	Those substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils, uncovered process wastes, manure, fertilizers, oil substances, ashes, kiln dust, and garbage dumpster leakage.
Level pool routing	The basic technique of storage routing used for sizing and analyzing detention storage and determining water levels for ponding water bodies. The level pool routing technique is based on the continuity equation: inflow minus outflow equals change in storage.
Local government	Any county, city, town, or special purpose district having its own incorporated government for local affairs.
Low flow channel	An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and/or baseflow, directly to the outlet without detention.
Low permeable liner	A layer of compacted till or clay, or a geomembrane.
Maintenance	Repair and maintenance includes activities conducted on currently serviceable structures, facilities, and equipment that involves no expansion or use beyond that previously existing and resulting in no significant adverse hydrologic impact. It includes those usual activities taken to prevent a decline, lapse, or cessation in the use of structures and systems and includes replacement of disfunctioning facilities, including cases where environmental permits require replacing an existing structure with a different type structure, as long as the functioning characteristics of the original structure are not changed. For example, replacing a collapsed, fish blocking, round culvert with a new box

culvert under the same span, or width, of roadway. For further details on the application of this manual to various road management functions, please see Section 2.1.1.

MEP — Maximum Extent Practicable. The highest level of effectiveness that can be achieved through the use of personnel and best achievable technology. In determining what is the maximum extent practicable, Ecology shall consider, at a minimum, the effectiveness, engineering feasibility, commercial availability, safety, and the cost of the measures.

Metals — Elements such as lead, mercury, copper, cadmium and zinc which are of environmental concern because they can be toxic to aquatic life and do not degrade over time.

Mitigation — In the following order of preference, mitigation means:

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

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

Monitoring — The systematic 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.

Native vegetation — Vegetation comprised of plant species that are indigenous to Eastern Washington and which reasonably could have been expected to naturally occur on the site. Plant species classified as noxious weeds are excluded from this definition.

Natural conditions — Surface water quality that was present before any human-caused pollution. When estimating natural conditions in the headwaters of a disturbed watershed it may be necessary to use the less disturbed conditions of a neighboring or similar watershed as a reference condition.

Natural location
Means the location of those channels, swales, and other non-manmade conveyance systems as defined by the first documented topographic contours existing for the subject property, either from maps or photographs, or such other means as appropriate. In the case of outwash soils with relatively flat terrain, no natural location of surface discharge may exist.

New development
Land disturbing activities, including Class IV general forest practices that are conversions from timber land to other uses; structural development, including construction or installation of a building or other structure; creation of impervious surfaces; and subdivision, short subdivision and binding site plans, as defined and applied in Chapter 58.17 RCW. Projects meeting the definition of redevelopment shall not be considered new development.

Nonpoint source pollution
Pollution that enters any waters of the State from any dispersed land-based or water-based activities and does not result from discernible, confined, or discrete conveyances.

NPDES
National Pollutant Discharge Elimination System. A provision of the Clean Water Act which prohibits point-source discharges of pollutants into waters of the United States unless a special permit is issued and administered by the U.S. Environmental Protection Agency or by Ecology as the delegated authority in Washington State. Municipal Separate Stormwater Sewer Systems are classified as point-source discharges.

NRCS Method
See SCS Method.

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-line facilities
Water quality treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow-splitter.

Off-system storage
Facilities for holding or retaining excess flows over and above the carrying capacity of the stormwater conveyance system, in chambers, tanks, lagoons, ponds, or other basins that are not a part of the subsurface sewer system.

Oil/water separator
A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

On-line facilities
Water quality treatment facilities which receive all of the stormwater runoff from a drainage area. Flows above the water quality design flow rate or volume are passed through at a lower percent removal efficiency.

On-site stormwater management BMPs
Development and mitigation techniques that serve to infiltrate, disperse, and retain stormwater runoff on a project site.

Operational BMPs Operational BMPs are a type of Source Control BMP. They are schedules of activities, prohibition of practices, and other managerial practices to prevent or reduce pollutants from entering stormwater. Operational BMPs include formation of a pollution prevention team, good housekeeping, preventive maintenance procedures, spill prevention and clean-up, employee training, inspections of pollutant sources and BMPs, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

Ordinary high water mark The line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area. The ordinary high water mark is found by examining the bed and banks of a stream and ascertaining where the presence and action of waters are so common and usual, and so long maintained in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation. In any area where the ordinary high water mark cannot be found, the line of mean high water shall substitute. In any area where neither can be found, the channel bank shall be substituted. In braided channels and alluvial fans, the ordinary high water mark or substitute shall be measured so as to include the entire stream feature.

Orifice An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow, generally used for the purpose of measurement or control of water.

Outlet Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet channel A waterway constructed or altered primarily to carry water from man-made structures, such as terraces, tile lines, and diversions.

Overflow A pipeline or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into receiving waters or other points of disposal, after a regular device has allowed the portion of the flow which can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.

Overflow rate Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.

Overtopping Flow over the limits of a containment or conveyance element.

Particle size The effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods.

Peak discharge	The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.
Peak-shaving	Controlling post-development peak discharge rates to pre-development levels by providing temporary detention in a BMP.
Percolation	The movement of water through soil.
Percolation rate	The rate, often expressed in minutes/inch, at which clear water, maintained at a relatively constant depth, will seep out of a standardized test hole that has been previously saturated. The term percolation rate is often used synonymously with infiltration rate (short-term infiltration rate).
Perennial stream	A stream or stream segment that does not go dry at any time during a year of normal rainfall.
Permanent Stormwater Control (PSC) Plan	A plan which includes permanent BMPs for the control of pollution from stormwater runoff after construction and/or land disturbing activity has been completed
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.
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 that are extracted from plants and animals.
pH	A measure of the alkalinity or acidity of a substance which is conducted by measuring the concentration of hydrogen ions in the substance. A pH of 7.0 indicates neutral water. A 6.5 reading is slightly acid.
Physiographic	Characteristics of the natural physical environment (including hills).
Plan Approval Authority	The Plan Approval Authority is defined as that department within a local government that has been delegated authority to approve stormwater site plans.
Plat	A map or representation of a subdivision showing the division of a tract or parcel of land into lots, blocks, streets, or other divisions and dedications.
Point discharge	The release of collected and/or concentrated surface and stormwater runoff from a pipe, culvert, or channel.
Point of compliance	The location at which compliance with a discharge performance standard or a receiving water quality standard is measured.

Pollution Contamination or other alteration of the physical, chemical, or biological properties, of waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental or injurious to the public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

Pollution-generating impervious surface (PGIS) Those impervious surfaces considered to be a significant source of pollutants in stormwater runoff. Such surfaces include those which are subject to: vehicular use; industrial activities (as further defined in this glossary); or storage of erodible or leachable materials, wastes, or chemicals, and which receive direct rainfall or the run-on or blow-in of rainfall. Metal roofs are also considered to be PGIS unless they are coated with an inert, non-leachable material.

A surface, whether paved or not, shall be considered PGIS if it is regularly used by motor vehicles. The following are considered PGIS: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways. The following are not considered PGIS: paved bicycle pathways separated from and not subject to drainage from roads for motor vehicles, fenced fire lanes, and infrequently used maintenance access roads.

Pollution-generating pervious surface (PGPS) Any non-impervious surface subject to use of pesticides and fertilizers or loss of soil. Typical PGPS include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields.

Predeveloped condition The native vegetation and soils that existed at a site prior to the influence of Euro-American settlement.

Prediction For the purposes of this document an expected outcome based on the results of hydrologic modeling and/or the judgment of a trained professional civil engineer or geologist.

Pretreatment The removal of material such as solids, grit, grease, and scum from flows prior to physical, biological, or physical treatment processes to improve treatability. Pretreatment may include screening, grit removal, settling, oil/water separation, or application of a Basic Treatment BMP prior to infiltration.

Process wastewater The used water and solids from an industrial source. This water should be directed to a treatment facility and kept separate from the stormwater generated from the site.

Project — Any proposed action to alter or develop a site. The proposed action of a permit application or an approval, which requires drainage review.

Project site — That portion of a property, properties, or right of way that is subject to land disturbing activities and new or replaced impervious surfaces.

Properly Functioning Soil System (PFSS) — Equivalent to engineered soil/landscape system. This can also be a natural system that has not been disturbed or modified.

Rare, threatened, or endangered species — Threatened and endangered species means those native plant or animal species that are listed in rule by the Washington State Department of Fish and Wildlife pursuant to RCW 77.12.020 as threatened (WAC 232-12-011) or endangered (WAC 232-12-014), or that are listed as threatened or endangered species under the federal Endangered Species Act, 16 U.S.C. 1533. Rare plant or animal species are regionally relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats; rare species are unofficial species of concern.

Rational Method — A method 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. In this Manual, the use of the Rational Method is limited to sizing only certain types of runoff treatment facilities; see Chapter 4.

Reach — A length of a water body with uniform characteristics.

Receiving waters — Bodies of water or surface water systems to which surface runoff is discharged via a point source of stormwater or via sheet flow.

Recommended BMPs — As used in Chapters 2 and 8, recommended BMPs are those BMPs that are not expected to be mandatory by local governments at new development and redevelopment sites. However, they may improve pollutant control efficiency, and may provide a more comprehensive and environmentally effective stormwater management program.

Redevelopment — On a site that is already substantially developed (i.e., has 35% or more of existing impervious surface coverage), the replacement of impervious surfaces, including buildings and other structures and replacement of impervious parking and road surfaces that is not part of a routine maintenance activity. Any new impervious surfaces created by a redevelopment project are subject to the requirements for new development.

Regional detention facility — A stormwater quantity control structure designed to correct existing 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 sited to detain stormwater runoff from a number of new developments or areas within a catchment.

Release rate The computed peak rate of surface and stormwater runoff from a site.

Replaced impervious surface For structures, the removal and replacement of any exterior impervious surfaces or foundation. For other impervious surfaces, the removal down to bare soil or base course and replacement.

Residential density The number of dwelling units per unit of surface area. Net density includes only occupied land. Gross density includes unoccupied portions of residential areas, such as roads and open space.

Retention The process of collecting and holding surface and stormwater runoff with no surface outflow.

Retention/detention (R/D) facility 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 frequency or recurrence interval A statistical term for the average expected time interval between events (e.g. flows, floods, droughts, or rainfall) that equal or exceed given conditions.

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. As applied in this manual, it also means the portion of rainfall or other precipitation that becomes surface flow and interflow.

Saturation point In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.

SCS Soil Conservation Service (now the Natural Resources Conservation Service), U.S. Department of Agriculture

SCS Method A single-event hydrologic analysis technique for estimating runoff based on the Curve Number method. The Curve Numbers are published by the SCS, now NRCS, in *Urban Hydrology for Small Watersheds, 55 TR, June 1986*. Since the change in the agency's name, the method may be referred to as the NRCS Method.

Seasonal stream A stream or segments of a stream that normally goes dry during a year of normal rainfall. Seasonal streams often receive water from springs and/or long-continued water supply from melting snow or other sources.

Sediment Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits, and is transported by, suspended in, or deposited by water.

Settleable solids Those suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.

Sheet flow Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Siltation The process by which a river, lake, or other waterbody becomes clogged with sediment. Silt can clog gravel beds and prevent successful salmon spawning.

Site The area defined by legal boundaries of a parcel or parcels of land that is (are) subject to new development or redevelopment. For road projects, the length of the project site and the right-of-way boundaries define the site.

Soil stabilization The use of measures such as rock lining, vegetation or other engineering structures to prevent the movement of soil when loads are applied to the soil.

Sorption The physical or chemical binding of pollutants to sediment or organic particles.

Source control BMP A structure or operation that is intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants. This manual separates source control BMPs into two types. *Structural source control BMPs* are physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater. *Operational BMPs* are non-structural practices that prevent or reduce pollutants from entering stormwater. See Chapter 8 for details.

Spill control device A tee section or turn down elbow designed to retain a limited volume of pollutant that floats on water, such as oil or antifreeze. Spill control devices are passive and must be cleaned-out for the spilled pollutant to actually be removed.

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.

Storage routing A method to account for the attenuation of peak flows passing through a detention facility or other storage feature.

Storm drain system Refers to the system of gutters, pipes, streams, or ditches used to carry surface and stormwater from surrounding lands to streams or lakes.

Storm sewer A sewer that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a storm drain.

Stormwater That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a stormwater drainage system into a defined surface water body, 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 ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil/water separators, and biofiltration swales.

Stormwater Management Manual for Eastern Washington (Stormwater Manual) This Manual, as prepared by Ecology, contains BMPs to prevent, control or treat pollution in stormwater and reduce other stormwater-related impacts to waters of the State. The Stormwater Manual is intended to provide guidance on measures necessary in eastern Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

Stormwater Site Plan (SSP) The comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the Stormwater Site Plan will vary with the type and size of the project, and individual site characteristics. It includes a Construction Stormwater Pollution Prevention Plan (Construction SWPPP) and a Permanent Stormwater Control Plan (PSC Plan). Guidance on preparing a SSP is provided in Chapter 3.

Stream An area where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is an area that demonstrates clear evidence of the passage of water including, but not limited to, hydraulically sorted sediments or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water year-round. This definition is not meant to include irrigation ditches, canals, stormwater runoff devices or other entirely artificial watercourses unless they are used to convey streams naturally occurring prior to construction. Those topographic features that resemble streams but have no defined channels (i.e.

swales) shall be considered streams when hydrologic and hydraulic analyses done pursuant to a development proposal predict formation of a defined channel after development.

Subbasin A drainage area that drains to a water-course or water body named and noted on common maps and which is contained within a basin.

Susceptibility The ease with which contaminants can move from the land surface to the aquifer, based solely on the types of surface and subsurface materials in the area. Susceptibility usually defines the rate at which a contaminant will reach an aquifer unimpeded by chemical interactions with the vadose zone media.

Suspended solids Organic or inorganic particles 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.

Tightline A continuous length of pipe that conveys water from one point to another (typically down a steep slope) with no inlets or collection points in between.

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.

TMDL Total Maximum Daily Load, also known as a Water Cleanup Plan. A calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the water body can be used for the purposes the State has designated. The calculation must also account for seasonable variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each water body, for example, drinking water supply, contact recreation (swimming), and aquatic like support (fishing), and the scientific criteria to support that use. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs.

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.

Travel time The estimated time for surface water to flow between two points of interest.

Treatment BMP A BMP that is intended to remove pollutants from stormwater. A few examples of treatment BMPs are detention ponds, oil/water separators, biofiltration swales, and constructed wetlands.

Treatment liner A layer of soil that is designed to slow the rate of infiltration and provide sufficient pollutant removal so as to protect groundwater quality.

Treatment train A combination of two or more treatment facilities connected in series.

Turbidity Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid.

UIC Underground Injection Control, a Federal regulatory program established to protect underground sources of drinking water from UIC well discharges. A UIC well is defined as a bored, drilled, or driven shaft whose depth is greater than the largest surface dimension; or a dug hole whose depth is greater than the largest surface dimension; or an improved sinkhole; or a subsurface fluid distribution system which includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of UIC wells or a subsurface infiltration systems are drywells, drain fields, catch basins, pipe or french drains and other similar devices that discharge to ground.

Urban runoff Stormwater from streets and adjacent domestic or commercial properties that may carry pollutants of various kinds into storm sewers or drywells and/or receiving waters.

Variance See Exception.

Water body segment A stream reach or portion of a water body generally having the same characteristics. Water body segments may be defined by reaches between confluences with major tributaries or by section lines on a 1:24,000 scale topographical map.

Watershed The land area that drains into a stream, lake, or other body of water. An area of land that contributes runoff to one specific delivery point. Large watersheds may be composed of several smaller subwatersheds, each of which contributes runoff to different runoff locations that ultimately combine at a common delivery point or receiving water. The words "watershed" and "basin" are often used interchangeably.

Water quality A term used to describe the chemical, physical, and biological characteristics off water, usually in respect to its suitability for a particular purpose.

Water quality criteria Levels or measures of water quality considered necessary to protect a beneficial use.

Water quality standards Minimum requirements of purity of water for various uses; levels or measures of water quality considered necessary to protect a beneficial use. In Washington State, the Department of Ecology sets water quality standards.

Waters of the State State waters include lakes, rivers, ponds, streams, inland waters, underground waters, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of the state of Washington.

Water table The upper surface or top of the saturated portion of the soil or bedrock layer, indicating the uppermost extent of groundwater.

Wetlands Areas characterized by saturated or nearly saturated soils most of the year that form an interface between terrestrial (land-based) and aquatic environments. Wetlands include marshes around lakes or ponds and along river or stream channels.

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Chapter 2 - Core Elements for New Development and Redevelopment

2.1 Introduction

This chapter identifies and defines the eight Core Elements of stormwater management. These Core Elements are applicable to new development and redevelopment projects in eastern Washington that discharge to surface waters or to UIC rule-authorized subsurface infiltration systems. Not all Core Elements apply to every project, and depending on the type and size of a project, different combinations of the eight Core Elements will apply. See Chapter 1 of this Manual for the regulatory framework and conditions under which the Manual may be required for various projects. Best Management Practices (BMPs) for implementing the Core Elements are described in Chapters 5 through 8 of this Manual. Specific project exemptions are listed in Section 2.1.1 below. See the Glossary for definitions of many of the words and phrases that are used in this section.

The Core Elements are:

1. Preparation of a Stormwater Site Plan
2. Construction Stormwater Pollution Prevention
3. Source Control of Pollution
4. Preservation of Natural Drainage Systems and Outfalls
5. Runoff Treatment
6. Flow Control
7. Operation and Maintenance
8. Local Requirements

Each of these Core Elements is described in detail in Section 2.2. Table 2.A and Figure 2.A are intended to assist project proponents in determining which Core Elements apply to a given project. Project proponents need to be familiar with the contents of this Chapter.

Both Guidelines and Supplemental Guidelines are provided under the Redevelopment definition and under the Core Elements. The guidelines must be followed in order for a project to comply with the stormwater management provisions set forth in this Manual. Supplemental guidelines are optional and are included for consideration under special circumstances; these guidelines may be required in certain jurisdictions.

Table 2.A -- Matrix for use in determining applicability of Core Elements to new development and redevelopment projects in eastern Washington.

Total Impervious Surface Area	Pollutant-Generating Impervious Surface (PGIS) Area	#1 Preparation of Stormwater Site Plan (SSP)	#2 Construction Stormwater Pollution Prevention	#3 Source Control of Pollution	#4 Preservation of Natural Drainage Systems and Outfalls	#5 Runoff Treatment	#6 Flow Control	# 7 Operation and Maintenance	#8 Local Requirements
Less than 10,000 SF	Less than 5,000 SF	No *(1)*	Yes	Yes	Yes	No *(2)*	No	No *(1)*	Yes
Less than 10,000 SF	5,000 SF or Greater	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
10,000 SF or Greater	Less than 5,000 SF	Yes	Yes	Yes	Yes	No *(2)*	Yes	Yes	Yes
10,000 SF or greater	5,000 SF or greater	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

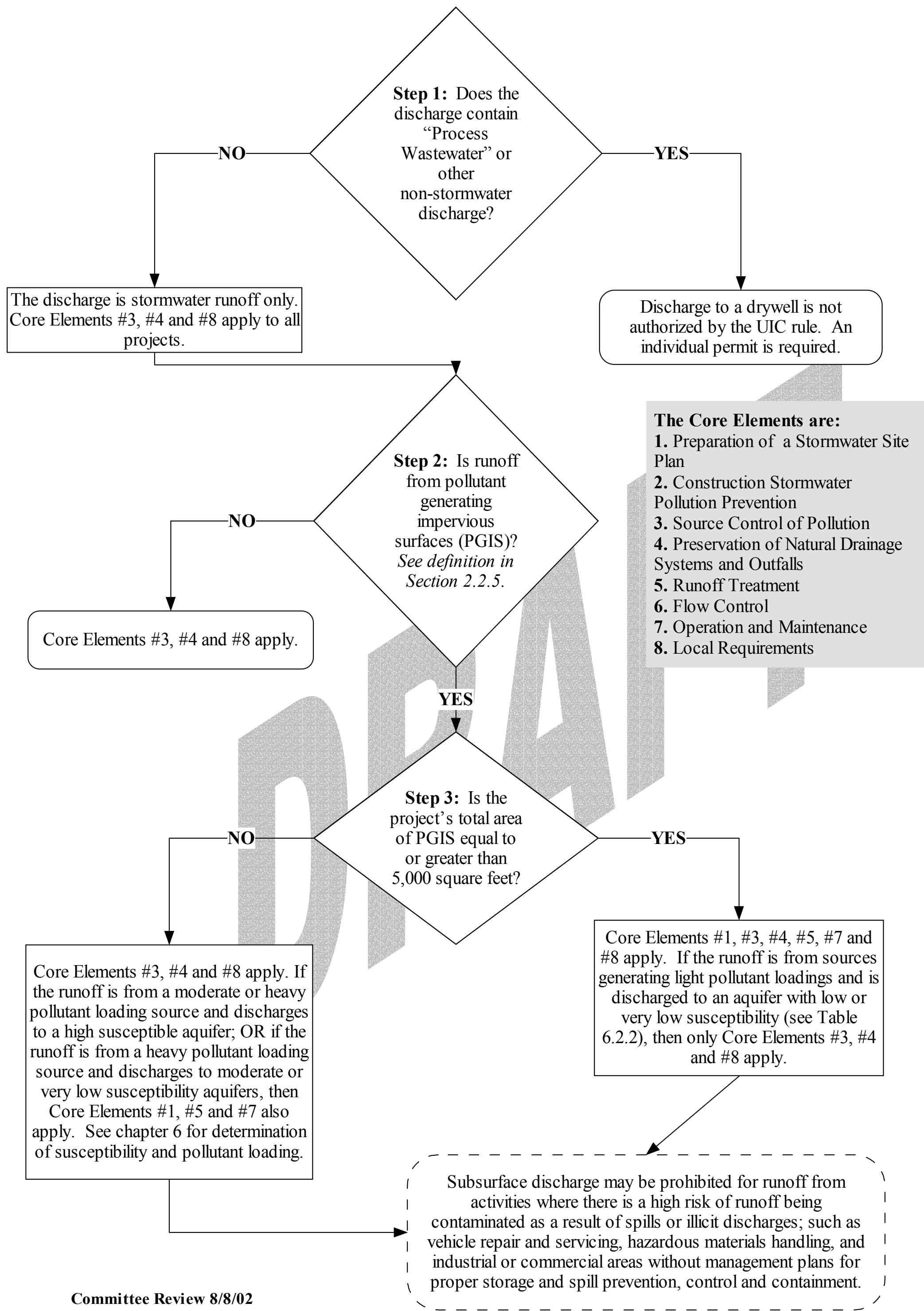
See Chapter 1 of this Manual for the regulatory framework and conditions under which the Manual may be required for various projects. See Chapters 5 and 6 of this Manual for additional information on requirements for discharges to drywells and other UIC rule-authorized subsurface infiltration systems. See the Glossary or Section 2.2.5 for the definition of Pollutant-Generating Impervious Surface (PGIS).

(1) Stormwater site plans and operation and maintenance are required for discharges to drywells and other UIC rule-authorized subsurface infiltration systems where runoff treatment is required.

(2) Runoff treatment is required for discharges to drywells and other UIC rule-authorized subsurface infiltration systems from all PGIS with heavy pollutant loading and from areas with moderate pollutant loading to aquifers with high susceptibility.

Figure 2.A
Flow chart for determining applicability of Core Elements to projects with drywells and other UIC rule-authorized subsurface infiltration systems

Guidance is provided in Chapter 6 of this manual for determining pollutant loading source and aquifer susceptibility classifications; and for site-by-site justification and requirements for discharges from moderate or heavy pollutant loading sources to highly susceptible aquifers. All projects should consider implementation of Core Element #2.



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2.1.1 Exemptions

All new development is subject to one or more of the Core Elements (see Section 2.2) unless specifically exempted below.

Forest Practices

Forest practices regulated under Title 222 WAC are exempt from the provisions of the Core Elements. Conversions of forest lands to other uses are not exempt.

Commercial Agriculture

Commercial agriculture practices involving working the land for production are generally exempt. However, the construction of impervious surfaces is not exempt.

Underground Utility Projects

Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics are only subject to Core Element #2 Construction Stormwater Pollution Prevention.

Road and Parking Area Maintenance

The following road and parking area maintenance practices are exempt: pothole and square cut patching, overlaying existing asphalt or concrete pavement with asphalt or concrete without expanding the area of coverage, shoulder grading, reshaping/regrading drainage systems, crack sealing, resurfacing with in-kind material without expanding the road prism, and vegetation maintenance.

Non-exempt practices: The following road and parking area maintenance practices are not categorically exempt. The extent to which the manual applies is explained for each circumstance.

- Removing and replacing a paved surface to base course or lower, or repairing the roadway base. If impervious surfaces are not expanded, only Core Element #2 Construction Stormwater Pollution Prevention will be applicable. If impervious surfaces are expanded, the new surfaces are subject to all of the Core Elements.
- Paving graveled shoulders or otherwise extending the pavement edge without increasing the size of the road prism. These are considered new impervious surfaces and are subject to all of the Core Elements.

Information for Reviewers: *The following bullet is intended to identify which road upgrade projects should be required to provide stormwater infrastructure (treatment and flow control). Upgrading from dirt to gravel, or from gravel to BST, is inexpensive but the runoff characteristics of the road surface change with each upgrade: there is more impervious surface area. Upgrading from BST to asphalt or concrete is expensive but the runoff characteristics are not changed to the same extent.*

> ***2-1 Feedback requested:*** *Should the requirement be based on the change in runoff characteristics, the cost of the project, or some combination of the two? Should improvements with regard to dust control also be considered?*

- Resurfacing by upgrading from dirt or gravel or bituminous surface treatment (BST or "chip seal") to asphalt or concrete. These are considered new impervious surfaces and are subject to all of the Core Elements.

2.1.2 New Development

New development is the conversion of previously undeveloped or pervious surfaces to impervious surfaces and managed landscape areas not specifically exempt above in Section 2.1.1. All new development is required to comply with Core Element #2 Construction Stormwater Pollution Prevention, Core Element #3 Source Control of Pollution, Core Element #4 Preservation of Natural Drainage Systems and Outfalls, and Core Element #8 Local Requirements. When the thresholds for Core Element #5 Runoff Treatment or Core Element #6 Flow Control are met, Core Element #1 Preparation of a Stormwater Site Plan and Core Element #7 Operation and Maintenance also apply.

2.1.3 Redevelopment

Objective

The intent of requiring certain redevelopment projects to upgrade their sites to meet stormwater management standards is to correct existing water quality problems caused by urban runoff. More stringent redevelopment thresholds and requirements may be identified through a water cleanup plan such as a Total Maximum Daily Load (TMDL) study and allocation or another basin planning process.

> ***2-2 Feedback requested:*** *A "developed site" is defined below as a site with at least 35% existing impervious surface coverage (consistent with the Stormwater Management Manual for Western Washington). What is the best way to define a developed site? Should each local jurisdiction establish its own definition?*

Redevelopment is defined as the replacement of impervious surfaces on a developed site with at least 35% existing impervious surface coverage, with the exception of replacements defined in Section 2.1.1 as maintenance activities. The Core Elements apply to all new impervious surfaces created by the project regardless of whether the redevelopment thresholds are met.

Redevelopment projects have the same requirements as new development projects in order to minimize the impacts from new surfaces. To encourage redevelopment projects, replaced surfaces are not required to meet new stormwater standards unless all four of the criteria in the redevelopment threshold below are met or exceeded. As long as the replaced surfaces have similar pollution-generating potential, the amount of pollutants discharged should not be significantly different. However, if the redevelopment project scope exceeds the area criteria noted below, the replaced surfaces are also required to meet current stormwater standards, consistent with other utility standards. (When a structure or a property undergoes significant remodeling, local governments often require the site to meet new building code requirements such as onsite sewage disposal systems, and fire systems.)

Guidelines

The Core Elements apply to all new impervious surfaces created by the project regardless of whether the redevelopment thresholds are met. When the following threshold is met, the Core Elements also apply to the replaced impervious surfaces. For projects that are implemented in incremental stages, the redevelopment threshold applies to the total amount of impervious surfaces added or replaced after local or State stormwater requirements are in place.

Once the threshold has been met, the Core Elements shall be applied to the portion of the site affected by the project. Table 1.B shows examples of applying the definition to four hypothetical redevelopment projects. Core Element #6 (Flow Control) does not apply unless required by the local jurisdiction or through a basin plan. On-site flow control is encouraged wherever possible. To maintain the integrity and function of the treatment systems, stormwater treatment facilities must be sized for the entire flow that is directed to them.

The redevelopment threshold is:

- The project replaces 5,000 square feet or more of pollutant-generating impervious surfaces (see Section 2.2.5), and
- The replaced impervious surfaces represent 50% or more of the existing impervious surfaces within the project limits, and

Information for reviewers: *The following bullet is intended to clarify that not all sites which are redeveloped in accordance with this Manual and then again at some point in the future should have to comply with new requirements that arise between the publication of this Manual and the next redevelopment.*

> ***2-3 Feedback requested**: What is the appropriate maximum time frame for such an exemption from new treatment requirements? (see note to reviewers above)*

- The site was most recently developed more than five years before this Manual was published or before equivalent or more stringent stormwater treatment was required by the local jurisdiction, and
- Treatment facilities at the site do not perform according to the requirements of this Manual.

Table 1.B – Examples of runoff treatment requirements for new and replaced impervious surfaces at four hypothetical 8-acre project sites

Impervious Surface Area (Acres; project site is a total of 8 acres)				**Is Runoff Treatment Required?**
Existing	Replaced	New	Total Proposed	
7.2	3	0	3	**No**, the replaced area is <50% of the existing impervious area.
4	3	0	3	**Yes**, the replaced area is >50% of the existing impervious area.
2	2	1	3	**Yes**, for new impervious area but not replaced; the existing impervious area is <35% of project site.
4	4	3.2	7.2	**Yes**, for new and replaced surfaces; the replaced area is >50% of the existing impervious area.

If the local jurisdiction has an equivalent retrofit program in place, then those requirements may replace these thresholds. The program must meet the intent of the requirements above and may need to be approved by the permitting authority. The requirements must be at least as stringent as the thresholds above, meaning that the number and types of projects regulated by the new requirements is the same or greater. Local governments can select from various bases for identifying projects that must retrofit the replaced impervious surfaces on the project site. Those can include:

- Exceeding 50% of the assessed value of the existing improvements;
- Exceeding 50% of the replacement value of the existing site;
- Exceeding a certain dollar value of improvements;

- Exceeding a certain ratio of the new impervious surfaces to the total of replaced plus new impervious surfaces; or exceeding an established threshold of added or replaced surfaces (e.g. the project adds 10,000 square feet or more of new impervious surfaces or replaces 20,000 square feet of impervious surfaces);
- There is a change in the use of the site to a use with greater potential to contaminate stormwater.

The local government may allow the Core Elements to be met for an equivalent (flow and pollution characteristics) area within the same site. For public road projects, the equivalent area does not have to be within the project limits, but must drain to the same water body segment and be located upstream from a confluence with another water body downstream from the project site.

A local government may provide exemptions or institute a maximum retrofitting cost provision for redevelopment projects from compliance with Core Elements for treatment, flow control, and wetlands protection as applied to the replaced impervious surfaces if the local government has adopted a plan and a schedule that fulfills those requirements in regional facilities.

Supplemental Guidelines

Local governments may institute a stop-loss provision on the application of stormwater requirements to replaced impervious surfaces. A stop-loss provision is an upper limit on the extent to which a requirement is applied. For instance, there could be a maximum percentage of the estimated total project costs that are dedicated to meeting stormwater requirements. A project would not have to incur additional stormwater costs above that maximum though the standard redevelopment requirements will not be fully achieved. Allowances may also be made for sites that would, by imposing the treatment requirement, become non-conforming to other requirements that apply to the site. The allowance for a stop-loss provision pertains to the extent that treatment, flow control and wetlands protection requirements are imposed on replaced impervious surfaces. It does not apply to meeting stormwater requirements for new impervious surfaces.

Local governments may also establish criteria for allowing redevelopment projects to pay a fee in lieu of constructing water quality or flow control facilities on a redeveloped site. At a minimum, the fee should be the equivalent of an engineering estimate of the cost of meeting all applicable stormwater requirements for the project. The local government should use such funds for the implementation of stormwater control projects that would have similar benefits to the same receiving water as if the project had constructed its required improvements. Expenditure of such funds is subject to other state statutory requirements.

Ecology cautions local governments about the potential long-term consequences of allowing a fee-in-lieu of stormwater facilities. Sites that are allowed to pay a fee continue without stormwater controls. If it is determined, through future basin planning for instance, that controls on such sites are necessary to achieve water quality goals or legal requirements, the public may bear the costs for providing those controls.

Sites with 100% existing building coverage that are currently connected to a municipally-owned storm sewer may continue to be connected without treatment, although additional local requirements such as flow restrictors may be required.

2.1.4 Local Exceptions/Variances

Exceptions to the Core Elements may be granted prior to permit approval and construction. The approving authority of the local government may grant an exception following an application for an exception with legal public notice per the local jurisdiction's guidance and requirements for exceptions and variances. The administrator's decision should include a written finding of fact that documents the following:

- There are special physical circumstances or conditions affecting the property such that the strict application of these provisions would deprive the applicant of all reasonable use of the parcel of land in question, and every effort to find creative ways to meet the intent of the Core Elements has been made; and
- That the granting of the exception will not be detrimental to the public health and welfare, nor injurious to other properties in the vicinity and/or downstream, and to the quality of waters of the state; and
- The exception is the least possible exception that could be granted to comply with the intent of the Core Elements.

If the local government chooses to allow jurisdiction-wide exceptions or variances to the requirements of the Manual, those exceptions must be approved by the permitting authority. Project-specific design deviations based on site-specific conditions generally do not require approval of the permitting authority and are left to the discretion of the local jurisdiction.

Supplemental Guidelines

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

2.2 Core Elements

This section describes the eight Core Elements for stormwater management at development and redevelopment sites. Chapters 5 through 8 of this Manual contain Best Management Practices (BMPs) to choose from in implementing these Core Elements for each project.

2.2.1 Core Element #1: Preparation of a Stormwater Site Plan (SSP)

Objective

Stormwater management is most successful when integrated into project planning and design. Projects are expected to demonstrate compliance with the applicable Core Elements through preparation of a Stormwater Site Plan.

Guidelines

All projects that meet the thresholds for water quality or flow control requirements (Core Element #5 or #6) are expected to complete a Stormwater Site Plan (SSP). When required, Stormwater Site Plans shall be prepared in accordance with Chapter 3 of this Manual. Projects proposed by departments and agencies within the local government with jurisdiction must comply with this requirement. The local government shall determine the process for ensuring proper project review, inspection, and compliance by its own departments and agencies.

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element applies when runoff treatment is required (see Core Element #5).

2.2.2 Core Element #2: Construction Stormwater Pollution Prevention

Objective

Runoff from project sites during the construction phase can contribute quantities of sediment and other contaminants sufficient to result in water quality violations. Controlling erosion and preventing sediment and other pollutants from leaving the project site during the construction phase is achievable through implementation of selected Best Management Practices (BMPs) that are appropriate both to the site and to the season during which construction activities take place. The Construction Stormwater Pollution Prevention Plan (SWPPP) identifies project-specific guidance for preventing pollution resulting from erosion and sediment runoff during the construction phase. A well-written SWPPP provides guidance that is neither over- nor under-protective for the project site. The Construction SWPP should include seasonally-appropriate guidance and anticipate adjustments that may be necessary in the event of delays in the construction schedule. If deemed appropriate, Construction SWPPPs may be revised during the construction phase of the project. The Construction SWPPP must be maintained on the construction site for reference and use by project personnel.

Guidelines

All projects are responsible for preventing erosion and discharge of sediment into surface waters and must consider each of the twelve elements of pollution prevention in order to determine which controls are appropriate for the project site. Chapter 7 of this Manual identifies and describes appropriate Best Management Practices (BMPs) for each of these elements.

Construction SWPPP Elements

The twelve Construction SWPPP elements are listed below. See Chapter 7 of this Manual for a description of each of these elements and suggested BMPs for each element.

1. Mark Clearing Limits
2. Establish Construction Access
3. Control Flow Rates
4. Install Sediment Controls
5. Stabilize Soils
6. Protect Slopes
7. Protect Drain Inlets
8. Stabilize Channels and Outlets
9. Control Pollutants
10. Control De-Watering
11. Maintain BMPs
12. Manage The Project

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element is not required, but projects should protect drywells from receiving sediment-laden runoff and other pollutants per SWPPP Element 9. See Supplemental Guidelines below.

Supplemental Guidelines

If a Construction SWPPP is found to be inadequate with respect to applicable erosion and sediment control requirements, then the approving authority within the local jurisdiction should require that other BMPs be implemented as appropriate.

The local jurisdiction may allow development of generic Construction SWPPPs that apply to commonly conducted public road activities that trigger this Core Element.

Construction Stormwater Pollution Prevention is recommended for all sites with drywells. Without preventive measures, sediment-laden runoff can enter newly constructed or existing drywells, reducing their infiltration capacity and lifetime of operation or increasing maintenance costs; other pollutants such as fuel can contaminate groundwater.

2.2.3 Core Element #3: Source Control of Pollution

Objective

The intent of Source Control Best Management Practices (BMPs) is to prevent stormwater from coming into contact with pollutants. Source control BMPs are a cost-effective means of reducing pollutant loading and concentrations in stormwater and should be a first consideration in all projects.

Guidelines

Projects shall apply all known, available and reasonable source control BMPs. Source control BMPs shall be selected, designed, and maintained according to this Manual.

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element is required for all projects with discharges to drywells and other UIC rule-authorized subsurface infiltration systems.

Supplemental Guidelines

A basin plan adopted and implemented by a local jurisdiction or a Total Maximum Daily Load (TMDL, also known as a Water Clean-up Plan) may be used to develop more stringent source control requirements that are tailored to a specific basin.

Source Control BMPs include Operational BMPs and Structural Source Control BMPs. See Chapter 8 of this Manual for design details of these BMPs. For construction sites, see Chapter 7.

2.2.4 Core Element #4: Preservation of Natural Drainage Systems and Outfalls

Objective

Preservation of natural drainage systems provides multiple benefits for stormwater management. Creating new drainage patterns results in more site disturbance and more potential for erosion and sedimentation during and after construction. Creating new discharge points can create significant stream channel erosion problems as the receiving water body typically must adjust to the new flows. Diversions can cause greater impacts than would otherwise occur by discharging runoff at the natural location. Wetlands can be severely degraded by discharges from urban development due to pollutants in the runoff and also due to disruption of the natural hydrology (especially changes in water levels and the duration of inundations) of the wetland system.

Guidelines

Natural drainage patterns should be maintained, and discharges from the project site should occur at the natural location, to the maximum extent practicable. The manner by which runoff is discharged from the project site must not cause a significant adverse impact to downstream receiving waters and down-gradient properties. All outfalls require energy dissipation.

This Core Element includes stormwater infiltration if that is the natural discharge method for the site. The designer shall investigate whether shallow groundwater, a sensitive aquifer, or other concerns will affect design choices for the project.

In order to maintain natural drainage systems to the maximum extent practicable, the options for stormwater discharge are, in order of preference:

1. Infiltrate on-site.
2. Infiltrate off-site.
3. Maintain dispersed sheet flow to match natural conditions.
4. Discharge to existing ditch networks, canals, or other dispersal methods that allow for potential groundwater recharge.
5. Discharge to wetlands, if allowed.
6. Discharge to existing stormwater systems.
7. Create a new outfall for discharge to surface waters.

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element applies to all projects.

Applicability to wetlands: Discharge of stormwater to existing wetlands, either directly or via a conveyance system, should be avoided unless the wetland receives surface runoff from the existing site. If possible, only stormwater from landscape and roof areas should be discharged to wetlands. The discharge must comply with all applicable Core Elements to ensure that wetlands receive the same level of protection as any other waters of the State.

A wetland can be considered for hydrologic modification and/or for use in stormwater treatment if:

- According to the Eastern Washington Wetland Rating System (see the draft rating form provided in Appendix 2A) it is a Category 4 wetland, or
- It is a Category 3 wetland and the following criteria are met:

- The wetland has monotypic vegetation of similar age and class, lacks special habitat features, and is isolated from other aquatic systems.
- The wetland has been previously disturbed by human activity, as evidenced by agriculture, fill areas, ditches, and/or introduced or invasive weedy plant species.
- The wetland has been deprived of a significant amount of its water supply by draining or previous urbanization (e.g., by loss of groundwater supply), and stormwater runoff is sufficient to augment the water supply.
- Construction for structural or hydrologic modification in order to provide runoff quantity or quality control will disturb relatively little of the wetland.
- The wetland can provide the required storage capacity for quantity or quality control through an outlet orifice modification to increase storage of water, rather than through raising the existing overflow. Orifice modification is likely to require less construction activity and consequent negative impacts.
- Under existing conditions the wetland experiences 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).
- The wetland is threatened by potential impacts exclusive of stormwater management, and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership.
- The wetland lies in the natural routing of the runoff and allows runoff discharge at the natural location.
- There is good evidence that the wetland actually can be restored or enhanced to perform other functions in addition to runoff quantity or quality control.

2-4 Feedback requested: *The following bullet is intended to provide additional scrutiny of some wetlands that may not be captured by the above criteria. How might these criteria be clarified?*

- The wetland does not exhibit any of the following features:
  - Regionally unusual biological community types; animal habitat features of relatively high value in the region; or the presence of protected commercial or sport fish;

- A significant priority peat system or forested zone that will experience a substantially altered hydroperiod as a result of the proposed action;
- Configuration and topography that will require significant modification that may threaten fish stranding;
- 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.

This requirement does not excuse any discharge from the obligation to apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC, or state ground water standards, Chapter 173-200 WAC. Additional treatment requirements to meet those standards may be required by federal, state, or local governments.

Supplemental Guidelines

For projects with no identified discharge point, local governments may wish to adopt guidance for disposal of water collected for runoff treatment per the requirements of Core Element #5 Runoff Treatment. The guidance is intended to protect downstream properties from flooding as a result of post-construction concentrated runoff.

Where no conveyance system exists at the adjacent down-gradient property line, and the discharge was previously unconcentrated flow or significantly lower concentrated flow, then measures must be taken to prevent down-gradient impacts. Drainage easements from downstream property owners may be needed and should be obtained prior to approval of engineering plans.

Where no conveyance system exists at the abutting downstream property line and the natural (existing) discharge is unconcentrated, any runoff concentrated by the proposed project must be discharged as follows:

- If the 25-year peak discharge is less than or equal to 0.1 cfs under developed conditions, then the concentrated runoff may be discharged in a manner that serves to disperse flows.
- If the 25-year peak discharge is less than or equal to 0.25 cfs under developed conditions, then the concentrated runoff may be discharged through a dispersal trench or other dispersal system, provided the applicant can demonstrate that there will be no significant adverse impact to downhill properties or drainage systems.
- If the 25-year peak discharge is greater than 0.25 cfs for the developed conditions, or if a significant adverse impact to downgradient properties or drainage systems is likely, then a conveyance system within a drainage easement must be provided to convey the concentrated runoff across the downstream properties to an acceptable

discharge point (i.e., an enclosed drainage system or open drainage feature where concentrated runoff can be discharged without significant adverse impact).

Designs for outfall systems to protect against adverse impacts from concentrated runoff are included in Chapter 5 of this Manual.

2.2.5 Core Element #5: Runoff Treatment

Objective

The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms so that beneficial uses of receiving waters are maintained, and where applicable, restored. Since the most effective BMPs remove only about 80% of the total suspended solids contained in the runoff treated – and a much smaller percentage of the dissolved pollutants – a conservative approach is encouraged. When site conditions are appropriate, infiltration can potentially be the most effective Best Management Practice for runoff treatment.

Guidelines

When required, treatment facilities shall be selected, designed, constructed, operated and maintained in accordance with the guidance in Chapter 6 of this Manual. The hydrologic analysis methods used to size runoff treatment facilities is provided in Chapter 4. All runoff treatment facilities must be sized for the applicable design storm(s) described in this section or according to alternative guidance as required by the local jurisdiction.

In order to maintain the integrity and function of the treatment systems, stormwater runoff treatment facilities must be sized for the entire flow that is directed to them.

If it is possible for the project to meet treatment requirements by dispersal and infiltration, the runoff should not be collected and concentrated; otherwise flow control (Core Element #6) may be required.

Treatment facilities applied in accordance with this manual are presumed to meet the requirement of state law to provide all known available and reasonable methods of treatment (RCW 90.52.040, RCW 90.48.010). This technology-based treatment requirement does not excuse any discharge from the obligation to apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC; state ground water quality standards, Chapter 173-200 WAC; state sediment management standards, Chapter 173-204 WAC; and the underground injection control program, Chapter 173-218 WAC. Additional treatment to meet those standards may be required by federal, state, or local governments.

Runoff treatment is required for all projects creating 5,000 square feet or more of pollutant-generating impervious surfaces (PGIS) with discharges to surface waters. PGIS are considered to be significant sources of pollutants in stormwater runoff. Such surfaces include those which are subject to vehicular use, industrial activities, or storage of erodible or leachable materials which receive direct rainfall or run-on or blow-in of rainfall. Metal roofs are also considered to be PGIS unless coated with an inert, non-leachable material. Treatment is required for discharges to all surface waters of the State, including perennial and seasonal streams, lakes and wetlands where the PGIS threshold is met. Certain exemptions may exist for Category 4 wetlands (see Core Element #4).

A surface, whether paved or not, shall be considered PGIS if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways. The following are not considered regularly-used surfaces and may be excluded from the calculation of total PGIS for the project: paved bicycle pathways and pedestrian sidewalks that are separated from and not subject to drainage from roads for motor vehicles, fenced fire lanes, and infrequently used maintenance access roads.

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: See Figure 2.A. All projects with greater than 5,000 square feet of PGIS must provide treatment for stormwater runoff discharging to drywells that are:

- Located above an aquifer with moderate or high susceptibility and the discharge is from any pollutant-loading source area.
- Located above an aquifer with very low susceptibility and the discharge is from a moderate or heavy pollutant-loading source area.

See Chapter 6 of this Manual for determination of pollutant-loading source area and aquifer susceptibility classifications.

This Core Element also applies to projects with heavy pollutant-loading source areas and less than 5,000 square feet of PGIS. This Core Element does not apply to discharges from non-pollutant generating surfaces (NPGIS), although pre-treatment for removal of solids may be needed to protect the long-term function of the drywell.

Discharges from pollution-generating impervious surfaces into a drywell or other infiltration facility, after pretreatment for solids reduction, can be acceptable if the geologic matrix and depth to groundwater provide sufficient treatment capacity as determined per the criteria in Chapter 6 of this Manual. Drywells or other infiltration facilities that discharge into soils without sufficient treatment capacity must be preceded by runoff treatment in accordance with this Core Element.

Discharges to drywells and other subsurface infiltration systems may not be allowed from industrial and commercial sites that use, store, and handle hazardous substances that have the potential to reach the subsurface and do not have a stormwater pollution prevention plan in accordance with the industrial stormwater permit program and/or the upcoming UIC rule requirements, Chapter 173-218 WAC. Note that discharges to drywells that contain process water or other any discharges besides stormwater are not UIC rule-authorized and require individual permits.

Additional local requirements may apply for any discharge to a drywell or infiltration facility.

Special High-Use Treatment: Projects proposing to develop or redevelop a high-use site must provide oil controls in addition to any other water quality controls required per this Core Element. High use sites generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil.

A high-use site is any one of the following (Watershed Protection Techniques, 1994; Seattle METRO, 1990; King County Surface Water Management, 1998):

- A commercial or industrial site with an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area, or
- A commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including routinely delivered heating oil, or
- A commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more diesel vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.), or
- A road intersection with a measured ADT count of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements. High-use roadway intersections shall treat lanes where vehicles accumulate during the signal cycle, including left and right turn lanes and through lanes, from the beginning of the left turn pocket. If no left turn pocket exists, the treatable area shall begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, treatment may be limited to any two of the collection areas.
- Fueling facilities.
- Vehicle maintenance and repair facilities.

High-use sites must treat runoff from the high-use portion of the site using oil control treatment options in Chapter 6 of this Manual prior to discharge or infiltration. For high-use sites located within a larger project area, only the impervious area associated with the high-use site is subject to oil control treatment, but the flow from that area must be separated; otherwise the treatment controls must be sized for the entire area. The ADT traffic threshold shall be estimated using information from Trip Generation, published by the Institute of Transportation Engineers, or from a traffic study prepared by a professional engineer or transportation specialist with experience in traffic estimation.

Treatment Facility Sizing: Each local jurisdiction must adopt only one of each of the following criteria in order to provide for consistent sizing of treatment facilities: a water quality design volume, and a water quality design flow rate. The jurisdiction may adopt either the preferred or an acceptable alternative in each case. Local jurisdictions should also identify a preferred method to calculate water quality design volume. Additional information, including the methods used to identify design storm volumes and flow rates, is included in Chapter 4 of this Manual, Hydrologic Analysis and Design. Specific design criteria for treatment facilities also may be assigned in Chapter 6 in order to achieve the performance goal of a particular BMP.

Information for Reviewers: *The preferred approaches below are based on a scientific analysis of historic precipitation patterns across eastern Washington. The derivation of these design storms is described in Chapter 4, Appendix 4A. The resulting storms are presumed to realistically reflect the types of rainfall commonly experienced in eastern Washington. The short-duration storm is an intense 3-hour summer thunderstorm and the long-duration storm is a less intense 72-hour winter/spring rainstorm. Use of these newly developed design storm distributions is proposed here for the first time and at the time of publication has not yet been field tested. The storm distributions were developed as part of Ecology's overall effort to tailor this Manual to the unique climatic aspects of eastern Washington. More discussion is provided under Core Element #6 Flow Control.*

The acceptable alternatives listed below are currently in use by local jurisdictions in eastern Washington. In some cases these current approaches require treatment of a greater volume of runoff than the preferred approaches below would require. It is generally not practical to treat 100% of the annual runoff volume generated by a project site. The storm with a six-month return frequency is believed to generate at least 90% of the annual surface runoff; this amount is considered to be a reasonable goal for capturing as many contaminants as practicable. For sizing volume-based BMPs, a past approach has been to treat the first flush of each storm event, which is believed to carry the majority of the pollutants in urban runoff. Research is inconclusive as to which method is more effective, and there is some overlap between the two approaches.

Proper operation and maintenance of the BMPs may be more significant than the actual volume of runoff treated in protecting receiving waters over the long term.

Water quality design volume: Volume-based treatment BMPs are sized the same whether located upstream or downstream from detention facilities:

Information for Reviewers: *The water quality design volume is based on the amount of runoff generated from a project site by a given precipitation depth. For the same project site, the precipitation depth identified by each of the following methods may be greater or less than the depth identified by the preferred alternative. Since the depth of precipitation for the regional long-duration storm (the 6-month, 72-hour storm) is calculated by multiplying the 6-month, 24-hour storm by a scaling factor greater than one, the preferred design volume is always more than alternative design volume #2 below. In Region 2, 0.5 inches of rainfall may be greater than the depth of precipitation during the regional long-duration storm; while in Region 3, 0.5 inches may be less than the depth of precipitation during the regional long-duration storm.*

Preferred design volume: The volume of post-developed runoff predicted from the regional long-duration storm with a six-month return frequency. Acceptable alternative design volumes:

1. In Region 2, volume-based facilities may be sized for the predicted post-development runoff produced by 0.5 inches of runoff from all impervious surface areas that contribute flow to the treatment facility. In Region 3, volume-based facilities also may be sized for the predicted post-development runoff produced by 0.5 inches of runoff from impervious surfaces that contribute flow to the treatment facility, but no infiltration credits may be granted for sizing treatment facilities using this method. See Figure 2.B for a map of the approximate delineation of the four climatic regions in eastern Washington. A more detailed figure is provided in Chapter 4.
2. The volume of post-developed runoff predicted from the 24-hour storm with a six-month return frequency.

Snowmelt factor:

2-5 Feedback requested: *In most years and in most areas of eastern Washington, snowmelt during rainstorms increases runoff volume. Snow that has accumulated on or has been plowed from PGIS may have higher concentrations of pollutants than runoff generated by rainfall. Should a snowmelt factor based on the water content of the average depth of snow be added to the depth of precipitation for calculating the water quality design volume? If so, should a snowmelt factor be applied in every climatic region?*

> ***2-6 Feedback requested:*** *Should all volume-based treatment facilities have a bypass that diverts all volumes in excess of the 25-year storm?*

Water quality design flow rate:

For runoff treatment facilities preceding detention facilities or when detention facilities are not required:

- Preferred design flow rate: The post-developed runoff flow rate from the short-duration storm with a six-month return frequency. Note that a longer time interval than the computation time step used in the modeling may be specified in the BMP design criteria.

> ***Information for Reviewers:*** *SBUH and other SCS-based calculation methods are considered to be equivalent. However, the short-duration and SCS Type II design storm distributions result in outputs with different time steps (5 or 10 minutes). Accordingly, the designer must pay close attention to the design specifications for each BMP.*

- Acceptable alternative design flow rates:
  1. The post-developed runoff flow rate from the SCS type II 24-hour storm with a six-month return frequency. Note that a longer time interval than the computation time step used in the modeling may be specified in the BMP design criteria.
  2. The post-developed runoff flow rate calculated by the rational method using the two-year Mean Recurrence Interval (see Chapter 4). This method may only be used to design facilities based on instantaneous peak flow rates.

For runoff treatment facilities sited downstream of detention facilities:

- The full 2-year release rate of the detention facility.

A bypass shall be provided unless the facility is able to convey the 25-year short-duration storm without exceeding the maximum allowable velocity or shear stress specified for the BMP in order to avoid causing damage to the facility or dislodging pollutants from within it.

Supplemental Guidelines

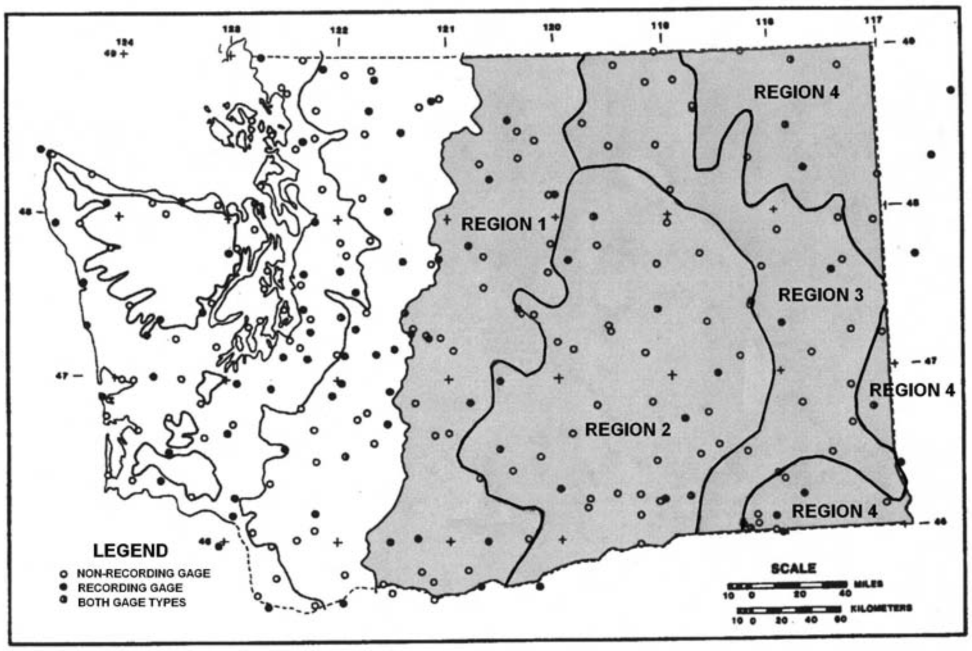
See Chapters 4 and 6 of this Manual for detailed guidance on selection, design, construction, operation and maintenance of treatment facilities. The preferred water quality design volume and flow rates are intended to size facilities to capture and effectively treat at least 90% of the annual runoff volume in eastern Washington. See Appendix 4A for background on their derivation.

Stormwater treatment facilities are not allowed within a wetland or its natural vegetated buffer except for:

- Necessary conveyance systems approved by the local government; or
- As allowed in a wetland mitigation plan.

This requirement does not excuse any discharge from the obligation to apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC, or state ground water standards, Chapter 173-200 WAC. Additional treatment requirements to meet those standards may be required by federal, state, or local governments.

Figure 2.B – Approximate delineation of climatic regions in eastern Washington



2.2.6 Core Element #6: Flow Control

Objective

Flow control is provided in order to prevent increases in the stream channel erosion rates that are characteristic of natural conditions. Urbanization and increased impervious surfaces (without facilities to infiltrate runoff from the more frequent, smaller storms) disrupts the equilibrium of stream channels. The increased runoff leads to bankfull conditions more often, causing more sediment transport and habitat disruption. When comparing the pre-developed (or existing) hydrograph with the developed condition hydrograph, the concern is not limited to the peak flow events; mitigating the duration of the flood flows is also important for stream channel stability and habitat. Detention basins that match peak runoff directly contribute more water to a stream over a longer period of time and extend the length of time the peak discharge rate is "at work" on the streambed, moving sediments. The cumulative impacts of many detention basins operating in a watershed and merging downstream further compound flooding and erosion problems. Erosion problems from an aquatic ecosystem perspective are much more subtle than from an engineering perspective: streambank undercutting and failures occur long after changes to the habitat function of the streambed.

Wherever possible, infiltration is the preferred method of flow control for urban runoff. Discharges to wetlands should maintain the hydrology (depth and duration of inundation) of the existing condition in order to protect the unique vegetation and other characteristics necessary to support existing and designated uses.

The intent of this Core Element is to prevent cumulative future impacts from urban runoff; the impacts of prior flow modifications in eastern Washington are not addressed through this Manual. Design specifications for conveyance and flood protection are determined by local jurisdictions. This Core Element does not address these issues.

Guidelines

Projects that create 10,000 square feet or more of total impervious surfaces and do not qualify for an exemption shall construct stormwater flow control facilities for any discharge of stormwater directly, or through a conveyance system, into surface water. Discharges to groundwater are exempt from flow control requirements. Flow control facilities shall be selected, designed, constructed, operated and maintained according to the criteria in Chapters 4 and 5 of this Manual. The requirements below apply to projects whose stormwater discharges into a non-exempt surface water, either directly or indirectly through a natural or man-made conveyance system. For a list of exempt surface waters, see the Exemptions section at the end of this Core Element.

In order to prevent localized erosion, energy dissipation at the point of discharge is required for all projects unless site-specific conditions or extremely low discharge rates warrant an exception.

Flow control design requirements to protect stream morphology: For all design storm distributions except the short-duration storm distribution (see "Design Storms" below), projects shall limit the peak release rate of the post-developed 2-year runoff volume to 50% of the pre-developed two-year peak flow and maintain the pre-developed 25-year peak runoff rate. For the short-duration storm distribution, projects shall maintain the pre-developed 2-and 25-year peak runoff rates and withhold the additional runoff volume produced by the 2-year event in the detention facility for evaporation or infiltration. Special consideration for cases where the 2-year peak flow rate is zero, or below the minimum capacity for a practicable outlet structure design are listed below.

Information for Reviewers: *The reason for defining the lowest release rate of a detention facility as 50% of the 2-year pre-developed peak runoff rate is to reduce the total amount of erosive work done on a frequent basis within the stream channel. See Chapter 1 (Section 1.2.1) for more information.*

Flow control design requirements to protect wetland hydrology: If the wetland does not have an outlet to a stream or has a direct outlet to an exempt stream, the project shall maintain the pre-developed 2-year and 25-year peak runoff rates for the long-duration storm; otherwise the project shall meet the flow control design requirement above to protect stream morphology. Category 3 or 4 wetlands may be excluded from this requirement (and used as detention and/or treatment facilities) if the criteria in Core Element #4 Preservation of Natural Drainage Systems and Outfalls are met; see also the draft Eastern Washington Wetland Rating System in Appendix 2A.

Special consideration for very low two-year pre-developed peak runoff rates: In many cases the two-year pre-developed flow rate is zero cubic feet per second, or the flow rate is so small that it is impracticable to design a pond to release at the prescribed flow rate from an engineered outlet structure. In these cases the total post-developed 2-year storm runoff must be infiltrated (preferred) or stored in a retention pond for evaporation, and the detention pond designed to release the pre-developed 10-year and 25-year flow rates. See Chapter 5 for release structure design information.

Snowmelt factor:

2-7 Feedback requested: *In most years and in most areas of eastern Washington, snowmelt during rainstorms increases runoff volume. Should a snowmelt factor based on the water content of the average depth of snow be added to the depth of precipitation for calculating the pre- and post-development runoff volumes? If so, should the snowmelt factor be applied in every climatic region?*

Design storms:

Information for Reviewers: *A commonly accepted practice in calculating the runoff produced by a single rainfall event is to use a synthetic rainfall distribution rather than an actual storm. The generic storm distribution currently used in many parts of eastern Washington is the SCS Type II storm, a mass-centered 24-hour storm distribution developed by the Soil Conservation Service (now the Natural Resource Conservation Service) and published in 1986 and identified for use in virtually all of the interior (non-coastal) United States. The SCS Type IA storm, published at the same time, has been used in Western Washington and in places along the* *east slopes of the Cascades; it is a less intense 24-hour rainfall distribution.*

As part of the background work in developing this Manual, historical precipitation patterns were analyzed to produce regionalized summer (short-duration thunderstorms) and winter/spring (less intense, long-duration rainfall) design storm distributions that reflect the rainfall patterns in four distinct climatic regions of eastern Washington (see Figure 2.B) and the seasonal variation across all of eastern Washington. The resulting storms are presumed to realistically reflect the types of rainfall commonly experienced in eastern Washington. The results of this analysis are described in detail in Chapter 4, Appendix 4A and are currently under review. Use of these newly developed design storm distributions is proposed here for the first time and at the time of publication has not yet been field tested.

Ecology proposes to have a phase-in period for implementing the use of the new rainfall distributions. Part of the reason for the phase-in is methodology: the methods and procedures will not be familiar to many practicing engineers, and additional training may be required. Another reason is to provide an opportunity for field testing of these design methods. During this public comment period, the Eastern Washington Stormwater Manual Subcommittee is looking for feedback on the various options proposed below for establishing the flow control standards for each climatic region of eastern Washington.

2-8 Feedback requested: *Please provide feedback on the options listed below for establishing the flow control design storm distribution standard. Which options make sense for protecting the streams in each region? Which options are likely to be successfully implemented by the designers and operators of the facilities? What other options or combination of options should be considered?*

- Design storm distribution for Regions 1 and 4:
  - Option 1: the regional long-duration storm distribution.
  - Option 2: the SCS Type IA storm distribution.
  - Option 3: the SCS Type II storm distribution.
  - Option 4: allow the design criteria currently in use by the local jurisdictions to be used.
  - Option 5: allow the design criteria currently in use by the local jurisdictions to be used until studies are completed and a final flow control standard is adopted by Ecology.

- Design storm distribution for Region 2:
    - Option 1: the short-duration storm distribution.
    - Option 2: the regional long-duration storm distribution.
    - Option 3: the SCS Type II distribution.
    - Option 4: identify a storm distribution for areas with less than 10 inches per year of average annual precipitation and apply the Region 3 storm distribution to sites with more than 10 inches of average annual precipitation.
    - Option 5: allow the design criteria currently in use by the local jurisdictions to be used.
    - Option 6: allow the design criteria currently in use by the local jurisdictions to be used until studies are completed and a final flow control standard is adopted by Ecology.
- Design storm distribution for Region 3:
    - Option 1: the regional long-duration storm distribution.
    - Option 2: the SCS Type II storm distribution.
    - Option 3: allow the design criteria currently in use by the local jurisdictions to be used.
    - Option 4: allow the design criteria currently in use by the local jurisdictions to be used until studies are completed and a final flow control standard is adopted by Ecology.
- Design storm distribution option to consider for any climatic region of eastern Washington: both the short-duration and the regional long-duration storm distributions.

> ***Information for Reviewers:*** *If both design storms are required, the facility will need to be designed to operate one way in the summer and another in the winter/spring. This might be accomplished by allowing flow through a weir or gate during the summer, with the gate located such that the difference in pre- and post-developed runoff for the summer storm is captured below the outlet, and closing the gate during the winter/spring months so that the facility operates by using a designed outlet structure; or perhaps by designing a bypass at the inflow to route the summer storm peak flow rates around the pond; other design ideas are welcomed.*

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element does not apply. See Chapter 5 for supplemental guidance on sizing drywells.

Supplemental Guidelines

Local jurisdictions may adopt a conservative, restricted set of curve numbers for estimating pre-development runoff.

Local jurisdictions may require detention basins to be designed to match the 10-year peak flow in addition to 50% of the two-year peak flow and the full 25-year peak flow. The purpose of this design specification is to improve the function of the detention basin in matching predeveloped peaks between 50% of the two-year peak flow and the full 25-year peak flow and possibly reduce the size of the detention facility.

Local jurisdictions may engage in basin planning, studies, zoning restrictions etc. that result in watershed- or reach- specific changes to the requirements of this Core Element. See also Exemption #10 below and guidance for adding water bodies to Exemption #6.

Exemptions

Flow control is not required for all discharges to surface waters in eastern Washington in order fulfill the objective of this Core Element to protect stream morphology. The exemptions listed below are provided to assist local jurisdictions in determining which discharges should be subjected to this Core Element. Any project may be subject to local requirements for flow control to prevent flooding. All projects are encouraged to infiltrate stormwater runoff on site to the greatest extent possible.

In consideration of other environmental issues, a local jurisdiction may wish to require flow control for one or more of the types of projects or water bodies listed below. Conversely, following analysis of a particular water body and/or its watershed, a local jurisdiction may determine that flow control is not necessary for certain discharges or to protect certain water bodies, or decide to provide a regional stormwater facility instead of requiring site-by-site flow control facilities. See the additional information below the list of exemptions.

The following projects and discharges are exempt from flow control requirements; runoff treatment may still be required per Core Element #5:

1. A project that does not discharge runoff – either directly or through a conveyance system – to surface water, including any project using infiltration as the method of disposing of stormwater runoff.
2. A project able to disperse, without discharge to surface waters, the post-developed 25-year runoff on property that is under the functional control of the project proponent.
3. A road project able to disperse, without discharge to surface waters, the post-developed 25-year runoff on public land for which this use has been specifically authorized by the controlling agency.
4. A project constructing less than 10,000 square feet of total impervious surfaces or generating less than
   0.1 cfs increase in runoff for the regional long-duration storm with a 25-year return frequency.

5. A project discharging to stream reaches consisting primarily of irrigation return flows and not providing habitat for fish spawning and rearing. The local irrigation district may impose other requirements.

6. A project discharging directly to free-flowing reaches of the Columbia, Snake, or Pend Oreille Rivers; directly to Lake Chelan, or Banks Lake; directly to reservoirs on the Columbia, Snake, Pend Oreille, or Spokane Rivers; or directly to another reservoir with outlet controls that are operated for varying discharges to the downstream reaches. In order to be exempted, the discharge shall meet the following requirements:

    a. The project area must be drained by a conveyance system that is comprised entirely of manmade conveyance elements (e.g., pipes, ditches, outfall protection, etc.) and extends to the ordinary high water line of the receiving water; and

    b. Any erodible elements of the manmade conveyance system for the project area must be adequately stabilized to prevent erosion; and

    c. Surface water from the project area must not be diverted from or increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact.

    Local jurisdictions may petition Ecology to add other rivers and lakes to the list in this exemption by submitting basin planning and studies of projected maximum build-out conditions for the watersheds.

> ***Information for Reviewers:*** *The Columbia, Snake, and Pend Oreille Rivers' watersheds are presumed by Ecology to meet the conditions of Exemption #10 below and therefore local jurisdictions are not required to perform basin studies for those watersheds. The reservoirs are included because the operation of the outlets – not the inflows to the reservoirs – controls instream flows in the reaches below the reservoirs, regardless of on-site surface flow controls.*

7. A project discharging to wetlands that have no surface water outlet do not need to meet the flow control requirements to protect stream morphology; flow control may still be required to protect the wetland (see the guidelines above).

8. A project located at a site with less than 10" average annual rainfall that is discharging to a seasonal stream which is not connected via surface flow to a perennial stream.

9. A project that discharges to an intermittent stream or channel which contains a stream only during runoff-producing events and does not discharge directly to a perennial stream.

> ***Information for Reviewers:*** *The following exemption attempts to define another condition (besides #2 and #3 above) under which rural*

projects may be exempted from flow control. The basis for the definition of the exemption is research in humid areas where irreversible impacts to streams occur at as little as 4% effective impervious area when flow control is not required and less than 65% of the natural vegetative cover is retained; at 10% effective impervious area, all streams are impacted when flow control is not required. In the absence of similar research in arid lands, Ecology recommends an approach based on the best available science. See Chapter 1 (Section 1.2.1) for more information.

10. A project discharging to a lake, river, or stream where the long-term, projected total impervious surface area in the contributing watershed for that water body is less than 4% of the total area based on current and probable future zoning requirements as determined through a basin analysis conducted by the local jurisdiction.

Any additional exemptions to this Core Element are left to the local jurisdiction based on basin planning and studies. These plans and studies should consider the total impervious area in the watershed under likely future development scenarios, other possible development impacts or contributions toward increasing future streamflow volumes, changing the stream channel morphology and/or increasing the potential for streambank erosion; other potential cumulative downstream effects; and unique habitat characteristics.

2.2.7 Core Element #7: Operation and Maintenance

Objective

Inadequate maintenance or improper operation is a common cause of failure for stormwater facilities, including drywells. To ensure that stormwater control facilities are adequately maintained and properly operated, projects are required to plan for and perform appropriate preventive maintenance and performance checks at regular intervals.

Guidelines

Where structural BMPs are required, projects shall operate and maintain the facilities in accordance with an Operation and Maintenance (O&M) plan that is prepared in accordance with the provisions in Chapters 5 and 6 of this Manual. The O&M plan shall address all proposed stormwater facilities and BMPs, and identify the party (or parties) responsible for maintenance and operation. At private facilities, a copy of the plan shall be retained onsite or within reasonable access to the site, and shall be transferred with the property to the new owner. For public facilities, a copy of the plan shall be retained in the appropriate department. A log of maintenance activity that indicates what actions were taken shall be kept and be available for inspection by the local government.

The local jurisdiction may develop a generic O&M plan for BMPs that are commonly used in public projects; commercial and residential property developers may also develop generic O&M plans for BMPs that are commonly used in their projects. Checklists of O&M actions and procedures may be helpful to the operators.

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element is required for all projects requiring runoff treatment.

Supplemental Guidelines

The description of each BMP in Chapters 5, 6, and 7 of this Manual includes a section on maintenance. Chapter 6 includes a schedule of maintenance standards for drainage facilities. Local governments should consider more detailed requirements for maintenance logs, such as a record of where wastes are disposed.

2.2.8 Core Element #8: Local Requirements

Objective

This manual describes the minimum Core Elements for stormwater management at project sites in eastern Washington. Due to the variety in hydrology, climate, topography, soils, and priorities for protection of water resources in some areas of eastern Washington, discretion is provided to local jurisdictions in expanding and implementing stormwater requirements.

Guidelines

All projects, regardless of size, shall meet additional local requirements for flood control, discharges to wetlands, protection of sensitive areas, basin plans, aquifer protections, special water quality requirements based on Total Maximum Daily Load (TMDL) or Water Clean-up Plan, or for any other purpose. Check with the local jurisdiction for the local requirements that are applicable to your project.

Applicability to drywells and other UIC rule-authorized subsurface infiltration systems: This Core Element is required for all projects.

2.3 Optional Guidance

The following guidance is offered as recommendations to local governments.

2.3.1 Financial Liability

Performance bonding or other appropriate financial guarantees should be required for all projects to ensure construction of drainage facilities in compliance with these standards. The type of financial instrument required is less important than ensuring there are adequate funds available in the event that performance is unsatisfactory or non-compliance occurs.

2.3.2 Adjustments

Adjustments to the Core Elements may be granted prior to permit approval and construction. The drainage manual administrator of the local government may grant an adjustment provided that a written finding of fact is prepared, that addresses the following:

- The adjustment provides substantially equivalent environmental protection, and
- The objectives of safety, function, environmental protection and facility maintenance, based upon sound engineering, are met.

2.3.3 Thresholds

Local jurisdictions may decrease the size of regulated projects and increase the number of requirements.

Appendix 2A – Eastern Washington Wetlands Rating Form

WETLANDS RATING FORM – EASTERN WASHINGTON
DRAFT – June 2002

Name of wetland (if known): ____
Location: 1/4 S: _______ of 1/4 S: _______ SEC: ______ TWNSHP: ______ RNGE: ______

Person(s) Rating Wetland: ____________________ Affiliation: ___________________
Date of site visit: _______

SUMMARY OF RATING

Category based on **FUNCTIONS** provided by wetland I___ II___ III___ IV___

Category based on **VALUES** supported by wetland I___ II___ III___ N/A___

Enter the "highest" Category from above.
This is the Category for the wetland.

Does the wetland being rated meet any of the criteria below? If you answer YES to any of the questions below you will need to protect the wetland according to the regulations regarding the special characteristics found in the wetland.

a) Check List for Wetlands That Need Special Protection, and That Are Not Included in the Rating	***b) ES***	***c) O***
d) *1. Is the wetland in an area (e.g. GIS polygon) that has been documented as a habitat for any* ***State or Federally listed Threatened or Endangered plant or animal species****? For the purposes of this rating system, "documented" means the wetland is on the appropriate state or federal database.*		*)*
f) *2. Does the wetland contain individuals of* ***Federal or State-listed Threatened or Endangered plant or animal species****? (information that is not on the state databases in #1 above)*	***g)***	***h)***
i) *3. Does the wetland contain individuals of* ***Priority species*** *listed by the WDFW for the state? (see text for list current at time of printing)*	***j)***	***k)***
4. Does the wetland have a **local significance** in addition to its functions. For example, the wetland has been identified in the Shoreline Master Program, the Critical Areas Ordinance, or in a local management plan as having special significance.		

Does the wetland being categorized meet any of the criteria for the following wetland types? The criteria for identifying these wetlands are described in the following section. These types of wetlands have importance and value that may supercede their functions. They will have to be categorized using questions 4-8, as well as questions 1-3.

Check List for Special Wetlands Included in the Rating System	YES	NO
Vernal Pool		
Alkali		
Forested		
Bog		
Natural Heritage Wetland		

Vernal pools - Vernal pools are precipitation based, seasonal wetlands. For the purposes of this rating system they include only “scabland-rock” and “rainpool” vernals. To be classified as a vernal pool the wetland should meet at least **two** of the following criteria:		
• Its only source of water is rainfall or snowmelt from a small contributing basin and has no groundwater input	**Y**	**N**
• Wetland plants are typically present only in the spring; the summer vegetation is typically upland annuals. *NOTE: If you find perennial, “obligate”, wetland plants the wetland is probably NOT a vernal pool*	**Y**	**N**
• The soil in the wetland are shallow (< 30 cm or 1ft deep) and is underlain by an impermeable layer such as basalt or clay.	**Y**	**N**
• Surface water is present for less than 120 days during the “wet” season.	**Y**	**N**
Alkali wetlands – The wetland meets **one** of the following two criteria		
• The wetland has a conductivity > 3.0 mS.	**Y**	**N**
• The wetland has a conductivity between 2.0 - 3.0 mS, and its plant cover in vegetated areas is more than 50% alkali plant species (see Table…).	**Y**	**N**
OR		
• The wetland meets two of the following three sub-criteria.	**Y**	**N**
o Salt encrustations around more than 80% of the edge of the wetland	**y**	**n**
o More than ¾ of the plant cover consists of species listed on Table ___	**y**	**n**
o A pH above 9.0. All alkali wetlands have a high pH, but please note that some freshwater wetlands may also have a high pH. Thus, pH alone is not a good indicator of alkali wetlands.	**y**	**n**
Natural Heritage Wetlands - The wetland is on record with the Washington Natural Heritage Program as a high quality native wetland.	**Y**	**N**

Bogs -The wetland is relatively undisturbed, has organic soils (NRCS definition of organic) deeper than 16 inches, and **one** of the following conditions is met:	**Y**	**N**
• Sphagnum mosses are a common ground cover (>30%) in area of organic soils AND the cover of invasive species (see Table ...) is less than 10% in moss area.	**y**	**n**
• Herbaceous wetland plants ("emergent" species) are the only vegetation class present (shrubs or trees < 10% cover) in the area of organic soils, AND at least one of the species listed in Table.. is a dominant or co-dominant, AND the cover of invasive species (see Table ..) less than 10%?	**y**	**n**
Forested Wetlands – The wetland has at least ¼ acre of native trees (such as alder, cedar, hemlock, cottonwood, and some willow species, etc.) within its boundary that meet these **two** criteria:	**Y**	**N**
• The trees provide a canopy over at least 30% of the ground within the extent of their distribution (at least ¼ acre).	**y**	**n**
• The trees are at least 20ft tall	**y**	**n**

To complete the next part of the data sheet you will need to determine the Hydrogeomorphic Class of the wetland being rated.

The hydrogeomorphic classification groups wetlands into those that function in similar ways. This simplifies the questions needed to answer how well the wetland functions. The Hydrogeomorphic Class of a wetland can be determined using the key below.

CLASSIFICATION KEY

1. Does the wetland **meet both** of the following criteria?

___The wetland is on the shores of a body of open water (without permanent erect vegetation) where at least 20 acres (8 ha) are permanently inundated (ponded or flooded);

___At least 30% of the open water area is deeper than 3 m (10 ft)?

NO – go to Step 2

YES – The wetland class is **Lake Fringe (Lacustrine Fringe)**

2. Does the wetland **meet all** of the following criteria?

____The wetland is on a slope (note that slope can be very gradual),

____The water flows through the wetland in one direction (unidirectional) and usually comes from seeps. It may flow subsurface, as sheetflow, or in a swale without distinct banks.

____The water leaves the wetland **without being impounded**?

NOTE: *Surface water does not pond in these type of wetlands except occasionally in very small and shallow depressions or behind hummocks(depressions are usually <3ft diameter and less than a foot deep).*

NO - go to Step 3

YES – The wetland class is **Slope**

3. Is the wetland in a valley or stream channel where it gets inundated by overbank flooding from that stream or river? In general, the flooding should occur at least once every ten years to answer "yes."

NO - go to Step 4

YES – The wetland class is **Riverine**

4. Is the wetland in a topographic depression in which water ponds, or is saturated to the surface, at some time in the year. This means that any outlet, if present, is higher than the interior of the wetland.

NO – go to Step 5

YES – The wetland class is **Depressional**

5. Your wetland seems to be difficult to classify. Sometimes we find characteristics of several different hydrogeomorphic classes within one wetland boundary. For example, seeps at the base of a slope grade into a riverine floodplain, or a small stream within a depressional wetland has a zone of flooding along its sides. If you have a wetland with several HGM classes present within its boundaries use the following table to identify the appropriate class to use.

HGM Classes Within Wetland	**Class to Use in Rating**
Slope + Riverine	**Riverine**
Slope + Depressional	**Depressional**
Slope + Lake Fringe	**Lake Fringe**
Depressional + Riverine	**Depressional**
Depressional + Lake Fringe	**Depressional**

If you are unable still to determine which of the above criteria apply to your wetland, or you have more than 2 HGM classes within a wetland boundary, classify the wetland as **Depressional** for the rating.

CATEGORIZATION BASED ON FUNCTIONS PROVIDED BY WETLAND

	WATER QUALITY FUNCTIONS - Indicators that wetland functions to improve water quality	**Points**
	1.1 Opportunity multiplier – Does the wetland have the opportunity to improve water quality? Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland?*(see text for more detailed guidance)* **YES** multiply score in 1.2, 1.3, 1.4 , or 1.5 **by 2** **NO** multiply score in 1.2, 1.3, 1.4 , or 1.5 **by 1**	**x 2 or x 1**
	Answer only the questions that are appropriate for the hydrogeomorphic class of the wetland	
D	**1.2 DEPRESSIONAL WETLANDS**	
D	Characteristics of surface water flows out of the wetland: Wetland has no surface water outlet - points = 5 Wetland has an intermittently flowing , or highly constricted, outlet – points = 3 Wetland has a permanently flowing surface outlet – points = 1	
D	The soil 2 inches below the surface is clay, organic, or smells anoxic (hydrogen sulfide or rotten eggs). YES points = 3 NO points = 0	
D	Characteristics of persistent vegetation (emergent, shrub, and/or forest): Wetland has persistent, ungrazed, vegetation >2/3 of area points = 5 Wetland has persistent, ungrazed, vegetation >1/3 of area points = 3 Wetland has persistent, ungrazed vegetation >1/10 of area points = 1 Wetland has persistent, ungrazed vegetation <1/10 of area points = 0	
D	Characteristics of seasonal ponding or inundation. *This is the area of ponding/inundation that fluctuates every year. Do not count the area that is permanently ponded..* Area seasonally ponded is > ½ total area of wetland points = 3 Area seasonally ponded is > ¼ total area of wetland points = 1 Area seasonally ponded is < ¼ total area of wetland points = 0 NOTE: *See text for indicators of seasonal and permanent inundation/flooding.*	
D	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 1.1)	x ____
D	**1.2 TOTAL - Depressional Wetlands** For **Water Quality Improvement Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	

R	**1.3 RIVERINE WETLANDS**	
R	Characteristics of surface depressions within wetland that can trap sediments during a flooding event: Depressions cover >1/3 area or wetland points = 6 Depressions cover > 1/10 area or wetland points = 3 Depressions cover < 1/10 area or wetland points = 1 No depressions present points = 0	
R	Characteristics of the vegetation in the wetland: Forest or shrub > 2/3 the area of the wetland points = 10 Forest or shrub > 1/3 area of the wetland points = 5 Persistent, ungrazed, emergent plants > 2/3 area of wetland points = 5 Persistent, ungrazed emergent plants > 1/3 area of wetland points = 2 Forest, shrub, and persistent emergent < 1/3 area of wetland points = 0	
R	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 1.1)	**x______**
R	**1.3 TOTAL -Riverine Wetlands -** For **Water Quality Improvement Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	
L	**1.4 LAKE FRINGE WETLANDS**	
L	Average width of vegetation along the lakeshore (do not include aquatic bed): Vegetation is more than 33ft (10m) wide points = 6 Vegetation is more than 16 (5m) wide points = 3 Vegetation is more than 6ft (2m) wide points = 1	
L	Characteristics of the vegetation in the wetland: Emergent plants cover >90% of the vegetated area points = 6 Emergent plants cover >2/3 of the vegetated area points = 4 Emergent plants cover >1/3 of the vegetated area points = 3 Any erect vegetation (non-aquatic bed) in > 2/3 area points = 3 Any erect vegetation in > 1/3 area points = 1 Aquatic bed cover > 2/3 vegetated area points = 0	
L	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 1.1)	**x______**
L	**1.4 TOTAL -Lake Fringe Wetlands** For **Water Quality Improvement Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	

S	**1.5 SLOPE WETLANDS**	
S	Characteristics of average slope of wetland: Slope is1% or less (i.e. a 1foot drop in elevation within 100 ft horizontal distance) points = 3 Slope is 1% - 2% points = 2 Slope is 2% - 5% points = 1 Slope is greater than 5% points = 0	
S	The soil 2 inches below the surface is clay, organic, or smells anoxic (hydrogen sulfide or rotten eggs). YES = 3 points NO = 0 points	
S	Characteristics of the vegetation in the wetland that trap sediments and pollutants: *Choose the points appropriate for the description that best fit conditions in the wetland. Dense vegetation means you have trouble seeing the soil surface.* Dense, ungrazed, emergent vegetation > 90% of the wetland. points = 6 Dense, ungrazed, emergent vegetation > 1/2 area points = 3 Dense, ungrazed, emergent vegetation > 1/4 area points = 1 More than 1/4 area grazed, mowed, tilled or veg. is not dense points = 0	
S	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 1.1)	x______
S	**1.5 TOTAL Slope Wetlands -** For **Water Quality Improvement Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	

	2. HYDROLOGIC FUNCTIONS - Indicators that wetland functions to reduce flooding, stream degradation, and shoreline erosion	Points
	2.1 Opportunity multiplier –Depressional, Riverine, or Slope Wetlands: Is the wetland in a landscape position where the flood storage, or reduction in water velocity, it provides helps protect downstream property and aquatic resources from flooding or excessive and/or erosive flows? *(Answer NO if the major source of water is irrigation return flow or it controlled by a reservoir)* **OR** **Lake Fringe Wetlands:** Are there features along the shore that will be impacted if the shoreline erodes? **YES** multiply score in 2.2, 2.3, 2.4 , or 2.5 **by 2** **NO** multiply score in 2.2, 2.3, 2.4 , or 2.5 **by 1**	**x 2 or x 1**
	Answer the questions that are appropriate for the hydrogeomorphic class of the wetland	
D	**2.2 DEPRESSIONAL WETLANDS**	
D	Characteristics of outlet for surface water flows: Wetland has no surface water outlet - points = 8 Wetland has an intermittently flowing, or highly constricted, outlet – points = 4 Wetland has a permanently flowing surface outlet – points = 1	
D	Depth of storage during wet periods: *Estimate the height of ponding above the surface of the wetland and record the appropriate points (see text for description of measuring height)*. Marks of ponding are at least 3 ft from surface of wetland (or area of permanent ponding) points = 8 Marks are at least 2 ft from surface OR the wetland is a "headwater" wetland" *(see text)* points = 6 Marks are at least 1ft from surface points = 4 Marks are at least 6 in. ft from surface points = 2 No marks above 6 in. evident; wetland has only saturated soils or very shallow ponding points = 0	
D	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 2.1)	x
D	**2.2 TOTAL Depressional Wetlands-** For **Hydrologic Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	

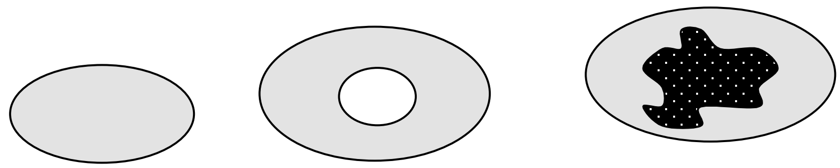
R	**2.3 RIVERINE WETLANDS**	
R	Characteristics of overbank storage the wetland provides: *Estimate the average width of the wetland in the direction of the flow and the width of the stream or river channel (distance between banks). Calculate the ratio of width of wetland/ width of stream.* If the ratio is more than 2 — points = 10 If the ratio is between 1 – 2 — points = 8 If the ratio is ½ – 1 — points = 4 If the ratio is ¼ - ½ — points = 2 If the ratio is < ¼ — points = 1	
R	Characteristics of vegetation that slow down water velocities during floods: *Treat large woody debris as "forest or shrub". Choose the points appropriate for the best description.* Forest or shrub for more than 2/3 the area of the wetland. — points = 6 Forest or shrub for >1/3 area OR Emergent plants > 2/3 area — points = 4 Forest or shrub for > 1/10 area OR Emergent plants > 1/3 area — points = 2 Vegetation does not meet above criteria — points = 0	
R	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 2.1)	x______
R	**2.3 TOTAL Riverine Wetlands -** For **Hydrologic Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	
L	**2.4 LAKE FRINGE WETLANDS**	
L	Average width and characteristics of vegetation along the lakeshore (do not include aquatic bed): *(choose the the highest scoring description that matches conditions in the wetland)* > ¾ of fringe vegetation is shrubs or trees at least 33 ft (10m) wide — points = 6 > ¾ of fringe vegetation is shrubs or trees at least 6 ft. (2 m) wide — points = 4 > ¾ of fringe vegetation is erect emergent at least 33 ft (10m) wide — points = 4 Fringe vegetation is at least 6 ft (2m) wide — points = 2 Fringe vegetation is less than 6 ft (2m) wide — points = 0	
L	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 1.1)	x______
L	**2.4 TOTAL Lake Fringe Wetlands -** Final score for **Hydrologic Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	

S	**2.5 SLOPE WETLANDS**	
S	Characteristics of vegetation that reduce the velocity of surface flows during storms. *Choose the points appropriate for the description that best fit conditions in the wetland.* Dense, ungrazed, **erect** vegetation covers > 90% of the area of the wetland. (stems of plants should be thick enough (usually > 1/8in), or dense enough, to remain erect during surface flows) points = 6 Dense, ungrazed, **erect** vegetation > 1/2 area of wetland points = 3 Dense, ungrazed, **erect** vegetation > 1/4 area points = 1 More than 1/4 of area is grazed, mowed, tilled or veg. is not erect points = 0	
S	Characteristics of slope wetland that holds back small amounts of flood flows: The slope wetland has small surface depressions that can retain water over at least 10% of its area. YES points = 2 NO points = 0	
S	*Add the points in the boxes above*	
	Opportunity Multiplier (from question 2.1)	x_____
S	**2.5 TOTAL Slope Wetlands -** For **Hydrologic Functions** Multiply the sum above by the "opportunity multiplier" ***Add score to total on p. 13***	

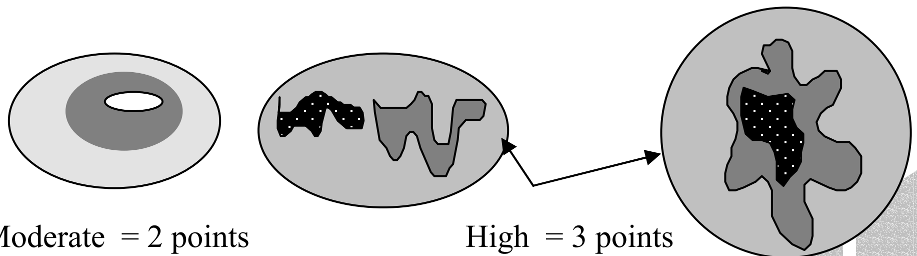
3. HABITAT FUNCTIONS - Indicators that wetland functions to provide important habitat	**Points**
These questions apply to wetlands of all HGM classes.	
3.1 <u>Vegetation structure</u>: *Check the types of vegetation types or structures present if the type covers more than 10% of the area of the wetland or ¼ acre.* ____Aquatic bed ____Emergent plants 0-12 inches high (0 – 30 cm) ____Emergent plants 12 – 40 inches high (30 – 100cm) ____Emergent plants > 40 inches high (> 100 cm) ____Scrub/shrub (areas where shrubs have >30% cover) ____Forested (areas where trees have >30% cover) *Add the number of vegetation types or structures that qualify. If you have:* 4-6 types *record* points = 3 3 types points = 2 2 types points = 1 1 type points = 0	
3.2 Is one of the vegetation types "aquatic bed"? YES = 1 point NO = 0 points	
3.3 <u>Surface Water</u>: 3.3.1 Does the wetland have areas of "open" water (without emergent or shrub plants) over at least 10% of its area during the spring (March – early June) OR in early fall (August – end of September)? *Note: answer YES for Lake Fringe wetlands* YES = 3 points & go to 3.4 NO = go to 3.3.2 3.3.2 Does the wetland have an intermittent or permanent stream within its boundaries or along one side (answer yes only if 3.3.1 is NO)? YES = 3 points NO = 0 points	
3.4 <u>Richness of Plant species</u> Count the number of plant species in the wetland that cover at least 10 ft^2. (*different patches of the same species can be combined to meet the size threshold)* *You do not have to name the species.* *Do not include European Millefoil, reed canarygrass, purple loosestrife, Russian Olive, Phragmites ,Canadian Thistle, and Salt Cedar (Tamarisk)* If you counted: > 10 species points = 2 4-9 species points = 1 < 4 species points = 0 points	

3.5 Interspersion of habitats

Decided from the diagrams below whether interspersion between types of vegetation structure (described in 13.1), or vegetation structures and unvegetated areas (can include open water or mudflats) is high, medium, low, or none.



None = 0 points Low = 1 point Moderate = 2 points



Moderate = 2 points High = 3 points

NOTE: If you have four or more vegetation structures or three vegetation structures and open water the rating is always “high”.

3.6 Special Habitat Features

Check the habitat features that are present in the wetland. The number of checks is the number of points you put into the next column.

____Loose rocks larger than 4” within the area of surface ponding or in stream.

____Large, downed, woody debris within the wetland (>4in. diameter).

____Cattails or Bulrushes are present within the wetland.

____Standing snags in the wetland or within 1m of the edge (diameter at the bottom > 4 inches).

____Emergent or shrub vegetation in areas that are permanently inundated/ponded. *The presence of “yellow flag” Iris is a good indicator.*

____Stable steep banks of fine material that might be used by beaver or muskrat for denning (>30 degree slope) OR signs of recent beaver activity

____ **TOTAL** Habitat Features

INDICATORS OF OPPORTUNITY

3.7 Buffers

Choose the description that best represents condition of buffer of wetland. The highest scoring criterion that applies to the wetland is to be used in the rating. See text for definition of "undisturbed."

- 100 m (330ft) of relatively undisturbed naturally vegetated areas, rocky areas, or open water >95% of circumference. No developed areas within undisturbed part of buffer. **Points = 5**
- 100 m (330 ft) of relatively undisturbed naturally vegetated areas, rocky areas, or open water > 50% circumference. **Points = 4**
- 50 m (170ft) of relatively undisturbed naturally vegetated areas, rocky areas, or open water >95% circumference. **Points = 4**
- 100 m (330ft) of relatively undisturbed naturally vegetated areas, rocky areas, or open water > 25% circumference, . **Points = 3**
- 50 m (170ft) of relatively undisturbed naturally vegetated areas, rocky areas, or open water for > 50% circumference. **Points = 3**

If buffer does not meet any of the three criteria above

- No paved areas or buildings within 25 m (80ft) of wetland > 95% circumference. Light to moderate grazing, or lawns are OK. **Points = 2**
- No paved areas or buildings within 50m of wetland for >50% circumference. Light to moderate grazing, or lawns are OK. **Points = 2**
- Heavy grazing in buffer. **Points = 1**
- Vegetated buffers are <2m wide (6.6ft) for more than 95% of the circumference (e.g . tilled fields, paving, basalt bedrock extend to edge of wetland **Points = 0**.
- Buffer does not meet any of the criteria above. **Points = 1**

3.8 Wet Corridors

3.8.1 Is the wetland part of a relatively undisturbed and unbroken, vegetated corridor with flowing water throughout most of the year? (*road crossings, tilled fields to edge of stream, pasture to edge of stream, are considered breaks in the corridor*).

YES = 4 points (go to 3.9) NO = go to 3.8.2

3.8.2 1 Is the wetland part of a relatively undisturbed and unbroken, vegetated corridor, with water flowing seasonally OR a Lake Fringe wetland?

YES = 2 points (go to 3.9) NO go to 3.8.3

3.8.3 Is the wetland within a 1/2 mile of any permanent stream, seasonal stream, or lake (*do not include man-made ditches*)?

YES = 1 point NO = 0 points

3.9 <u>Near or adjacent to other priority habitats listed by WDFW</u> Which of the following priority habitats are within 330ft (100m) of the wetland? ____Aspen Stands - Pure or mixed stands of aspen greater than 0.8 ha (2 acres). ____Cliffs - Greater than 7.6 m (25 ft) high and occurring below 1524 m (5000 ft). ____Old-growth forests (east of Cascade crest): In general, stands will be >150 years of age, with 25 trees/ha (10 trees/acre)> 53 cm (21 in) dbh, and 2.5-7.5 snags/ha (1 - 3 snags/acre) > 30-35 cm (12-14 in) diameter. Downed logs may vary from abundant to absent. Evidence of human-caused alterations to the stand will be absent or so slight as to not affect the ecosystem's essential structures and functions. ____Mature forests Stands with average diameters exceeding 53 cm (21 in) dbh; crown cover may be less that 100%; decay, decadence, numbers of snags, and quantity of large downed material is generally less than that found in old-growth; 80 - 160 years old east of the Cascade crest. ____Prairies and Steppe Relatively undisturbed areas (as indicated by dominance of native plants) where grasses and/or forbs form the natural climax plant community. ____Shrub-steppe Tracts of land consisting of plant communities with one or more layers of perennial grasses and a conspicuous but discontinuous layer of shrubs. These tracts should contain a variety of habitat features (e.g., variety of topography, riparian areas, canyons, habitat edges, plant communities). ____Talus Homogenous areas of rock rubble ranging in average size 0.15 - 2.0 m (0.5 - 6.5 ft), composed of basalt, andesite, and/or sedimentary rock, including riprap slides and mine tailings. May be associated with cliffs. ____Caves **2 or more Priority Habitats = 4 points 1 Habitat = 2 points**	
3.10 <u>Landscape</u> *(choose the description of the landscape around the wetland that best fits*) The wetland is in an area where annual rainfall is less than 12 inches, and its water regime is not influenced by irrigation practices, dams, or water control structures? (*Generally, this means outside boundaries of reclamation areas, irrigation district, or dammed reservoirs.* points = 5 There are at least 3 other wetlands within ½ mile, and the connections between them are relatively undisturbed (light grazing and lake shore OK, but connections should NOT be bisected by roads, fill, fields, or other development). points = 5 There are at least 3 other wetlands within ½ mile, BUT the connections between them are disturbed? points = 2 There is at least 1 wetland within ½ mile. points = 1 There are no wetland within ½ mile points = 0	

<u>3.11 Indicator of reduced habitat functions</u> Do the areas of open water in the wetland have a resident population of carp (see text for indicators of the presence of carp)? YES = **-** 10 points NO = 0 points	*Points will be subtracted*
3. *SCORE FOR INDICATORS OF HABITAT FUNCTIONS – add the points in the boxes above*	

SCORE FOR WATER QUALITY IMPROVEMENT FUNCTIONS	
SCORE FOR HYDROLOGIC FUNCTIONS	
SCORE FOR HABITAT FUNCTIONS	
TOTAL	
Category I = Score >70 **Category II = Score 51-69** **Category III = Score 30-50** **Category IV = Score < 30**	Category

CATEGORIZATION BASED ON VALUES

Please determine if the wetland meets the attributes described below and circle the appropriate Category. If the attribute does not apply, mark the box in the N/A column.	**Category**	
4. Natural Heritage Wetland (Important and Significant) Is the wetland on record with the Washington Natural Heritage Program as a high quality native wetland? YES = Category I NO = N/A	**CAT. I**	☐
5. Vernal pools (Important and Significant) 5.1 Is the wetland a vernal pool in an area where there are at least 3 other wetlands of any type, or bodies of open water, within 0.5 miles? YES = CAT. II NO = go to 5.2 5.2 Is the wetland a vernal pool? YES – CAT. III NO = N/A	**CAT. II**	☐
6. Alkali wetlands (Important, Significant, and Rare) Is the wetland an alkali wetland because it meets one of the three criteria listed previously? YES = CAT. I NO = N/A	**CAT. I**	☐
7. Bogs (Cannot Replicate and Sensitive to Disturbance) Does the wetland have an area of bog that meet the conditions listed previously. YES = CAT. I NO = N/A	**CAT. I**	☐
8. Forested Wetland (Cannot Replicate in a reasonable time) 8.1 Does the wetland have at least 1/4 acre of slow growing forest (slow growing forests include those where more than 50% of the tree species (by cover) are Pine, Cedar, Spruce ……. YES = CAT. I NO = go to 8.2 8.2 Does the wetland have at least ¼ acre of fast growing forest (fast growing forests include those where more than 50% of the tree species (by cover) are Cottonwood, Alder, Willow, ….. YES = CAT. II NO = N/A	**CAT. I** **CAT. II**	☐
Category of wetland based on Values *Choose the "highest" rating if wetland falls into several categories.* If you answered N/A for all attributes enter N/A		

Table of Contents

Chapter 3 - Preparation of Stormwater Site Plans

3.1 Introduction

The Stormwater Site Plan is the comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the Stormwater Site Plan will vary with the type and size of the project, individual site characteristics, and any special requirements of the local jurisdiction.

The scope of the Stormwater Site Plan also varies depending on the applicability of Core Elements (see Chapter 2).

This chapter describes the contents of a Stormwater Site Plan and provides a general procedure for how to prepare the plan. The specific BMPs and design methods and standards to be used are contained in Chapters 4 to 8.

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

State law requires that engineering work be performed by or under the direction of a professional engineer licensed to practice in Washington State. Plans involving construction of treatment facilities or flow control facilities (detention ponds or infiltration basins), structural source control BMPs, or drainage conveyance systems generally involve engineering principles and should be prepared by or under the direction of a licensed engineer. Construction Stormwater Pollution Prevention Plans (SWPPPs) that involve engineering calculations must also be prepared by or under the direction of a licensed engineer.

3.2 Stormwater Site Plans: Step-By-Step

3.2.1 The Steps to Developing a Stormwater Site Plan

Four basic steps should be followed during the preparation of a stormwater site plan.

Step 1 – Collect and Analyze Information on Existing Conditions

Step 2 – Determine Applicable Core Elements

Step 3 – Prepare a Permanent Stormwater Control Plan

Step 4 – Prepare a Construction Stormwater Pollution Prevention Plan

Steps 1 and 2 are qualtitative in nature, while Steps 3 and 4 synthesize the information gathered in Steps 1 and 2 into practical designs. Additional information on data collection and investigation can be found in Design and Construction of Urban Stormwater Management Systems, ASCE, 1992. The level of detail needed for each step depends upon the project size, as explained in the individual steps. A narrative description of each of these steps follows.

Step 1 – Collect and Analyze Information on Existing Conditions

Collect and review information on the existing site conditions, including topography, drainage patterns, soils, ground cover, presence of any critical areas, adjacent areas, existing development, existing stormwater facilities, and adjacent on- and off-site utilities. Analyze data to determine site limitations including:

- Areas with high potential for erosion and sediment deposition (based on soil properties, slope, etc.); and
- Locations of sensitive and critical areas (e.g. vegetative buffers, wetlands, steep slopes, floodplains, geologic hazard areas, streams, etc.).

Delineate these areas on the site map required as part of Step 3, Prepare a Permanent Stormwater Control Plan. Prepare an Existing Conditions Summary that will be submitted as part of the Site Plan. Part of the information collected in this step should be used to help prepare the Construction Stormwater Pollution Prevention Plan.

Offsite Analysis and Mitigation Procedure (for projects with surface discharge only)

Development projects that discharge stormwater offsite are required to submit an offsite analysis report that assesses the potential off-site water quality, erosion, slope stability, and drainage impacts associated with the project and that proposes appropriate mitigation of those impacts. Projects that do not discharge stormwater offsite do not need to perform an offsite analysis. An initial qualitative analysis should extend downstream for the entire flow path from the project site to the receiving water or up to one mile, whichever is less. If a receiving water is within one-quarter mile, the analysis should extend within the receiving water to one-quarter mile from the project site. The analysis should extend one-quarter mile beyond any improvements proposed as mitigation. The analysis should extend upstream to a point where any backwater effects created by the project cease. Upon review of the qualitative analysis, the local jurisdiction may require that a quantitative analysis be performed. A full description of a typical offsite analysis procedure, along with a sample checklist to aid in the preparation and review of an offsite analysis, are included in Appendix 3A.

Step 2 – Determine and Read the Applicable Core Elements

The NPDES Phase II permit or local jurisdiction establishes project size thresholds for the application of Core Elements (in Chapter 2), to new development and redevelopment projects. The designer of the Stormwater Site Plan should meet with local officials to agree on the applicable Core Elements, prior to proceeding to Step 3.

Step 3 – Prepare a Permanent Stormwater Control Plan

Select stormwater control BMPs and facilities that will serve the project site in its developed condition.

A preliminary design of the BMPs and facilities is necessary to determine how they will fit within and serve the entire preliminary development layout. After a preliminary design is developed, the designer may want to reconsider the site layout to reduce the need for construction of facilities, or the size of the facilities by reducing the amount of impervious surfaces created and increasing the areas to be left undisturbed. After the designer is satisfied with the BMP and facilities selections, the information must be presented within a Permanent Stormwater Control Plan. The Permanent Stormwater Control Plan typically consists of a Drainage Report and a set of Construction Plans.

Drainage Report

The Drainage Report is to be inclusive, clear, legible, and reproducible, with a complete set of drainage computations. The computations are to be presented in a rational format with information included so as to allow a reviewer to be able to reproduce the same results. The computations should provide sufficient information for an unbiased third party to be able to review the report and determine that all applicable standards have been met. All assumptions and computer input and output data, and variables listed in the computer printouts, should be clearly identified. Computer printouts should clearly show which subbasin(s) they are applicable to, and the design storm event identified thereon if multiple-storm events are addressed in the design. Copies of any design charts, nomographs or other design aids used in the analysis should be included in the calculations.

All relevant geotechnical information related to the project, and all site specific soil logs and subsurface testing information should be included in the Drainage Report or provided in a separate report prepared and stamped by the geotechnical engineer.

The Drainage Report should also include a basin map. Under most conditions both a pre-developed basin map and post-developed basin map should be provided, unless deemed unnecessary by the local review authority. See Appendix 3B for a checklist of items to be included on the basin map.

The Drainage Report is to identify any existing drainage facility which is clearly inadequate or needs repair, such as collapsed culverts or culverts with a substantial amount of debris. The condition and capacity of any existing drainage facility located onsite, which is proposed to be utilized by the development, should be evaluated and disclosed in the drainage report.

Calculations for detention and infiltration ponds may include the following: inflow and outflow hydrographs, level-pool routing calculations, a listing of the maximum water surface elevation, a pond volume rating table (e.g., stage vs. storage), and discharge rating table (e.g., stage vs. discharge). Each hydrograph and level-pool routing calculation sheet is to have clearly marked: the design storm event, the applicable subbasin(s), and the pond identification name, which corresponds with the basin map and plans.

The drainage submittal should incorporate all calculations for the determination of the required size of the systems. Typical calculations include:

- Hydrology computations
- Inlet Capacities
- Detention/Retention storage capacities
- Culvert and pipe system capacities and outlet velocities
- Ditch capacities and velocities
- Map with the project plotted thereon

A copy of any applicable floodplain maps, or studies within the project area should be included in the Drainage Report.

Construction Plans

Construction plans should be prepared for all open and closed stormwater collection systems. The plans should call out sufficient hydraulic and physical data for construction of the system, and future evaluation of the design. A checklist describing many of the items typically shown on construction plans is included in Appendix 3C.

Step 4 – Prepare a Construction Stormwater Pollution Prevention Plan

The Construction SWPPP must contain sufficient information to satisfy the local jurisdiction that the potential pollution problems have been adequately addressed for the proposed project. An adequate Construction SWPPP includes a narrative and drawings. The narrative is a written statement that explains the pollution prevention decisions made for a particular project. The narrative contains concise information concerning existing site conditions, construction schedules, and other pertinent items that are not contained on the drawings. The drawings and notes describe where and when the various BMPs should be installed, the performance the BMPs are expected to achieve, and actions to be taken if the performance goals are not achieved.

The 12 Elements listed below must be considered in the development of the Construction SWPPP unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the Construction SWPPP. These elements are described in detail in Chapter 7. They cover the general water quality protection strategies of limiting site impacts, preventing erosion and sedimentation, and managing activities and sources.

The 12 Elements are:

- Mark Clearing Limits
- Establish Construction Access
- Control Flow Rates
- Install Sediment Controls
- Stabilize Soils
- Protect Slopes
- Protect Drain Inlets
- Stabilize Channels And Outlets
- Control Pollutants
- Control De-Watering
- Maintain BMPs
- Manage the Project

A complete description of each Element and the BMPs applicable to particular Elements are given in Chapter 7.

On construction sites that discharge to surface water, the primary consideration in the preparation of the Construction SWPPP is compliance with the State Water Quality Standards. The step-by-step procedure outlined in Chapter 7 is recommended for the development of these Construction SWPPPs. A checklist is contained in Chapter 7 that may be helpful in preparing and reviewing the Construction SWPPP.

On construction sites that infiltrate all stormwater runoff, the primary consideration in the preparation of the Construction SWPPP is the protection of the infiltration facilities from fine sediments during the construction phase and protection of ground water from other pollutants. Several of the other elements are very important at these sites as well, such as marking the clearing limits, establishing the construction access, and managing the project.

3.2.2 Plans Required After Stormwater Site Plan Approval

This section includes the specifications and contents required of those plans submitted after the local government agency with jurisdiction has approved the original Stormwater Site Plan.

Stormwater Site Plan Changes

If the designer wishes to make changes or revisions to the originally approved stormwater site plan, the proposed revisions should be submitted to the local government agency with review authority prior to construction. The submittals should include the following:

1. Substitute pages of the originally approved Stormwater Site Plan that include the proposed changes.
2. Revised drawings showing any structural changes.
3. Any other supporting information that explains and supports the reason for the change.

Final Corrected Plan Submittal

If the project included construction of conveyance systems, treatment facilities, flow control facilities, or structural source control BMPs , the applicant should submit a final corrected plan (Record Drawings) to the local government agency with jurisdiction when the project is completed. These should be engineering drawings that accurately represent the project as constructed. These corrected drawings must be professionally drafted revisions that are stamped, signed, and dated by a licensed civil engineer registered in the state of Washington.

Appendix 3A – Offsite Analysis

Objective: To identify and evaluate offsite water quality, erosion, slope stability, and drainage impacts that may be caused or aggravated by a proposed project, and to determine measures for preventing impacts and for not aggravating existing impacts. Aggravated means increasing the frequency of occurrence and/or severity of a problem.

Supplemental Guidelines: Some of the most common and potentially destructive impacts of land development are erosion of downgradient properties, localized flooding, and slope failures. These are caused by increased surface water volumes and changed runoff patterns. Because these problems frequently do not have a related water quality impact, Ecology is not listing offsite analysis as a Core Element. However, taking the precautions of offsite analysis could prevent substantial property damage and public safety risks.

The existing or potential impacts to be evaluated and mitigated should include:

- Conveyance system capacity problems;
- Localized flooding;
- Upland erosion impacts, including landslide hazards;
- Stream channel erosion at the outfall location;
- Violations of surface water quality standards as identified in a Basin Plan or a TMDL (Water Clean-up Plan); or violations of ground water standards in a wellhead protection area.

Projects are required to initially submit, with the permit application, a qualitative analysis of each downstream system leaving the site. The analysis should accomplish four tasks:

Task 1 – Define and map the study area.

A submission of a site map showing property lines; a topographic map (at a minimum a USGS 1:24000 Quadrangle Topographic map) showing site boundaries, study area boundaries, downstream flowpath, and potential/existing problems.

Task 2 – Review all available information on the study area.

This should include all available basin plans, ground water management area plans, drainage studies, floodplain/floodway FEMA maps, wetlands inventory maps, Critical Areas maps, stream habitat reports, etc.

Task 3 – Field inspect the study area.

The design engineer should physically inspect the existing on- and offsite drainage systems of the study area for existing or potential problems and drainage features. An initial inspection and investigation should include:

- Investigate problems reported or observed during the resource review
- Locate existing/potential constrictions or capacity deficiencies in the drainage system
- Identify existing/potential flooding problems
- Identify existing/potential overtopping, scouring, bank sloughing, or sedimentation
- Identify significant destruction of aquatic habitat (e.g., siltation, stream incision)
- Collect qualitative data on features such as land use, impervious surface, topography, soils, presence of streams, wetlands
- Collect information on pipe sizes, channel characteristics, drainage structures
- Verify tributary drainage areas identified in Task 1
- Contact the local government office with drainage review authority, neighboring property owners, and residents about drainage problems
- Note date and weather at time of inspection

Task 4 – Describe the drainage system, and its existing and predicted problems

For each drainage system component (e.g., pipe, culvert, bridges, outfalls, ponds, vaults) the following should be covered in the analysis: location, physical description, problems, and field observations. All existing or potential problems (e.g., ponding water, erosion) identified in Tasks 2 and 3 above should be described. The descriptions should be used to determine whether adequate mitigation can be identified, or whether more detailed quantitative analysis is necessary. The following information should be provided for each existing or potential problem:

- Magnitude of or damage caused by the problem
- General frequency and duration
- Return frequency of storm or flow when the problem occurs (may require quantitative analysis)
- Water elevation when the problem occurs
- Names and concerns of parties involved
- Current mitigation of the problem
- Possible cause of the problem
- Whether the project is likely to aggravate the problem or create a new one.

Upon review of this analysis, the local government may require mitigation measures to address the problems, or a quantitative analysis, depending upon the presence of existing or predicted flooding, erosion, or water quality problems, and on the proposed design of the onsite drainage facilities. The analysis should repeat Tasks 3 and 4 above, using quantitative field data including profiles and cross-sections.

The quantitative analysis should provide information on the severity and frequency of an existing problem or the likelihood of creating a new problem. It should evaluate proposed mitigation intended to avoid aggravation of the existing problem and to avoid creation of a new problem.

Appendix 3B – Basin Maps

PROJECT: ____

LOCATION: ____

DESIGNER: ____________________ **COMPANY:** ________________

DATE: _______________________

The following items should be included on pre-developed and post-developed basin maps:

- ☐ Site boundary
- ☐ Basin limits, both on-site and off-site areas which contribute or receive stormwater runoff onto or from the project, field verified by the engineer.
- ☐ Drainage sub-basins. All sub-basins should be clearly labeled and correlated with the calculations.
- ☐ Topographic contours, which should extend beyond the project or drainage basin boundaries to the extent necessary to confirm basin limits used in the calculations; or, in the absence of topographic mapping being available, the Engineer may field verify the basin limits, including any contributing off-site areas, and should describe how the basin limits were determined.
- ☐ Significant drainage features, natural or man-made, such as creeks, seasonal drainage channels, culverts, closed depressions, manholes, etc.
- ☐ Time of concentration routes, clearly labeled and correlated with the calculations.
- ☐ Footprint of proposed drainage features, such as ponds, vegetated or other infiltration facilities, pipe routes, ditches, etc.
- ☐ Indications of floodplain limits, as defined by FEMA or other studies.
- ☐ North arrow and scale bar.
- ☐ Wetlands
- ☐ Existing easements

Appendix 3C – Stormwater Construction Plans

PROJECT: ____

LOCATION: ____

DESIGNER: ____________________ **COMPANY:** ________________

DATE: _______________________

The following items should be included on stormwater construction plans, as applicable:

- ☐ A plan-profile of all systems
- ☐ Invert elevations, slopes and lengths of ditches
- ☐ Cross sections of all open ditches
- ☐ Elevations of all inlet grates
- ☐ Size, types, invert elevations and lengths of all culverts and pipe systems
- ☐ Invert elevations of the existing or other proposed drainage system to which the drainage plan proposes to connect.
- ☐ Stationing of all inlets, culverts and pipe systems angle points
- ☐ Invert elevations of pipes at all structures such as catch basins or manholes
- ☐ Construction details for inlets, drywells, detention facilities, etc. (notes referring to Standard plans may suffice where applicable)
- ☐ Drainage easements with all survey information shown
- ☐ The location of existing underground and above ground utilities
- ☐ Lot grading elevations where appropriate
- ☐ Grading plan for drainage ponds. The grading plan should include existing contours, proposed contours and catch points. A typical cross-section of the pond should be provided in the plans, showing bottom of pond elevation, maximum water surface elevation for the design storm(s), inlet and outlet elevations, berm elevation and slopes, and keyway location and dimensions.
- ☐ Drainage ponds, pipe inlets and outlets, ditches, and drainage structures, which are serving public roads or are in single-family residential neighborhoods, should be horizontally defined with respect to property corners, street stationing, or a coordinate system.
- ☐ Drainage ditches should have their longitudinal grades defined with either a profile or elevation grades at intervals of 50 feet. Ditch centerlines and flow directions should be also be illustrated.

Table of Contents

Chapter 4 - Hydrologic Analysis and Design

4.1 Introduction

4.1.1 Purpose

The purpose of this chapter is to provide guidance for sizing (1) runoff treatment facilities for subsurface infiltration systems and surface water discharges; and (2) flow control facilities for protection of stream morphology.

4.1.2 Hydrologic Analysis Methods and Applicability

Information for Reviewers: *In order to protect receiving waters from the impacts of urban stormwater, certain hydrologic analysis and design information is needed. In addition to site-specific information, several parameters must be specified. First, a design storm must be selected to identify the amount and pattern of rainfall that will be used to determine runoff volume and flow rate. The design storm must have a precipitation depth (selected based on the recurrence interval) and a distribution. Then this design storm must be input to an appropriate hydrologic model that computes runoff from the site and determines the total the runoff volume and the peak runoff flow rate; these results are the basis for properly designing runoff treatment and flow control facilities to protect receiving waters.*

The Eastern Washington Stormwater Management Manual Subcommittee has been collecting and reviewing information about design storm and modeling options that may be appropriate for application in eastern Washington. The SCS Type II storm, which has been the standard storm distribution for some areas of eastern Washington for many years, is a generic storm published in 1986 and identified for use in virtually all of the interior (non-coastal) United States. Use of a custom design storm distribution that reflects historic rainfall patterns at locations around eastern Washington could result in improved stormwater management. Custom design storm distributions have been developed for four climatic regions of eastern Washington and are presented for reviewers' consideration here and in Chapter 2, Core Elements #5 and #6.

A Technical Advisory Working Group comprised of members of the subcommittee was recently convened to evaluate the custom storm distributions, assess their probable effectiveness in protecting streams in eastern Washington, and identify some of the associated costs and impacts. The Working Group has contacted outside experts to assist in evaluating the modeling options. In order for the Subcommittee to collect and consider the best possible information, this effort is continuing during the draft public comment period on the Manual. The Subcommittee and Working Group appreciate any suggestions and guidance that may be provided by reviewers during the public comment period. For reviewers that are interested in following the discussions and efforts of the Working Group, additional information will be posted at Ecology's stormwater website http://www.ecy.wa.gov/programs/wq/stormwater/index.html

The local jurisdiction may approve one or more of the following methods to analyze stormwater runoff from projects for design of runoff treatment and flow control BMPs subject to these Guidelines:

- Single Event Hydrograph Methods including SCS Hydrograph and Santa Barbara Urban Hydrograph (SBUH)
- SCS Curve Number Equations
- Level Pool Routing
- Rational Method
- Other Hydrograph Models Approved by Local Jurisdictions

Table 4-1.1 summarizes the situations in which each of these methods may be used.

Sections 4.4 through 4.7 describe the use of the Rational, SCS Curve Number Equations, Single Event Hydrograph, and Level Pool Routing methods in greater detail.

The chapter does not provide guidance for sizing flood control facilities, conveyance systems, or subsurface infiltration facilities (drywells), though these methods may be used. Contact the local jurisdiction regarding design requirements for these elements.

Table 4-1.1
Applicability of Hydrologic Analysis Methods
For Runoff Treatment and Flow Control Design

Method	Application
Single Event Hydrograph Method – Soil Conservation Service (SCS) Hydrograph or Santa Barbara Urban Hydrograph (SBUH)	Allowable method for computing peak runoff rates and runoff volumes for design of runoff treatment BMPs. Required method for design of flow control BMPs. Computer is recommended due to intensive nature of calculations. **Note 1**: Volumes have been predetermined for several BMPs based on the long-duration water quality storm. The only design information required is the 2-year 24-hour precipitation, the infiltration rate for design of infiltration swales, and the size of the contributing area. See Chapter 6. **Note 2:** Some SCS hydrograph models such as TR-55 are restricted to 24-hour hyetographs and will not allow the custom long and short-duration storm hyetographs developed for Eastern Washington.
Soil Conservation Service (SCS) Curve Number Equations	Allowable method for computing volumes for water quality facilities based on SCS Hydrograph method. Can be determined using a calculator.

Method	Application
Level-Pool Reservoir Routing	Required method for routing hydrograph and determining size of flow control BMPs. Input may be SCS or SBUH hydrographs. Computer is recommended due to intensive nature of calculations.
Rational	Allowable method for computing peak runoff rates for flow based water quality BMPs such as biofiltration swales and oil/water separators. Common method for designing drywells and conveyance systems. Can be determined using a calculator or spreadsheet program.
Other Hydrograph Models	Other models can be used if approved by the local jurisdiction and the models provide equivalent treatment levels. Computer is recommended for most models due to intensive nature of calculations.

4.1.3 Hydrologic Analysis for Core Element #5 - Runoff Treatment

Runoff treatment BMPs are utilized to treat the stormwater runoff from pollutant generating surfaces. Core Element #5 in Chapter 2 identifies the design storm that needs to be treated. The size of runoff treatment BMPs is determined in several ways.

Volume Based Treatment BMPs

For volume based BMPs, there are four methods. They are:

- Preferred Method 1 (PM1): This is the first of the two methods used to determine the preferred design volume. This method utilizes lookup tables based on the magnitude of the water quality storm and the swale infiltration rate. Sizing factors have been developed for bioinfiltration swales and wetponds in most areas of Eastern Washington to minimize calculations and simplify application. Input data consists of 2-year 24-hour precipitation and infiltration rate. Detention/depression storage on the impervious area and the infiltration capability of the treatment area is accounted for. This method is applicable in all areas with 2-year 24-hour precipitation less than 1.56 inches (all of Region 2 and portions of Regions 1, 3, and 4.) See Sections 6.4.4 and 6.8.3 for the lookup tables.
- Preferred Method 2 (PM2): This is the second of the two methods used to determine the preferred design volume. This method develops a Site Specific Hydrologic Analysis using the site specific infiltration rate, a coefficient for computing the 6-month storm and the long-duration storm hyetograph. The SCS Curve Number Equation or the Single Event Hydrograph method can be used to determine the size of a wetpond or bioinfiltration swales. The wetpond equals the total volume of the hydrograph determined via either method.

- Alternative Method 1 (AM1): This is the method used to determine the acceptable alternative design volume number 1. This method utilizes the Spokane Bioinfiltration Swale Sizing Method of 0.5 inch runoff with no infiltration. Multiply the pollution generating impervious surface (PGIS) area contributing to the swale times 0.5 inches. This is the treatment volume of the swale. This method is only applicable in Regions 2 and 3 and is only intended for the design of bioinfiltration swales.
- Alternative Method 2 (AM2): This is the method used to determine the acceptable alternative design volume number 2. This method develops a Site Specific Hydrologic Analysis using the site specific infiltration rate, a coefficient for computing the 6-month storm and the 24-hour SCS Type II hyetograph. The Single Event Hydrograph method is used to determine the size of a wetpond or bioinfiltration swales.

If the volume based design for Method PM2 or AM2 is of an infiltration swale, then the hydrograph needs to be routed through an infiltration facility using the level-pool reservoir routing method. For infiltration facilities the level-pool reservoir model input includes the infiltration area and rate.

Peak Flow Based Treatment BMPs

For peak flow based treatment BMPs, the peak flow rate is determined by the single event hydrograph method or the rational method. Input to the single event hydrograph methods such as SCS or SBUH is the pervious and impervious basin areas, pervious and impervious time of concentration, pervious and impervious curve number, design storm precipitation, and design storm hyetograph. The information for determining this input is provided in this chapter and from the site plan and topography. The water quality design storm is obtained by scaling the dimensionless design short-duration storm hyetograph by the 6-month 2-hour precipitation. The peak flow rate is one of the outputs of the hydrograph methods.

The rational method is a more conservative method commonly used for conveyance design, which will result in larger BMPs. However, the design is less complex, so this method may be desired for small projects. The 2-year mean recurrence interval precipitation should be used for the rational method which adds to the conservative result.

Hydrologic Analysis for Core Element #6 – Flow Control

Core Element #6 in Chapter 2 identifies the design storms that need to be matched when designing flow control BMPs and projects that are exempt from flow control. In order to design a flow control BMP, a hydrograph model needs to be run for the existing and developed conditions for each of the design storms. The suggested hydrograph method is the Single Event Hydrograph such as SCS or SBUH method, however local jurisdictions are authorized to use other methods or more stringent design storms criteria. Input to a Single Event Hydrograph Method is the pervious and impervious basin areas, pervious and impervious time of concentration, pervious and impervious curve number, design storm precipitation, and design storm hyetograph. The information for determining this input is provided in this chapter and from the site plan and topography.

After the existing and developed hydrographs are computed, the results are routed through a level-pool reservoir. The level-pool reservoir is a model of either a detention or infiltration facility. If it is a detention facility, the design includes a flow control structure consisting of one or more orifices in a riser or baffle wall which meter the output. If it is an infiltration facility the model input includes the infiltration area, rate, and an outfall if provided. The level pool routing method is used to optimize the size of the facility with the space and depth available and meet the design criteria from Core Element #6.

4.2 Design Storm Events

The design storms to be used in Eastern Washington are based on two parameters:

- Total rainfall volume (depth in inches).
- Rainfall distribution (dimensionless).

The design storm event is specified by return frequency and duration. The following sections explain total rainfall depth and rainfall distribution associated with a design storm.

All storm event hydrograph methods require the input of a rainfall distribution or design storm hyetograph. The design storm hyetograph is essentially a plot of rainfall depth versus time for a given design storm frequency and duration. It is usually presented as a dimensionless plot of unit rainfall depth (incremental rainfall depth for each time interval divided by the total rainfall depth) versus time.

Information for Reviewers: *A commonly accepted practice in calculating the runoff produced by a single rainfall event is to use a synthetic rainfall distribution rather than an actual storm. The generic storm distribution currently used in many parts of eastern Washington is the SCS Type II storm, a mass-centered 24-hour storm distribution developed by the Soil Conservation Service (now the Natural Resource Conservation Service) and published in 1986 and identified for use in virtually all of the interior (non-coastal) United States. The SCS Type IA storm, published at the same time, has been used in Western Washington and in places along the east slopes of the Cascades; it is a less intense 24-hour rainfall distribution.*

Information for Reviewers (continued): *As part of the background work in developing this Manual, historical precipitation patterns were analyzed to produce regionalized summer (short-duration thunderstorms) and winter/spring (less intense, long-duration rainfall) design storm distributions that reflect the rainfall patterns in four distinct climatic regions of eastern Washington (see Figure 2.B) and the seasonal variation across all of eastern Washington. The resulting storms are presumed to realistically reflect the types of rainfall commonly experienced in eastern Washington. The results of this analysis, described in detail in Chapter 4 (Section 4.2), are currently under review. Use of these newly developed design storm distributions is proposed here for the first time and at the time of publication has not yet been field tested.*

Ecology proposes to have a phase-in period for implementing the use of the new rainfall distributions. Part of the reason for the phase-in is methodology: the methods and procedures will not be familiar to many practicing engineers, and additional training may be required. Another reason is to provide an opportunity for field testing of these design methods. During this public comment period, the Eastern Washington Stormwater Manual Subcommittee is looking for feedback on the various options proposed below for establishing the flow control standards for each climatic region of eastern Washington. Consult Section 4.2.2 for a description of each climatic region and consult Figure 4-3.1 for a geographical location of each climatic region.

4-1 Feedback requested: *Please provide feedback on the options listed below for establishing the flow control design storm standard. Which options make sense for protecting the streams in each region? Which options are likely to be successfully implemented by the designers and operators of the facilities? What other options should be considered?*

Design storm distribution for Regions 1 and 4:

- Option 1: the regional long-duration storm distribution.
- Option 2: the SCS Type IA storm distribution.
- Option 3: the SCS Type II storm distribution.
- Option 4: allow the design criteria currently in use by the local jurisdictions to be used.
- Option 5: allow the design criteria currently in use by the local jurisdictions to be used until studies are completed and a final flow control standard is adopted by Ecology.

Design storm distribution for Region 2:

- Option 1: the short-duration storm distribution.
- Option 2: the regional long-duration storm distribution.

- Option 3: the SCS Type II distribution.
- Option 4: identify a storm distribution for areas with less than 10 inches per year of average annual precipitation and apply the Region 3 storm distribution to sites with more than 10 inches of average annual precipitation.
- Option 5: allow the design criteria currently in use by the local jurisdictions to be used.
- Option 6: allow the design criteria currently in use by the local jurisdictions to be used until studies are completed and a final flow control standard is adopted by Ecology.

Design storm distribution for Region 3:

- Option 2: the regional long-duration storm distribution.
- Option 3: the SCS Type II storm distribution.
- Option 4: allow the design criteria currently in use by the local jurisdictions to be used.
- Option 4: allow the design criteria currently in use by the local jurisdictions to be used until studies are completed and a final flow control standard is adopted by Ecology.

Design storm distribution option to consider for any climatic region of eastern Washington: both the short-duration and the regional long-duration storm distributions.

> ***Information for Reviewers:*** *If both design storms are required, the facility will need to be designed to operate one way in the summer and another in the winter/spring. This might be accomplished by allowing flow through a weir or gate during the summer, with the gate located such that the difference in pre- and post-developed runoff for the summer storm is captured below the outlet, and closing the gate during the winter/spring months so that the facility operates by using a designed outlet structure; or perhaps by designing a bypass at the inflow to route the summer storm peak flow rates around the pond; other design ideas are welcomed.*

4.2.1 SCS Type II and Type IA Hyetograph

The Type II hyetograph is the standard NRCS rainfall distribution that has been utilized in most of Eastern Washington. The Type II hyetograph has a high intensity peak and is also used throughout much of the United States. The Type IA hyetograph is utilized along the eastern slope of the Cascade Mountains as well as in Western Washington. These are two of four 24-hour storm distribution types commonly used in SCS hydrograph methods.

See Figure 4-2.1 and 4-2.2 for graphical representation of these two SCS hyetographs. Tabular values of these hyetographs are in Table 4-2.1 and 4-2.2.

FIGURE 4-2.1
Typical SCS Type IA Hyetograph

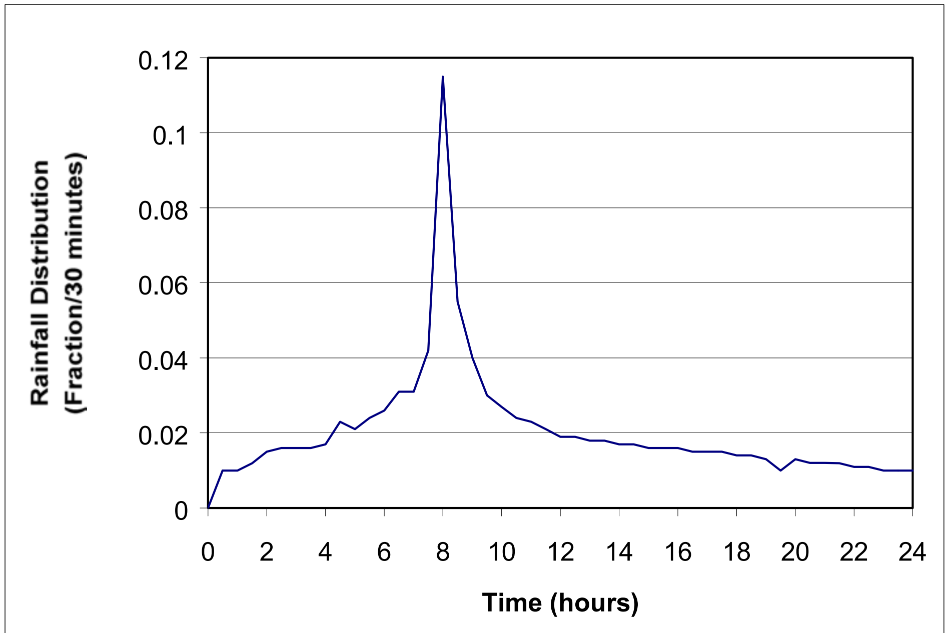
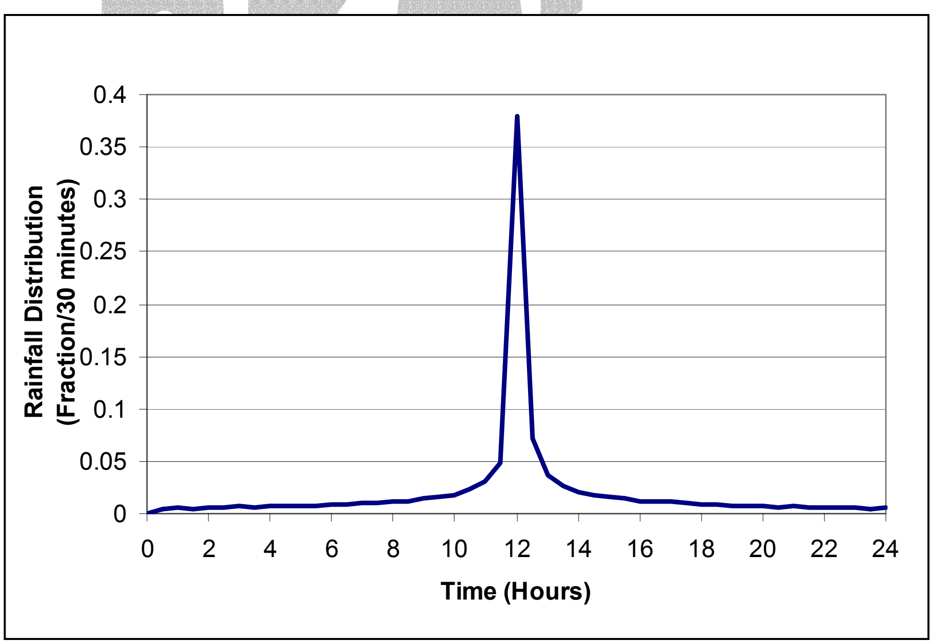


FIGURE 4-2.2
Typical SCS Type II Hyetograph



4.2.2 Custom Design Storm Hyetograph

Rainfall patterns during storms were analyzed in Eastern Washington by MGS Engineering Consultants. See Appendix 4A. They have drawn the conclusion that the SCS Type II rainfall distribution does not match the historical records.

There are two custom storm types of interest for stormwater analyses in eastern Washington: the short duration thunderstorm and the long duration winter storm.

Short-duration thunderstorms can occur in the late-spring through early-fall seasons and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash-flooding in urban areas and are important where flood peak discharge and/or erosion are design considerations.

Long-duration general storms can occur at anytime of the year, but are more common in the late-fall through winter period, and in the late-spring and early-summer periods. General storms in eastern Washington are characterized by sequences of storms and intervening dry periods, often occurring over several days. Low to moderate intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with moderate peak discharge and large runoff volumes. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early-spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

When utilizing the custom design storms, it is necessary to note that Eastern Washington has been divided into four climatic regions to reflect the differences in storm characteristics and the seasonality of storms. The four climatic regions (Figure 4-3.1) include:

Region 1 – East Slopes of Cascade Mountains

This region is comprised of mountain areas on the east slopes of the Cascade Mountains. It is bounded to the west by the Cascade crest and generally bounded to the east by the contour line of 16-inches mean annual precipitation.

Region 2 – Central Basin

The Central Basin region is comprised of the Columbia Basin and adjacent low elevation areas in central Washington. It is generally bounded to the west by the contour line of 16-inches mean annual precipitation at the base of the east slopes of the Cascade Mountains. The region is bounded to the north and east by the contour line of 12-inches mean annual precipitation. Many of the larger cities in eastern Washington are in this region including: Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.

Region 3 – Okanogan, Spokane, Palouse

This region is comprised of inter-mountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded to the northwest by the contour line of 16-inches mean annual precipitation at the base of the east slopes of the Cascade Mountains. It is bounded to the south and west by the contour line of 12-inches mean annual precipitation at the eastern edge of the Central Basin. It is bounded to the northeast by the Kettle River Range and Selkirk Mountains at approximately the contour line of 22-inches mean annual precipitation. It is bounded to the southeast by the Blue Mountains also at the contour line of 22-inches mean annual precipitation.

Region 4 – Northeastern Mountains and Blue Mountains

This region is comprised of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast, and includes the Blue Mountains in the southeast corner of eastern Washington. Mean annual precipitation ranges from a minimum of 22-inches to over 60-inches. The western boundary of this region is the contour line of 22-inches mean annual precipitation.

4.2.3 Storm Analysis

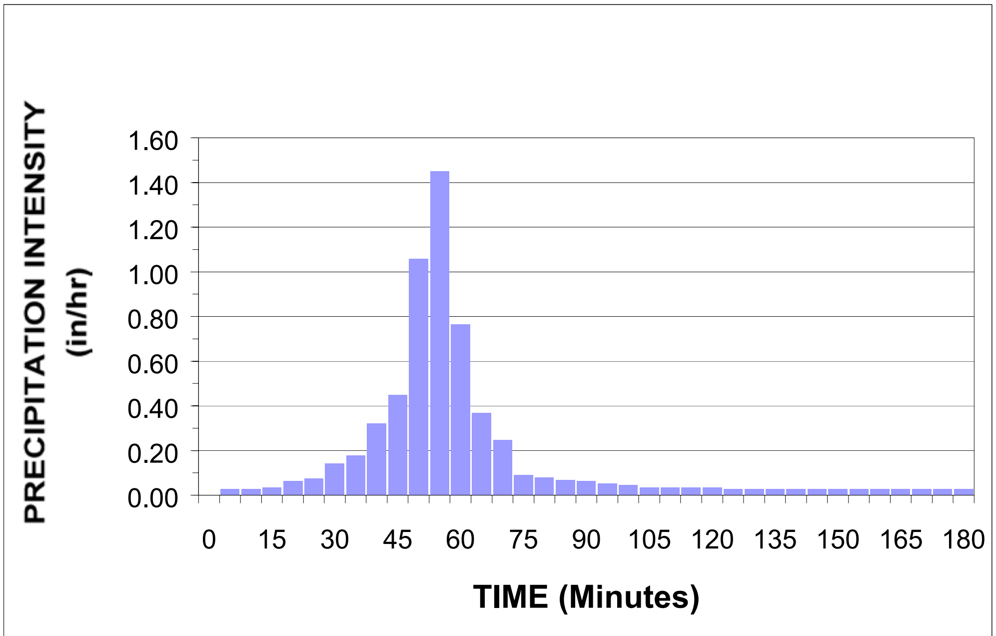
MGS Engineering Consultants concluded based upon analyses of these historical storms in Eastern Washington that the short-duration summer thunderstorm is the controlling storm for generating large peak discharges used for sizing of conveyance structures and biofiltration swales. Those analyses also indicate that the long-duration winter storm is the controlling storm for the design of stormwater detention and water quality treatment facilities where runoff volume is the primary concern.

Based on this information, synthetic design storms were developed for the short-duration thunderstorm and long-duration winter storm. The design storms were developed in a manner that replicated temporal characteristics observed in storms from areas climatologically similar to Eastern Washington. The design storm hyetograph is constructed by multiplying the dimensionless hyetograph times the total rainfall depth, in inches, for the design storm.

Short-Duration Storm

Summer thunderstorms are characterized by short durations, high intensity, and smaller volumes relative to winter storms. The short-duration storm was selected to be 3 hours in duration. The storm temporal pattern is shown in Figure 4-2.3. Tabular values of the summer storm are listed in Table 4-2.3. Precipitation input for developing a hydrograph from this hyetograph is the 2-hour precipitation. There is one short-duration storm for all climate regions in Eastern Washington.

FIGURE 4-2.3
Typical Short-Duration Storm Hydrograph
for 0.48 Inches Precipitation (5 Minute Increments)

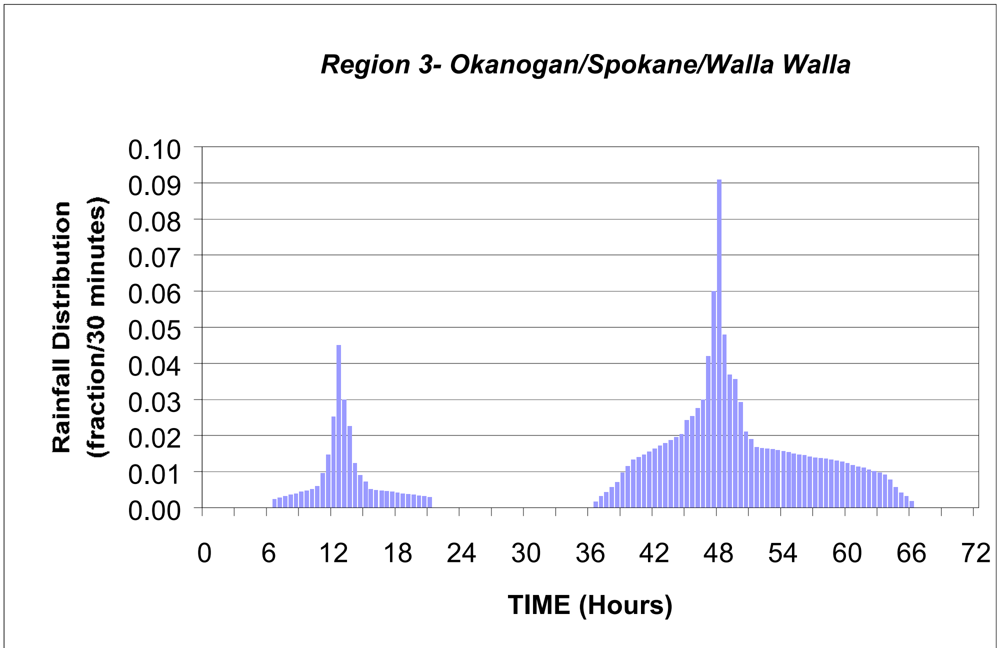


The precipitation intensities in the short-duration storm are higher than in the SCS Type IA, but lower than the SCS Type II, and the rainfall volume is 55-percent lower than a 24-hour storm. This short-duration storm pattern reflects the high-intensity, low-volume characteristics of summer convective storms in Eastern Washington area.

Long-Duration Storm

The long-duration storm was chosen to be 72-hours in duration to account for precipitation that occurs prior to and posterior to the maximum 24-hour period. The 72-hour long-duration storm hyetograph is shown in Figure 4-2.4. Typical long-duration water quality storm hydrographs for each region are shown in Figures 4-2.5 and 4-2.6. Tabular values of the long-duration storm are listed in Table 4-2.4 to 4-2.7. Precipitation input for developing a hydrograph from this hyetograph is the 24-hour precipitation. There is one long-duration storm for each climate region in Eastern Washington.

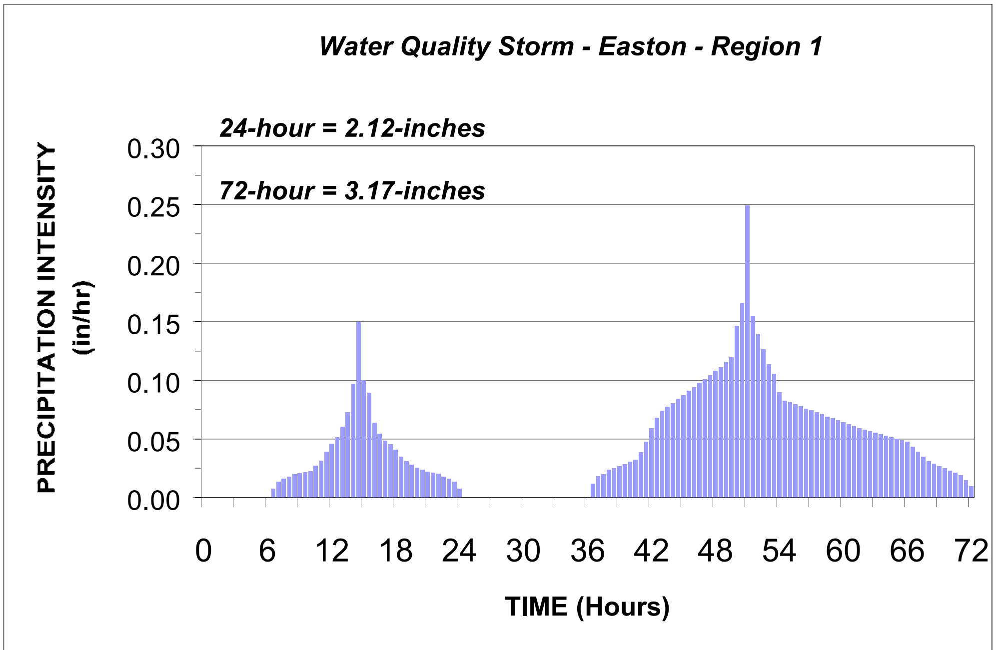
FIGURE 4-2.4
Typical Long-Duration Storm Hyetograph
(30 Minute Increments)



The intensities in the long-duration storm are much less than the SCS Type 1A and Type II distributions reflecting the lack of convective activity during long-duration storms in the fall, winter, and spring. However, the rainfall volume is 20 to 50 percent higher than the 24-hour SCS storm distributions because of the inclusion of precipitation prior to and posterior to the maximum 24-hour period.

See Figure 4-2.7 for a comparison of the SCS Type II, short duration, and long duration storm distributions.

Figure 4-2.5
Typical Long-Duration Storm Hydrographs for the 6-Month Water Quality Storm



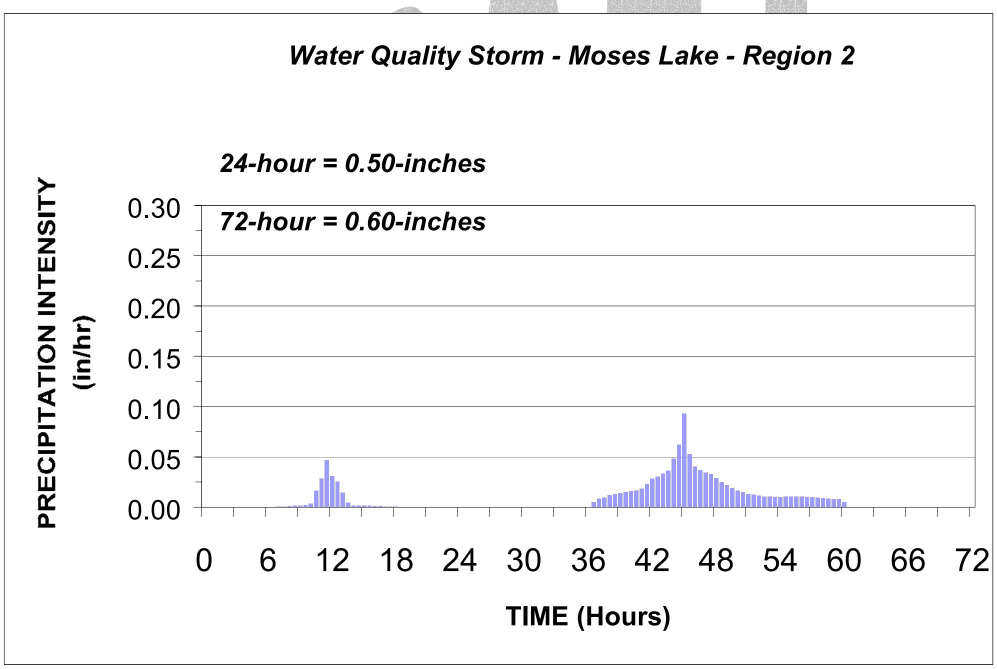
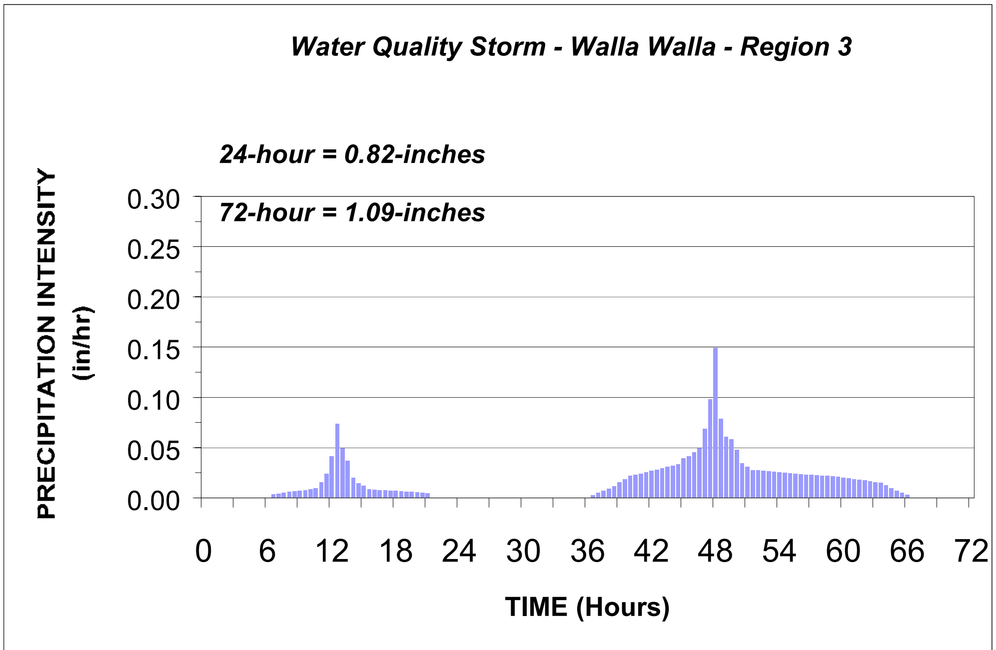


Figure 4-2.6
Typical Long-Duration Storm Hydrographs for the 6-Month Water Quality Storm *(continued)*



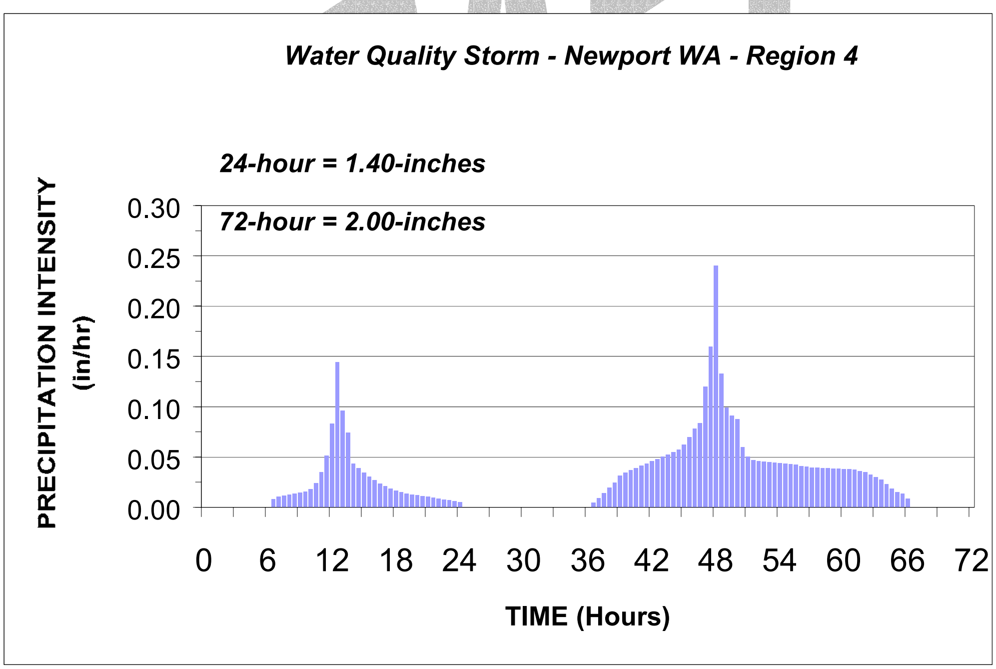


Figure 4-2.7
Comparison of SCS Type II, Short Duration, and Long Duration Storms

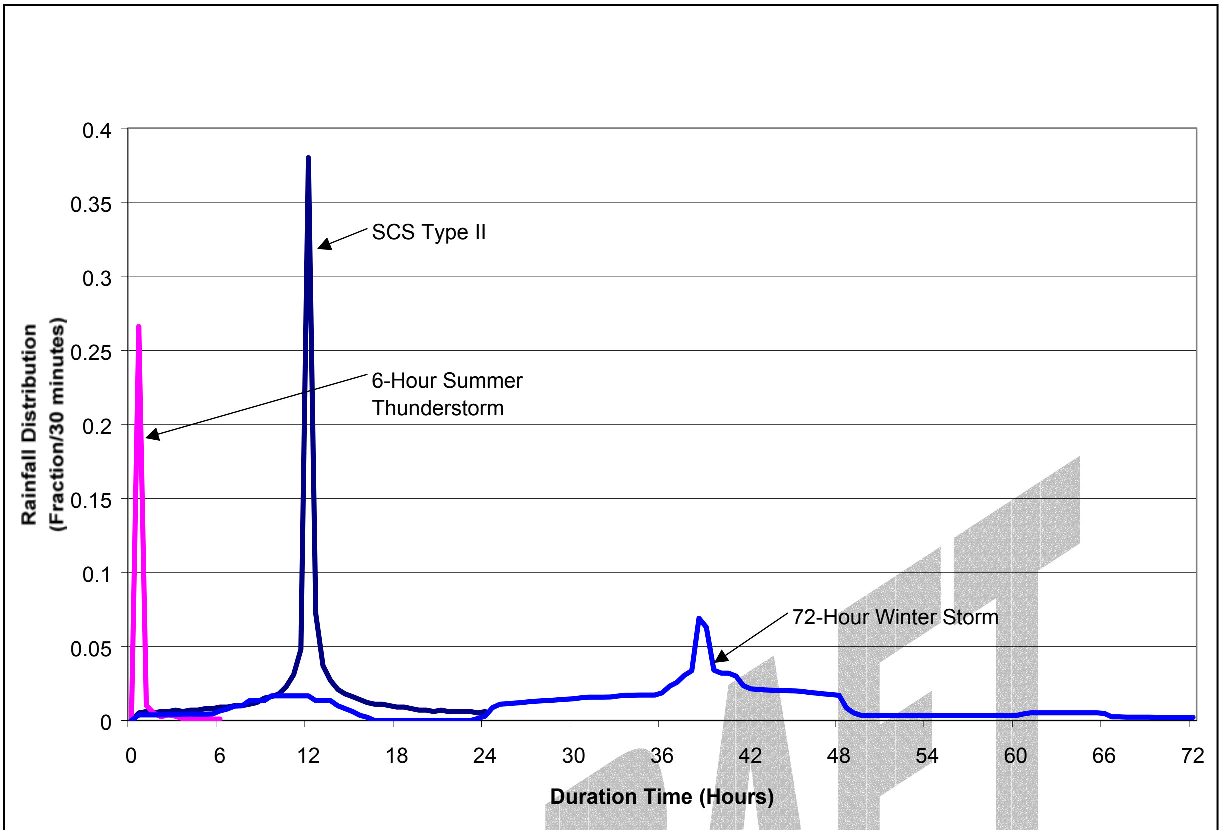


Table 4-2.1
SCS Type IA Storm Hyetograph Values

Time (0.1 hours)	Rainfall Fraction	Cumulative Rainfall Fraction
0.0	0.000	0.000
0.1	0.002	0.002
0.2	0.002	0.004
0.3	0.002	0.006
0.4	0.002	0.008
0.5	0.002	0.010
0.6	0.002	0.012
0.7	0.002	0.014
0.8	0.002	0.016
0.9	0.002	0.018
1.0	0.002	0.020
1.1	0.003	0.023
1.2	0.003	0.026
1.3	0.003	0.029
1.4	0.003	0.032
1.5	0.003	0.035
1.6	0.003	0.038
1.7	0.003	0.041
1.8	0.003	0.044
1.9	0.003	0.047
2.0	0.003	0.050
2.1	0.003	0.053
2.2	0.003	0.056
2.3	0.004	0.060
2.4	0.003	0.063
2.5	0.003	0.066
2.6	0.003	0.069
2.7	0.003	0.072
2.8	0.004	0.076
2.9	0.003	0.079
3.0	0.003	0.082
3.1	0.003	0.085
3.2	0.003	0.088
3.3	0.003	0.091
3.4	0.004	0.095
3.5	0.003	0.098
3.6	0.003	0.101
3.7	0.004	0.105
3.8	0.004	0.109
3.9	0.003	0.112
4.0	0.004	0.116
4.1	0.004	0.120
4.2	0.003	0.123
4.3	0.004	0.127
4.4	0.004	0.131
4.5	0.004	0.135
4.6	0.004	0.139
4.7	0.004	0.143
4.8	0.004	0.147
4.9	0.005	0.152
5.0	0.004	0.156
5.1	0.005	0.161
5.2	0.004	0.165
5.3	0.005	0.170
5.4	0.005	0.175
5.5	0.005	0.180
5.6	0.005	0.185
5.7	0.005	0.190
5.8	0.005	0.195
5.9	0.005	0.200
6.0	0.006	0.206
6.1	0.006	0.212
6.2	0.006	0.218
6.3	0.006	0.224
6.4	0.007	0.231
6.5	0.006	0.237
6.6	0.006	0.243
6.7	0.006	0.249
6.8	0.006	0.255
6.9	0.006	0.261
7.0	0.007	0.268
7.1	0.007	0.275
7.2	0.008	0.283
7.3	0.008	0.291
7.4	0.009	0.300
7.5	0.010	0.310
7.6	0.021	0.331
7.7	0.024	0.355
7.8	0.024	0.379
7.9	0.024	0.403
8.0	0.022	0.425
8.1	0.014	0.439
8.2	0.013	0.452
8.3	0.010	0.462
8.4	0.010	0.472
8.5	0.008	0.480
8.6	0.009	0.489
8.7	0.009	0.498
8.8	0.007	0.505
8.9	0.008	0.513
9.0	0.007	0.520
9.1	0.007	0.527
9.2	0.006	0.533
9.3	0.006	0.539
9.4	0.006	0.545
9.5	0.005	0.550
9.6	0.006	0.556
9.7	0.005	0.561
9.8	0.006	0.567
9.9	0.005	0.572
10.0	0.005	0.577
10.1	0.005	0.582
10.2	0.005	0.587
10.3	0.005	0.592
10.4	0.004	0.596
10.5	0.005	0.601
10.6	0.005	0.606
10.7	0.004	0.610
10.8	0.005	0.615
10.9	0.005	0.620
11.0	0.004	0.624
11.1	0.004	0.628
11.2	0.005	0.633
11.3	0.004	0.637
11.4	0.004	0.641
11.5	0.004	0.645
11.6	0.004	0.649
11.7	0.004	0.653
11.8	0.004	0.657
11.9	0.003	0.660
12.0	0.004	0.664
12.1	0.004	0.668
12.2	0.003	0.671
12.3	0.004	0.675
12.4	0.004	0.679
12.5	0.004	0.683
12.6	0.004	0.687
12.7	0.003	0.690
12.8	0.004	0.694
12.9	0.003	0.697
13.0	0.004	0.701
13.1	0.004	0.705
13.2	0.003	0.708
13.3	0.004	0.712
13.4	0.004	0.716

Table 4-2.1 (continued)
SCS Type IA Storm Hyetograph Values

Time (0.1 hours)	Rainfall Fraction	Cumulative Rainfall Fraction
13.5	0.003	0.719
13.6	0.003	0.722
13.7	0.004	0.726
13.8	0.003	0.729
13.9	0.004	0.733
14.0	0.003	0.736
14.1	0.003	0.739
14.2	0.004	0.743
14.3	0.003	0.746
14.4	0.003	0.749
14.5	0.004	0.753
14.6	0.003	0.756
14.7	0.003	0.759
14.8	0.004	0.763
14.9	0.003	0.766
15.0	0.003	0.769
15.1	0.003	0.772
15.2	0.004	0.776
15.3	0.003	0.779
15.4	0.003	0.782
15.5	0.003	0.785
15.6	0.003	0.788
15.7	0.004	0.792
15.8	0.003	0.795
15.9	0.003	0.798
16.0	0.003	0.801
16.1	0.003	0.804
16.2	0.003	0.807
16.3	0.003	0.810
16.4	0.003	0.813
16.5	0.003	0.816
16.6	0.003	0.819
16.7	0.003	0.822
16.8	0.003	0.825
16.9	0.003	0.828
17.0	0.003	0.831
17.1	0.003	0.834
17.2	0.003	0.837
17.3	0.003	0.840
17.4	0.003	0.843
17.5	0.003	0.846
17.6	0.003	0.849
17.7	0.002	0.851
17.8	0.003	0.854
17.9	0.003	0.857
18.0	0.003	0.860
18.1	0.003	0.863
18.2	0.002	0.865
18.3	0.003	0.868
18.4	0.003	0.871
18.5	0.003	0.874
18.6	0.002	0.876
18.7	0.003	0.879
18.8	0.003	0.882
18.9	0.002	0.884
19.0	0.003	0.887
19.1	0.003	0.890
19.2	0.002	0.892
19.3	0.003	0.895
19.4	0.002	0.897
19.5	0.003	0.900
19.6	0.003	0.903
19.7	0.002	0.905
19.8	0.003	0.908
19.9	0.002	0.910
20.0	0.003	0.913
20.1	0.002	0.915
20.2	0.003	0.918
20.3	0.002	0.920
20.4	0.002	0.922
20.5	0.003	0.925
20.6	0.002	0.927
20.7	0.003	0.930
20.8	0.002	0.932
20.9	0.002	0.934
21.0	0.003	0.937
21.1	0.002	0.939
21.2	0.002	0.941
21.3	0.003	0.944
21.4	0.002	0.946
21.5	0.002	0.948
21.6	0.003	0.951
21.7	0.002	0.953
21.8	0.002	0.955
21.9	0.002	0.957
22.0	0.002	0.959
22.1	0.003	0.962
22.2	0.002	0.964
22.3	0.002	0.966
22.4	0.002	0.968
22.5	0.002	0.970
22.6	0.002	0.972
22.7	0.002	0.974
22.8	0.002	0.976
22.9	0.002	0.978
23.0	0.002	0.980
23.1	0.002	0.982
23.2	0.002	0.984
23.3	0.002	0.986
23.4	0.002	0.988
23.5	0.002	0.990
23.6	0.002	0.992
23.7	0.002	0.994
23.8	0.002	0.996
23.9	0.002	0.998
24.0	0.002	1.000

Table 4-2.2
SCS Type II Storm Hyetograph Values

Time (0.1 hours)	Rainfall Fraction	Cumulative Rainfall Fraction
0.0	0.000	0.000
0.1	0.001	0.001
0.2	0.001	0.002
0.3	0.001	0.003
0.4	0.001	0.004
0.5	0.001	0.005
0.6	0.001	0.006
0.7	0.001	0.007
0.8	0.001	0.008
0.9	0.001	0.009
1.0	0.002	0.011
1.1	0.001	0.012
1.2	0.001	0.013
1.3	0.001	0.014
1.4	0.001	0.015
1.5	0.001	0.016
1.6	0.001	0.017
1.7	0.001	0.018
1.8	0.002	0.020
1.9	0.001	0.021
2.0	0.001	0.022
2.1	0.001	0.023
2.2	0.001	0.024
2.3	0.002	0.026
2.4	0.001	0.027
2.5	0.001	0.028
2.6	0.001	0.029
2.7	0.002	0.031
2.8	0.001	0.032
2.9	0.001	0.033
3.0	0.002	0.035
3.1	0.001	0.036
3.2	0.001	0.037
3.3	0.001	0.038
3.4	0.002	0.040
3.5	0.001	0.041
3.6	0.001	0.042
3.7	0.002	0.044
3.8	0.001	0.045
3.9	0.002	0.047
4.0	0.001	0.048
4.1	0.001	0.049
4.2	0.002	0.051
4.3	0.001	0.052
4.4	0.002	0.054
4.5	0.001	0.055
4.6	0.002	0.057
4.7	0.001	0.058
4.8	0.002	0.060
4.9	0.001	0.061
5.0	0.002	0.063
5.1	0.002	0.065
5.2	0.001	0.066
5.3	0.002	0.068
5.4	0.002	0.070
5.5	0.001	0.071
5.6	0.002	0.073
5.7	0.002	0.075
5.8	0.001	0.076
5.9	0.002	0.078
6.0	0.002	0.080
6.1	0.002	0.082
6.2	0.002	0.084
6.3	0.001	0.085
6.4	0.002	0.087
6.5	0.002	0.089
6.6	0.002	0.091
6.7	0.002	0.093
6.8	0.002	0.095
6.9	0.002	0.097
7.0	0.002	0.099
7.1	0.002	0.101
7.2	0.002	0.103
7.3	0.002	0.105
7.4	0.002	0.107
7.5	0.002	0.109
7.6	0.002	0.111
7.7	0.002	0.113
7.8	0.003	0.116
7.9	0.002	0.118
8.0	0.002	0.120
8.1	0.002	0.122
8.2	0.003	0.125
8.3	0.002	0.127
8.4	0.003	0.130
8.5	0.002	0.132
8.6	0.003	0.135
8.7	0.003	0.138
8.8	0.003	0.141
8.9	0.003	0.144
9.0	0.003	0.147
9.1	0.003	0.150
9.2	0.003	0.153
9.3	0.004	0.157
9.4	0.003	0.160
9.5	0.003	0.163
9.6	0.003	0.166
9.7	0.004	0.170
9.8	0.003	0.173
9.9	0.004	0.177
10.0	0.004	0.181
10.1	0.004	0.185
10.2	0.004	0.189
10.3	0.005	0.194
10.4	0.005	0.199
10.5	0.005	0.204
10.6	0.005	0.209
10.7	0.006	0.215
10.8	0.006	0.221
10.9	0.007	0.228
11.0	0.007	0.235
11.1	0.008	0.243
11.2	0.008	0.251
11.3	0.010	0.261
11.4	0.010	0.271
11.5	0.012	0.283
11.6	0.024	0.307
11.7	0.047	0.354
11.8	0.077	0.431
11.9	0.137	0.568
12.0	0.095	0.663
12.1	0.019	0.682
12.2	0.017	0.699
12.3	0.014	0.713
12.4	0.012	0.725
12.5	0.010	0.735
12.6	0.008	0.743
12.7	0.008	0.751
12.8	0.008	0.759
12.9	0.007	0.766
13.0	0.006	0.772
13.1	0.006	0.778
13.2	0.006	0.784
13.3	0.005	0.789
13.4	0.005	0.794

Table 4-2.2 (continued)
SCS Type II Storm Hyetograph Values

Time (0.1 hours)	Rainfall Fraction	Cumulative Rainfall Fraction
13.5	0.005	0.799
13.6	0.005	0.804
13.7	0.004	0.808
13.8	0.004	0.812
13.9	0.004	0.816
14.0	0.004	0.82
14.1	0.004	0.824
14.2	0.003	0.827
14.3	0.004	0.831
14.4	0.003	0.834
14.5	0.004	0.838
14.6	0.003	0.841
14.7	0.003	0.844
14.8	0.003	0.847
14.9	0.003	0.85
15.0	0.004	0.854
15.1	0.002	0.856
15.2	0.003	0.859
15.3	0.003	0.862
15.4	0.003	0.865
15.5	0.003	0.868
15.6	0.002	0.87
15.7	0.003	0.873
15.8	0.002	0.875
15.9	0.003	0.878
16.0	0.002	0.88
16.1	0.002	0.882
16.2	0.003	0.885
16.3	0.002	0.887
16.4	0.002	0.889
16.5	0.002	0.891
16.6	0.002	0.893
16.7	0.002	0.895
16.8	0.003	0.898
16.9	0.002	0.9
17.0	0.002	0.902
17.1	0.002	0.904
17.2	0.002	0.906
17.3	0.002	0.908
17.4	0.002	0.91
17.5	0.002	0.912
17.6	0.002	0.914
17.7	0.001	0.915
17.8	0.002	0.917
17.9	0.002	0.919
18.0	0.002	0.921
18.1	0.002	0.923
18.2	0.002	0.925
18.3	0.001	0.926
18.4	0.002	0.928
18.5	0.002	0.93
18.6	0.001	0.931
18.7	0.002	0.933
18.8	0.002	0.935
18.9	0.001	0.936
19.0	0.002	0.938
19.1	0.001	0.939
19.2	0.002	0.941
19.3	0.001	0.942
19.4	0.002	0.944
19.5	0.001	0.945
19.6	0.002	0.947
19.7	0.001	0.948
19.8	0.001	0.949
19.9	0.002	0.951
20.0	0.001	0.952
20.1	0.001	0.953
20.2	0.002	0.955
20.3	0.001	0.956
20.4	0.001	0.957
20.5	0.001	0.958
20.6	0.002	0.96
20.7	0.001	0.961
20.8	0.001	0.962
20.9	0.002	0.964
21.0	0.001	0.965
21.1	0.001	0.966
21.2	0.001	0.967
21.3	0.001	0.968
21.4	0.002	0.97
21.5	0.001	0.971
21.6	0.001	0.972
21.7	0.001	0.973
21.8	0.002	0.975
21.9	0.001	0.976
22.0	0.001	0.977
22.1	0.001	0.978
22.2	0.001	0.979
22.3	0.002	0.981
22.4	0.001	0.982
22.5	0.001	0.983
22.6	0.001	0.984
22.7	0.001	0.985
22.8	0.001	0.986
22.9	0.002	0.988
23.0	0.001	0.989
23.1	0.001	0.99
23.2	0.001	0.991
23.3	0.001	0.992
23.4	0.001	0.993
23.5	0.001	0.994
23.6	0.002	0.996
23.7	0.001	0.997
23.8	0.001	0.998
23.9	0.001	0.999
24.0	0.001	1

Table 4-2.3
Short-Duration Storm Hyetograph Values – All Regions
Note: Use 2-hour precipitation value to scale this storm hyetograph.

TIME (minutes)	TIME (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
0	0	0.0000	0.00000
5	0.08	0.0050	0.00500
10	0.17	0.0050	0.01000
15	0.25	0.0060	0.01600
20	0.33	0.0110	0.02700
25	0.42	0.0130	0.04000
30	0.50	0.0250	0.06500
35	0.58	0.0310	0.09600
40	0.67	0.0560	0.15200
45	0.75	0.0780	0.23000
50	0.83	0.1840	0.41400
55	0.92	0.2520	0.66600
60	1.00	0.1330	0.79900
65	1.08	0.0640	0.86300
70	1.17	0.0430	0.90600
75	1.25	0.0160	0.92200
80	1.33	0.0140	0.93600
85	1.42	0.0120	0.94800
90	1.50	0.0110	0.95900
95	1.58	0.0090	0.96800
100	1.67	0.0080	0.97600
105	1.75	0.0060	0.98200
110	1.83	0.0060	0.98800
115	1.92	0.0060	0.99400
120	2.00	0.0060	1.00000
125	2.08	0.0050	1.00500
130	2.17	0.0050	1.01000
135	2.25	0.0050	1.01500
140	2.33	0.0050	1.02000
145	2.42	0.0050	1.02500
150	2.50	0.0050	1.03000
155	2.58	0.0050	1.03500
160	2.67	0.0050	1.04000
165	2.75	0.0050	1.04500
170	2.83	0.0050	1.05000
175	2.92	0.0050	1.05500
180	3.00	0.0050	1.06000

Table 4-2.4: Long-Duration Storm Hyetograph Values; Region 1: Cascade Mountains

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00179	0.00179
7.0	0.00321	0.00500
7.5	0.00370	0.00870
8.0	0.00420	0.01290
8.5	0.00470	0.01760
9.0	0.00490	0.02250
9.5	0.00510	0.02760
10.0	0.00530	0.03290
10.5	0.00634	0.03924
11.0	0.00740	0.04664
11.5	0.00920	0.05584
12.0	0.01080	0.06664
12.5	0.01214	0.07878
13.0	0.01424	0.09302
13.5	0.01712	0.11014
14.0	0.02288	0.13302
14.5	0.03540	0.16842
15.0	0.02360	0.19202
15.5	0.02101	0.21303
16.0	0.01499	0.22802
16.5	0.01279	0.24081
17.0	0.01144	0.25225
17.5	0.01070	0.26295
18.0	0.00960	0.27255
18.5	0.00814	0.28069
19.0	0.00730	0.28799
19.5	0.00657	0.29456
20.0	0.00598	0.30054
20.5	0.00551	0.30605
21.0	0.00516	0.31121
21.5	0.00494	0.31615
22.0	0.00485	0.32100
22.5	0.00420	0.32520
23.0	0.00370	0.32890
23.5	0.00320	0.33210
24.0	0.00180	0.33390

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
24.5	0.00000	0.33390
25.0	0.00000	0.33390
25.5	0.00000	0.33390
26.0	0.00000	0.33390
26.5	0.00000	0.33390
27.0	0.00000	0.33390
27.5	0.00000	0.33390
28.0	0.00000	0.33390
28.5	0.00000	0.33390
29.0	0.00000	0.33390
29.5	0.00000	0.33390
30.0	0.00000	0.33390
30.5	0.00000	0.33390
31.0	0.00000	0.33390
31.5	0.00000	0.33390
32.0	0.00000	0.33390
32.5	0.00000	0.33390
33.0	0.00000	0.33390
33.5	0.00000	0.33390
34.0	0.00000	0.33390
34.5	0.00000	0.33390
35.0	0.00000	0.33390
35.5	0.00000	0.33390
36.0	0.00000	0.33390
36.5	0.00277	0.33667
37.0	0.00423	0.34090
37.5	0.00467	0.34557
38.0	0.00550	0.35107
38.5	0.00590	0.35697
39.0	0.00630	0.36327
39.5	0.00670	0.36997
40.0	0.00723	0.37720
40.5	0.00760	0.38480
41.0	0.00907	0.39387
41.5	0.01116	0.40503
42.0	0.01387	0.41890
42.5	0.01600	0.43490
43.0	0.01740	0.45230
43.5	0.01820	0.47050
44.0	0.01900	0.48950
44.5	0.01980	0.50930
45.0	0.02060	0.52990
45.5	0.02140	0.55130
46.0	0.02220	0.57350
46.5	0.02300	0.59650
47.0	0.02380	0.62030
47.5	0.02460	0.64490
48.0	0.02550	0.67040
48.5	0.02620	0.69660

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
49.0	0.02720	0.72380
49.5	0.02820	0.75200
50.0	0.03445	0.78645
50.5	0.03920	0.82565
51.0	0.05880	0.88445
51.5	0.03652	0.92097
52.0	0.03280	0.95377
52.5	0.02980	0.98357
53.0	0.02680	1.01037
53.5	0.02484	1.03521
54.0	0.02116	1.05637
54.5	0.01943	1.07580
55.0	0.01910	1.09490
55.5	0.01870	1.11360
56.0	0.01830	1.13190
56.5	0.01790	1.14980
57.0	0.01750	1.16730
57.5	0.01710	1.18440
58.0	0.01670	1.20110
58.5	0.01630	1.21740
59.0	0.01590	1.23330
59.5	0.01550	1.24880
60.0	0.01510	1.26390
60.5	0.01470	1.27860
61.0	0.01430	1.29290
61.5	0.01390	1.30680
62.0	0.01360	1.32040
62.5	0.01330	1.33370
63.0	0.01300	1.34670
63.5	0.01270	1.35940
64.0	0.01240	1.37180
64.5	0.01210	1.38390
65.0	0.01180	1.39570
65.5	0.01150	1.40720
66.0	0.01120	1.41840
66.5	0.01020	1.42860
67.0	0.00920	1.43780
67.5	0.00820	1.44600
68.0	0.00734	1.45334
68.5	0.00675	1.46009
69.0	0.00630	1.46639
69.5	0.00585	1.47224
70.0	0.00540	1.47764
70.5	0.00495	1.48259
71.0	0.00450	1.48709
71.5	0.00350	1.49059
72.0	0.00225	1.49284

Table 4-2.5

Long-Duration Storm Hyetograph Values; Region 2: Central Basin

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00030	0.00030
7.0	0.00060	0.00090
7.5	0.00090	0.00180
8.0	0.00120	0.00300
8.5	0.00150	0.00450
9.0	0.00180	0.00630
9.5	0.00210	0.00840
10.0	0.00394	0.01234
10.5	0.01669	0.02903
11.0	0.02831	0.05734
11.5	0.04680	0.10414
12.0	0.03120	0.13534
12.5	0.02549	0.16083
13.0	0.01451	0.17534
13.5	0.00445	0.17979
14.0	0.00202	0.18181
14.5	0.00192	0.18373
15.0	0.00172	0.18545
15.5	0.00152	0.18697
16.0	0.00132	0.18829
16.5	0.00112	0.18941
17.0	0.00092	0.19033
17.5	0.00072	0.19105
18.0	0.00052	0.19157
18.5	0.00000	0.19157
19.0	0.00000	0.19157
19.5	0.00000	0.19157
20.0	0.00000	0.19157
20.5	0.00000	0.19157
21.0	0.00000	0.19157
21.5	0.00000	0.19157
22.0	0.00000	0.19157
22.5	0.00000	0.19157
23.0	0.00000	0.19157
23.5	0.00000	0.19157
24.0	0.00000	0.19157
24.5	0.00000	0.19157
25.0	0.00000	0.19157
25.5	0.00000	0.19157
26.0	0.00000	0.19157
26.5	0.00000	0.19157
27.0	0.00000	0.19157
27.5	0.00000	0.19157
28.0	0.00000	0.19157
28.5	0.00000	0.19157
29.0	0.00000	0.19157
29.5	0.00000	0.19157
30.0	0.00000	0.19157
30.5	0.00000	0.19157
31.0	0.00000	0.19157
31.5	0.00000	0.19157
32.0	0.00000	0.19157
32.5	0.00000	0.19157
33.0	0.00000	0.19157
33.5	0.00000	0.19157
34.0	0.00000	0.19157
34.5	0.00000	0.19157
35.0	0.00000	0.19157
35.5	0.00000	0.19157
36.0	0.00000	0.19157
36.5	0.00544	0.19701
37.0	0.00856	0.20557
37.5	0.01000	0.21557
38.0	0.01200	0.22757
38.5	0.01300	0.24057
39.0	0.01400	0.25457
39.5	0.01500	0.26957
40.0	0.01600	0.28557
40.5	0.01700	0.30257
41.0	0.01869	0.32126
41.5	0.02281	0.34407
42.0	0.02832	0.37239
42.5	0.03050	0.40289
43.0	0.03350	0.43639
43.5	0.03650	0.47289
44.0	0.04842	0.52131
44.5	0.06220	0.58351
45.0	0.09330	0.67681
45.5	0.05275	0.72956
46.0	0.04025	0.76981
46.5	0.03717	0.80698
47.0	0.03483	0.84181
47.5	0.03307	0.87488
48.0	0.02893	0.90381
48.5	0.02519	0.92900
49.0	0.02189	0.95089
49.5	0.01906	0.96995
50.0	0.01670	0.98665
50.5	0.01480	1.00145
51.0	0.01336	1.01481
51.5	0.01234	1.02715
52.0	0.01156	1.03871
52.5	0.01096	1.04967
53.0	0.01054	1.06021
53.5	0.01032	1.07053
54.0	0.01028	1.08081
54.5	0.01038	1.09119
55.0	0.01046	1.10165
55.5	0.01046	1.11211
56.0	0.01040	1.12251
56.5	0.01025	1.13276
57.0	0.01004	1.14280
57.5	0.00974	1.15254
58.0	0.00926	1.16180
58.5	0.00868	1.17048
59.0	0.00832	1.17880
59.5	0.00781	1.18661
60.0	0.00500	1.19161
60.5	0.00000	1.19161
61.0	0.00000	1.19161
61.5	0.00000	1.19161
62.0	0.00000	1.19161
62.5	0.00000	1.19161
63.0	0.00000	1.19161
63.5	0.00000	1.19161
64.0	0.00000	1.19161
64.5	0.00000	1.19161
65.0	0.00000	1.19161
65.5	0.00000	1.19161
66.0	0.00000	1.19161
66.5	0.00000	1.19161
67.0	0.00000	1.19161
67.5	0.00000	1.19161
68.0	0.00000	1.19161
68.5	0.00000	1.19161
69.0	0.00000	1.19161
69.5	0.00000	1.19161
70.0	0.00000	1.19161
70.5	0.00000	1.19161
71.0	0.00000	1.19161
71.5	0.00000	1.19161
72.0	0.00000	1.19161

Table 4-2.6: Long-Duration Storm Hyetograph Values; Region 3: Okanogan – Spokane – Palouse

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00240	0.00240
7.0	0.00280	0.00520
7.5	0.00320	0.00840
8.0	0.00360	0.01200
8.5	0.00403	0.01603
9.0	0.00440	0.02043
9.5	0.00480	0.02523
10.0	0.00520	0.03043
10.5	0.00600	0.03643
11.0	0.00968	0.04611
11.5	0.01476	0.06087
12.0	0.02524	0.08611
12.5	0.04500	0.13111
13.0	0.03000	0.16111
13.5	0.02267	0.18378
14.0	0.01233	0.19611
14.5	0.00901	0.20512
15.0	0.00731	0.21243
15.5	0.00520	0.21763
16.0	0.00500	0.22263
16.5	0.00480	0.22743
17.0	0.00460	0.23203
17.5	0.00440	0.23643
18.0	0.00420	0.24063
18.5	0.00400	0.24463
19.0	0.00380	0.24843
19.5	0.00360	0.25203
20.0	0.00340	0.25543
20.5	0.00320	0.25863
21.0	0.00300	0.26163
21.5	0.00000	0.26163
22.0	0.00000	0.26163
22.5	0.00000	0.26163
23.0	0.00000	0.26163
23.5	0.00000	0.26163
24.0	0.00000	0.26163

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
24.5	0.00000	0.26163
25.0	0.00000	0.26163
25.5	0.00000	0.26163
26.0	0.00000	0.26163
26.5	0.00000	0.26163
27.0	0.00000	0.26163
27.5	0.00000	0.26163
28.0	0.00000	0.26163
28.5	0.00000	0.26163
29.0	0.00000	0.26163
29.5	0.00000	0.26163
30.0	0.00000	0.26163
30.5	0.00000	0.26163
31.0	0.00000	0.26163
31.5	0.00000	0.26163
32.0	0.00000	0.26163
32.5	0.00000	0.26163
33.0	0.00000	0.26163
33.5	0.00000	0.26163
34.0	0.00000	0.26163
34.5	0.00000	0.26163
35.0	0.00000	0.26163
35.5	0.00000	0.26163
36.0	0.00000	0.26163
36.5	0.00180	0.26343
37.0	0.00320	0.26663
37.5	0.00437	0.27100
38.0	0.00563	0.27663
38.5	0.00722	0.28385
39.0	0.00978	0.29363
39.5	0.01150	0.30513
40.0	0.01340	0.31853
40.5	0.01400	0.33253
41.0	0.01480	0.34733
41.5	0.01560	0.36293
42.0	0.01640	0.37933
42.5	0.01720	0.39653
43.0	0.01800	0.41453
43.5	0.01880	0.43333
44.0	0.01960	0.45293
44.5	0.02040	0.47333
45.0	0.02430	0.49763
45.5	0.02534	0.52297
46.0	0.02766	0.55063
46.5	0.03000	0.58063
47.0	0.04200	0.62263
47.5	0.06000	0.68263
48.0	0.09100	0.77363
48.5	0.04801	0.82164

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
49.0	0.03700	0.85864
49.5	0.03568	0.89432
50.0	0.02932	0.92364
50.5	0.02114	0.94478
51.0	0.01900	0.96378
51.5	0.01680	0.98058
52.0	0.01660	0.99718
52.5	0.01640	1.01358
53.0	0.01620	1.02978
53.5	0.01600	1.04578
54.0	0.01570	1.06148
54.5	0.01540	1.07688
55.0	0.01510	1.09198
55.5	0.01480	1.10678
56.0	0.01450	1.12128
56.5	0.01420	1.13548
57.0	0.01390	1.14938
57.5	0.01379	1.16317
58.0	0.01361	1.17678
58.5	0.01338	1.19016
59.0	0.01310	1.20326
59.5	0.01276	1.21602
60.0	0.01236	1.22838
60.5	0.01192	1.24030
61.0	0.01148	1.25178
61.5	0.01104	1.26282
62.0	0.01061	1.27343
62.5	0.01018	1.28361
63.0	0.00976	1.29337
63.5	0.00918	1.30255
64.0	0.00782	1.31037
64.5	0.00579	1.31616
65.0	0.00421	1.32037
65.5	0.00315	1.32352
66.0	0.00185	1.32537
66.5	0.00000	1.32537
67.0	0.00000	1.32537
67.5	0.00000	1.32537
68.0	0.00000	1.32537
68.5	0.00000	1.32537
69.0	0.00000	1.32537
69.5	0.00000	1.32537
70.0	0.00000	1.32537
70.5	0.00000	1.32537
71.0	0.00000	1.32537
71.5	0.00000	1.32537
72.0	0.00000	1.32537

Table 4-2.7
Long-Duration Storm Hyetograph Values; Region 4: Eastern Mountains
Note: Scale by 24-hour precipitation

Time (hours)	Rainfall Distribution (fraction)	Cumulative Distribution (fraction)
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00300	0.00300
7.0	0.00390	0.00690
7.5	0.00423	0.01113
8.0	0.00456	0.01569
8.5	0.00490	0.02059
9.0	0.00523	0.02582
9.5	0.00556	0.03138
10.0	0.00650	0.03788
10.5	0.00868	0.04656
11.0	0.01246	0.05902
11.5	0.01824	0.07726
12.0	0.02976	0.10702
12.5	0.05160	0.15862
13.0	0.03440	0.19302
13.5	0.02655	0.21957
14.0	0.01545	0.23502
14.5	0.01388	0.24890
15.0	0.01232	0.26122
15.5	0.01089	0.27211
16.0	0.00961	0.28173
16.5	0.00848	0.29020
17.0	0.00748	0.29768
17.5	0.00661	0.30430
18.0	0.00590	0.31019
18.5	0.00532	0.31552
19.0	0.00489	0.32040
19.5	0.00459	0.32499
20.0	0.00430	0.32930
20.5	0.00401	0.33330
21.0	0.00372	0.33702
21.5	0.00343	0.34045
22.0	0.00313	0.34358
22.5	0.00284	0.34642
23.0	0.00255	0.34897
23.5	0.00226	0.35123
24.0	0.00197	0.35319
24.5	0.00000	0.35319
25.0	0.00000	0.35319
25.5	0.00000	0.35319
26.0	0.00000	0.35319
26.5	0.00000	0.35319
27.0	0.00000	0.35319
27.5	0.00000	0.35319
28.0	0.00000	0.35319
28.5	0.00000	0.35319
29.0	0.00000	0.35319
29.5	0.00000	0.35319
30.0	0.00000	0.35319
30.5	0.00000	0.35319
31.0	0.00000	0.35319
31.5	0.00000	0.35319
32.0	0.00000	0.35319
32.5	0.00000	0.35319
33.0	0.00000	0.35319
33.5	0.00000	0.35319
34.0	0.00000	0.35319
34.5	0.00000	0.35319
35.0	0.00000	0.35319
35.5	0.00000	0.35319
36.0	0.00000	0.35319
36.5	0.00167	0.35486
37.0	0.00333	0.35819
37.5	0.00510	0.36329
38.0	0.00690	0.37019
38.5	0.00879	0.37898
39.0	0.01121	0.39019
39.5	0.01240	0.40259
40.0	0.01320	0.41579
40.5	0.01400	0.42979
41.0	0.01480	0.44459
41.5	0.01560	0.46019
42.0	0.01640	0.47659
42.5	0.01720	0.49379
43.0	0.01800	0.51179
43.5	0.01880	0.53059
44.0	0.01960	0.55019
44.5	0.02050	0.57069
45.0	0.02230	0.59299
45.5	0.02500	0.61799
46.0	0.02800	0.64599
46.5	0.03000	0.67599
47.0	0.04295	0.71894
47.5	0.05720	0.77614
48.0	0.08580	0.86194
48.5	0.04751	0.90945
49.0	0.03549	0.94494
49.5	0.03265	0.97759
50.0	0.03135	1.00894
50.5	0.02140	1.03034
51.0	0.01790	1.04824
51.5	0.01670	1.06494
52.0	0.01650	1.08144
52.5	0.01630	1.09774
53.0	0.01610	1.11384
53.5	0.01590	1.12974
54.0	0.01570	1.14544
54.5	0.01550	1.16094
55.0	0.01535	1.17629
55.5	0.01508	1.19137
56.0	0.01471	1.20608
56.5	0.01442	1.22050
57.0	0.01421	1.23471
57.5	0.01407	1.24878
58.0	0.01395	1.26273
58.5	0.01385	1.27658
59.0	0.01377	1.29035
59.5	0.01370	1.30405
60.0	0.01365	1.31770
60.5	0.01358	1.33128
61.0	0.01338	1.34466
61.5	0.01300	1.35766
62.0	0.01245	1.37011
62.5	0.01174	1.38185
63.0	0.01085	1.39270
63.5	0.00975	1.40245
64.0	0.00825	1.41070
64.5	0.00654	1.41724
65.0	0.00546	1.42270
65.5	0.00484	1.42754
66.0	0.00316	1.43070
66.5	0.00000	1.43070
67.0	0.00000	1.43070
67.5	0.00000	1.43070
68.0	0.00000	1.43070
68.5	0.00000	1.43070
69.0	0.00000	1.43070
69.5	0.00000	1.43070
70.0	0.00000	1.43070
70.5	0.00000	1.43070
71.0	0.00000	1.43070
71.5	0.00000	1.43070
72.0	0.00000	1.43070

4.2.4 Precipitation Magnitude/Frequency Analysis

The current source for precipitation magnitude-frequency estimates is NOAA Atlas II, which is based on data collected from about 1940 through 1966, and NOAA Technical Report Number 36, which used data through the late 1970's. In both of these studies, precipitation statistics were computed for each gage and used to produce point precipitation estimates at each site. The accuracy of the estimates was strongly related to the length of record at each site. Better estimates were obtained for more common events with lesser accuracy for more rare events.

The total depth of rainfall (in tenths of an inch) for storms of 24-hour duration and 2, 5, 10, 25, 50 and 100-year recurrence intervals are published by the NOAA. The information is presented in the form of "isopluvial" maps for each state. Isopluvial maps are contour maps where the contours represent total inches of rainfall for a specific duration.

The isopluvial map for Eastern Washington for the 2-year recurrence interval for the 2-hour duration storm event is shown in Figure 4-3.2. This map is from the Dam Safety Guidelines, Technical Note 3, Design Storm Construction, Washington State Department of Ecology, Water Resources Program, report 92-55G, April 1993. This map is used for designs based on the short-duration storm.

The isopluvial maps for Eastern Washington for the 2, 10, 25, 50 and 100-year recurrence interval for 24-hour duration storm events are shown in Figures 4-3.3 to 4-3.7. These are excerpted from NOAA Atlas 2. The NOAA Atlas 2 maps are on the internet at http://wrcc.sage.dri.edu/pcpnfreq.html. The 24-hour isopluvial maps are used for designs based on the long-duration storm and 24-hour storms.

4.2.5 Precipitation Magnitude for 24-Hour and Long-Duration Water Quality Storm

The frequency of the long-duration water quality storm is a 6-month recurrence interval or twice per year return. Unfortunately the NOAA Atlas 2 maps do not provide the precipitation amounts for this recurrence interval. The design of Volume Based Treatment BMPs for Methods PM2 and AM2 requires the conversion of 2-year 24-hour precipitation to 6-month 24-hour precipitation.

The following equation is used to determine the 6-month precipitation.

$$P_{wqs} = C_{wqs} (P_{2yr24hr})$$

where: P_{wqs} is the 24-hour precipitation (inches) for the storm recurrence interval of 6 months. This precipitation is used with the long-duration storm hyetograph or a 24-hour SCS Type II hyetograph.

C_{wqs} is a coefficient from Table 4-2.8 for computing the 6-month 24-hour precipitation based on the climate region; and

$P_{2yr24hr}$ is the 2-year, 24-hour precipitation from Figure 4-3.3.

Values of the coefficient C_{wqs} are based on the Generalized Extreme Value (GEV) distribution[3] whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington (Schaefer[6,8]). Table 4-2.8 lists values of the coefficient C_{wqs} for all four climate regions. Figure 4-3.1 can be used to determine the climate region for the site.

Table 4-2.8
Coefficients Cwqs For Computing Twice/Year
24-Hour Precipitation

Region #	Region Name	C_{wqs}
1	East Slope Cascades	0.70
2	Central Basin	0.66
3	Okanogan, Spokane, Palouse	0.69
4	NE & Blue Mountains	0.70

4.2.6 Precipitation Magnitude for Short-Duration Storms

The only mapped frequency of the short-duration storm is a 2-year recurrence interval. The design of Flow Based Treatment BMPs using the Single Event Hydrograph Model requires the conversion of the 2-year 2-hour precipitation to the 6-month 2-hour precipitation. The design of other BMPs or conveyance elements based on the short-duration storm could also require the conversion of the 2-year 2-hour precipitation to a different recurrence interval.

The following equation is used to determine 2-hour precipitation for a selected return period.

$$P_{sds} = C_{sds} (P_{2yr2hr})$$

where: P_{sds} is the 2-hour precipitation (inches) for a selected return period for the short-duration storm

C_{sds} is a coefficient from Table 4-2.9 for computing the 2-hour precipitation for a selected return period based on the 2-year 2-hour precipitation; and

P_{2yr2hr} is the 2-year, 2-hour precipitation from Figure 4-3.2.

Values of the coefficient Csds are based on the Generalized Extreme Value (GEV) distribution3 whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington (Schaefer6,8). Table 4-2.9 lists values of the coefficient Csds for selected return periods for various magnitudes of mean annual precipitation. An isopluvial map of mean annual precipitation is shown in Figure 4-3.1 and can be used to determine the mean annual precipitation for the site.

Table 4-2.9
Coefficients Csds for Computing 2-Hour Precipitation for Selected Return Periods

Region #	Mean Annual Precipitation (In)	6-Month	1-Year	10-Year	25-Year	50-Year	100-Year
2	6-8	0.61	0.79	1.63	2.17	2.68	3.29
	8-10	0.62	0.80	1.60	2.09	2.55	3.09
	10-12	0.64	0.81	1.56	2.02	2.44	2.92
2, 3	12-16	0.66	0.82	1.51	1.90	2.26	2.66
3	16-22	0.67	0.83	1.47	1.82	2.13	2.48
1, 4	22-28	0.69	0.84	1.43	1.74	2.01	2.31
	28-40	0.70	0.85	1.40	1.68	1.92	2.19
	40-60	0.72	0.86	1.36	1.61	1.82	2.05
	60-120	0.74	0.87	1.33	1.55	1.74	1.93

4.2.7 Rain-on-Snow Design Storm

The following information on rain-on-snow and snowmelt design is optional guidance for detention and water quality design when required by the local jurisdiction.

Rain-on-snow could effect the flow in the evaluation of the long-duration storms, especially in regions with high snowfall. It should be assumed that a long-duration design storm results in the complete melting and runoff of the typical snowpack. To determine the typical snowpack calculate the average daily snow depth from December to February which is available on the internet for many Eastern Washington locations at http://www.wrcc.dri.edu/summary/climsmwa.html. If the average daily snow depth is less than 1 inch, then the rain-on-snow effect is negligible and should not be regarded in the analysis. Assuming 20 percent moisture content, determine the water equivalent. A sample of the average daily snow depths and precipitation adjustment amount for selected cities is in Table 4-2.10.

Snowmelt should also be considered in water quality design. Melting snow from the roadways and from the snow piles alongside the roadways have significant amounts of pollutants generated from the vehicles, deicers, and roadway salts. The water quality facilities should be located downstream of the snowmelt areas and should be sized for snowmelt, especially in regions with high snowfall.

Table 4-2.10
Snowmelt Adjustment Factors

City	Average Daily Snow Depth (In.)	Water Equivalent (In.) (24-hour Storm Precipitation Adjustment)	24-Hour/72-Hour Precipitation Ratio – based on Climate Region	Long-Duration Storm Precipitation Adjustment (In.)
Colville	5.00	1.0	.70	.70
Clarkston	.33	N/A	N/A	N/A
Goldendale	1.67	.33	.67	.22
Moses Lake	.67	.13	.84	.11
Omak	4.67	.93	.75	.70
Pullman	1.33	.27	.70	.19
Richland	.33	N/A	N/A	N/A
Spokane Airport	2.33	.47	.75	.35
Walla Walla	1.00	.20	.75	.15
Wenatchee	2.67	.53	.84	.45
Yakima	2.00	.40	.84	.34

For projects that are located above 2500 feet elevation, a separate study or local data should be used as the average snow depth is significant and varies widely.

The assumption is that the entire average daily snow melt on the ground will melt during the long-duration storm. Since the long-duration storm is a three day duration, the water equivalent for the peak 24 hours will be less than if the long-duration storm were only 24 hours. The adjustment factor is the ratio of the 24-hour precipitation to the 72-hour precipitation and varies based on climate region. In order to utilize the snowmelt factor with the long-duration storm hyetograph, the Long-Duration Storm Precipitation Adjustment should be added to the 24-hour design storm precipitation.

The inches of snowmelt added to the design recurrence interval storm magnitude should yield a design storm that accounts for rain-on-snow and preserves the approximate probability of the design recurrence interval. The CN used shall be for normal Antecedent Moisture Condition II as shown in Figure 4-5.2.

If the Mean Annual Precipitation (MAP) at the project site varies from the MAP at the nearest known snowdepth record location, the average daily snowdepth will also vary. To determine the estimated average daily snowdepth, multiply the known average daily snowdepth and all other factors by the ratio of Mean Annual Precipitation (MAP) at the project site to the Mean Annual Precipitation at the record location.

For example: A project is located in Cashmere where the MAP is 14 inches. The nearest snowdepth record location is Wenatchee. The snowdepth at Wenatchee is 2.67 inches from Table 4-2.10 and the MAP from Figure 4-3.1 is 10 inches. The estimated snowdepth for Cashmere is 2.67 * 14/10 = 3.74 inches.

4.2.8 Using Hyetographs in Computer Models

The hyetographs are based on dimensionless storms. Note that the hyetographs are not unit hydrographs but add up to a value greater than one. When using the hyetographs in most computer models and the spreadsheet method, precipitation adjustments will automatically be made from the 2-hour precipitation for the short-duration storm and from the 24-hour precipitation for the long-duration storm.

Some computer programs may allow for unit hyetographs only. In those cases the hyetograph needs to be converted to a unit hyetograph and the precipitation needs to be adjusted to match the length of the design storm.

The conversion factor for the 2-hour precipitation to the short-duration (3-hour) storm is 1.06 in all regions.

The following table provides the conversion factor for the 24-hour precipitation to the long-duration (72-hour).

Table 4-2.11
Conversion Factor for 24-Hour to 72-Hour Precipitation
(for models which must use a unit hyetograph)

Region #	Region Name	Conversion Factor 24-hour to 72-hour Precipitation
1	East Slope Cascades	1.49
2	Central Basin	1.19
3	Okanogan, Spokane, Palouse	1.33
4	NE & Blue Mountains	1.43

Both dimensionless and unit hyetographs for all regions will be available on Ecology's website site.

4.3 Precipitation Maps

Precipitation maps for eastern Washington are included in Appendix 4B, as listed in the figures below:

Figure 4-3.1: Mean Annual Precipitation with Climate Regions

Figure 4-3.2: 2-year 2-hour Isopluvial Map

Figure 4-3.3: 2-year 24-hour Isopluvial Map

Figure 4-3.4: 10-year 24-hour Isopluvial Map

Figure 4-3.5: 25-year 24-hour Isopluvial Map

Figure 4-3.6: 50-year 24-hour Isopluvial Map

Figure 4-3.7: 100-year 24-hour Isopluvial Map

4.4 Rational Method

Applicability

The rational method is an allowable method for computing peak runoff rates for flow based runoff treatment BMPs such as biofiltration swales and oil/water separators. It is also a common method for computing the peak runoff rate for design of drywells and conveyance systems.

4.4.1 Introduction

The primary source for this section is the WSDOT Hydraulics Manual, 1998.

Design peak runoff rates may be determined by the Rational formula:

$$Q = C I A$$

where

Q = Runoff, cubic feet per second
C = Runoff coefficient
I = Rainfall intensity, inches per hour
A = Contributing area, acres

The runoff coefficients (C) should be based on Table 4-4.1.

The coefficients in Table 4-4.1 are applicable for peak storms of 10-year or less frequency. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff. Generally, when designing for a 25-year frequency, the coefficient should be increased by 10 percent. The runoff coefficient should never be increased above 0.90.

The equation for calculating rainfall intensity is:

$$I = m / (Tc)n$$

Where: I = Rainfall intensity in inches per hour

Tc = Time of concentration in minutes

The rainfall intensity (I) coefficients (m and n) have been determined for all major cities for the 2-, 10-, 25-, 50-, and 100-year mean recurrence intervals (MRI). These coefficients were developed from NOAA Atlas 2. The coefficients for selected cities in Eastern Washington are in Table 4-4.2.

4.4.2 Time of Concentration for Rational Method

If rainfall is applied at a constant rate over a drainage basin, it would eventually produce a constant peak rate of runoff. The amount of time that passes from the moment that the constant rainfall begins to the moment that the constant rate of runoff begins is called the time of concentration.

This is the time required for the surface runoff to flow from the most hydraulically remote part of the drainage basin to the location of concern.

Actual precipitation does not fall at a constant rate. A precipitation event will begin with a small rainfall intensity then, sometimes very quickly, build to a peak intensity and eventually taper down to no rainfall. Because rainfall intensity is variable, the time of concentration is included in the rational method so that the designer can determine the proper rainfall intensity to apply across the basin. The intensity that should be used for design purposes is the highest intensity that will occur with the entire basin contributing flow to the location where the designer is interested in knowing the flow rate. It is important to note that this may be a much lower intensity than the absolute maximum intensity. The reason is that it often takes several minutes before the entire basin is contributing flow but the absolute maximum intensity lasts for a much shorter time so the rainfall intensity that creates the greatest runoff is less than the maximum by the time the entire basin is contributing flow.

Most drainage basins will consist of different types of ground covers and conveyance systems that flow must pass over or through. These are referred to as flow segments. It is common for a basin to have flow segments that are overland flow and flow segments that are open channel flow. Urban drainage basins often have flow segments that are flow through a storm drain pipe in addition to the other two types. A travel time (the amount of time required for flow to move through a flow segment) must be computed for each flow segment. The time of concentration is equal to the sum of all the flow segment travel times.

For a few drainage areas, a unique situation occurs where the time of concentration that produces the largest amount of runoff is less than the time of concentration for the entire basin. This can occur when two or more subbasins have dramatically different types of cover (i.e., different runoff coefficients). The most common case would be a large paved area together with a long narrow strip of natural area. In this case, the designer should check the runoff produced by the paved area alone to determine if this scenario would cause a greater peak runoff rate than the peak runoff rate produced when both land segments are contributing flow. The scenario that produces the greatest runoff should be used, even if the entire basin is not contributing flow to this runoff.

The procedure described below for determining the time of concentration for overland flow was developed by the United States Natural Resources Conservation Service (formerly known as the Soil Conservation Service). It is sensitive to slope, type of ground cover, and the size of channel. The designer should never use a time of concentration less than 5 minutes. The time of concentration can be calculated as follows:

$$T_t = \frac{L}{K\sqrt{S}}$$

$$T_c = T_{t1} + T_{t2} + \ldots + T_{tnz}$$

where: T_t = Travel time of flow segment in minutes

T_c = Time of concentration in minutes

L = Length of segment in feet

K = Ground cover coefficient in feet per minute

S = Slope of segment in feet per feet

Table 4-4.1
Runoff Coefficients, C, For Rational Method -- 10-Year or Less Frequency

	FLAT	ROLLING 2% - 10%	HILLY OVER 10%
Pavement and Roofs	0.90	0.90	0.90
Earth Shoulders	0.50	0.50	0.50
Drives and Walks	0.75	0.80	0.85
Gravel Pavement	0.50	0.55	0.60
City Business Areas	0.80	0.85	0.85
Suburban Residential*	0.25	0.35	0.40
Single Family Residential*	0.30	.040	0.50
Lawns, Sandy Soil	0.10	0.15	0.20
Lawn, Heavy Soil	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay and Loam	0.50	0.55	0.60
Cultivated Land, Sand and Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	0.90
Parks and Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland and Forests	0.10	0.15	0.20
Meadows and Pasture Land	0.25	0.30	0.35
Pasture with Frozen Ground	0.40	0.45	0.50

Source: WSDOT Hydraulics Manual, January 1997

Note: Generally, when designing for a 25-year frequency, the coefficient should be increased by 10 percent. The runoff coefficient should never be increased above 0.90.

Table 4-4.2
Index to Rainfall Coefficients

Location	2-Year MRI		10-Year MRI		25-Year MRI		50-Year MRI		100-Year MRI	
	m	n	m	n	m	n	m	n	m	n
Clarkston and Colfax	5.02	0.628	8.24	0.635	10.07	0.638	11.45	0.639	12.81	0.639
Colville	3.48	0.558	6.98	0.610	9.07	0.626	10.65	0.635	12.26	0.642
Ellensburg	2.89	0.590	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Leavenworth	3.04	0.530	5.62	0.575	7.94	0.594	9.75	0.606	11.08	0.611
Moses Lake	2.61	0.583	6.99	0.655	9.58	0.671	11.61	0.681	13.63	0.688
Omak	3.04	0.583	6.63	0.633	8.74	0.647	10.35	0.654	11.97	0.660
Pasco and Kennewick	2.89	0.590	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Snoqualmie Pass	3.61	0.417	6.56	0.459	7.72	0.459	8.78	0.461	10.21	0.476
Spokane	3.47	0.556	6.98	0.609	9.09	0.626	10.68	0.635	12.33	0.643
Stevens Pass	4.73	0.462	8.19	0.500	8.53	0.484	10.61	0.499	12.45	0.513
Walla Walla	3.33	0.569	7.30	0.627	9.67	0.645	11.45	0.653	13.28	0.660
Wenatchee	3.15	0.535	6.19	0.579	7.94	0.592	9.32	0.600	10.68	0.605
Yakima	3.86	0.608	7.37	0.644	9.40	0.654	10.93	0.659	12.47	0.663

Source: WSDOT Hydraulics Manual, January 1997

Note: *MRI equals Mean Recurrence Interval*

Table 4-4.3
Ground Cover Coefficients

Type of Cover		K
Forest with heavy ground cover		150
Minimum tillage cultivation		280
Short pasture grass or lawn		420
Nearly bare ground		600
Small roadside ditch w/grass		900
Paved area		1,200
Gutter flow	4 in. deep	1,500
	6 in. deep	2,400
	8 in. deep	3,100
Storm Sewers	12 in. diam.	3,000
	18 in. diam.	3,900
	24 in. diam.	4,700
Open Channel Flow (n = .040)	12 in. deep	1,100
Narrow Channel (w/d =1)	2 ft. deep	1,800
	4 ft. deep	2,800
Open Channel Flow (n = .040)	1 ft. deep	2,000
Wide Channel (w/d =9)	2 ft. deep	3,100
	4 ft. deep	5,000

Source: WSDOT Hydraulics Manual, January 1997

4.5 SCS Curve Number Equations

Applicability

The SCS Curve number equations is an allowable method for computing storage volumes for volume based treatment BMPs based on the SCS hydrograph method. The SCS curve numbers are also used in the Single Event Hydrograph Methods such as SCS Hydrograph and Santa Barbara Urban Hydrograph.

4.5.1 Introduction

The primary source for this section is the Surface Water Management Manual for Western Washington, by Dept. of Ecology, 2001 and Urban Hydrology for Small Watersheds TR-55, by Natural Resources Conservation Service, 1986.

This method can be used to size the volume of treatment BMPs when the design criteria is based on the volume of runoff. Computer models are not required for this method. Required input consists of precipitation, pervious and impervious area and curve numbers.

4.5.2 Area

To obtain the highest degree of accuracy in hydrograph analysis, the proper selection of homogeneous basin areas is required. Significant differences in land use within a given drainage basin must be addressed by dividing the basin area into subbasin areas of similar land use and/or runoff characteristics. For example, a drainage basin consisting of a concentrated residential area and a large forested area should be divided into two subbasin areas accordingly. Hydrographs should then be computed for each subbasin area and summed to form the total runoff hydrograph for the basin.

To further enhance the accuracy of hydrograph analysis, all pervious and impervious areas within a given basin or subbasin shall be analyzed separately. This is done by computing separate hydrographs for each area and combining them to form the total runoff hydrograph. By analyzing pervious and impervious areas separately, the errors associated with averaging these areas are avoided and the true shape of the runoff hydrograph is better approximated.

4.5.3 Curve Number

The Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) has for many years conducted studies into the runoff characteristics of various land types. After gathering and analyzing extensive data, the NRCS has developed relationships between land use, soil type, vegetation cover, interception, infiltration, surface storage, and runoff. These relationships have been characterized by a single runoff coefficient called a "curve number (CN)." The National Engineering Handbook - Section 4: Hydrology (NEH-4, SCS, 1985) contains a detailed description of the development and use of the curve number method. The CN indicates the runoff potential of a watershed. Higher CNs have a higher potential for runoff. The CN is a combination of a hydrologic soil group, a land use and a treatment class (cover).

The combination of soil type and land use is called the "soil-cover complex." The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics. SCS has classified over 4,000 soil types into these four soil groups. Table 4-5.1 shows the hydrologic soil group of some of the common soils in Eastern Washington and provides a brief description of the four hydrologic soil group classifications. For details on the hydrologic soil group for other soil types refer to the SCS maps published for each county.

Table 4-5.1
Hydrologic Soil Group of Selected Soils in Eastern Washington
See SCS Soils Maps for Additional Soil and Hydrologic Groups

Soil Group	Hydrologic Group*	Soil Group	Hydrologic Group*
Athena	B	Laketon	C
Bernhill	B	Lance	B
Bong	A	Larkin	B
Bonner	B	Latah	D
Brickel	C	Marble	A
Bridgeson	D	Mondovi	B
Caldwell	C	Moscow	C
Cedonia	B	Naff	B
Cheney	B	Narcisse	C
Clayton	B	Nez Perce	C
Cocolalla	D	Palouse	B
Dearyton	C	Peone	D
Dragoon	C	Phoebe	B
Eloika	B	Reardan	C
Emdent	D	Schumacher	B
Freeman	C	Semiahmoo	D
Garfield	C	Snow	B
Garrison	B	Speigle	B
Glenrose	B	Spokane	C
Green Bluff	B	Springdale	A
Hagen	B	Tekoa	C
Hardesty	B	Uhlig	B
Hesseltine	B	Vassar	B
Konner	D	Wethey	C
Lakesol	B	Wolfeson	C

* From SCS, TR-55, Second Edition, June 1986, Appendix A.

Hydrologic Soil Group Classifications

A. Low runoff potential: Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-to-excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Moderately low runoff potential: Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Moderately high runoff potential: Soils have slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

D. High runoff potential: Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The following are important criteria/considerations for selection of CN values:

Many factors may affect the CN value for a given land use. For example, the movement of heavy equipment over bare ground may compact the soil so that it has a lesser infiltration rate and greater runoff potential than would be indicated by strict application of the CN value based on predevelopment conditions at the site.

Separate CN values must be selected for the pervious and impervious areas of an urban basin or subbasin. For all developed areas, the percent impervious must be estimated from best available plans, topography, or aerial photography and verified by field reconnaissance. Generally, the pervious area CN value shall be a weighted average of all the pervious area CN values within the subbasin. However, if two areas within the same subbasin have CN values which are different by more than 20 points, separate hydrographs need to be generated for the two areas and the hydrographs then added together to determine the subbasin's runoff characteristics.

Directly connected impervious areas are areas such as roofs and driveways from which runoff directly enters the drainage system without first traversing an area of pervious ground. They must all be considered as impervious areas. Unconnected impervious areas are areas whose runoff is spread over a pervious area as sheet flow and include such items as a tennis court in the middle of a lawn. Unconnected impervious areas can be weighted with pervious areas.

Table 4-5.2 gives CNs for agricultural, suburban, and urban land use classifications. These Curve Number values listed in Table 4-5.2 are applicable under normal antecedent moisture conditions (AMC II) and are the basis of design in Eastern Washington.

Conditions where there is high groundwater, or shallow bedrock can cause a significant increase in runoff. If these conditions exist, it needs to be addressed by the design engineer. For a more complete discussion of computing weighted CN values, see NRCS publication 210-VI-TR-55, Second Ed, June 1986.

Antecedent Moisture Condition

The moisture condition in a soil at the onset of a storm event, referred to as the antecedent moisture condition (AMC), has a significant effect on both the volume and rate of runoff. Recognizing that fact, the SCS developed three antecedent soil moisture conditions, labeled conditions I, II, and III. The description of each condition is:

AMC I: soils are dry but not to wilting point

AMC II: average conditions

AMC III: heavy rainfall, or light rainfall and low temperatures have occurred within the last 5 days; near saturated or saturated soil

The table shown below gives seasonal rainfall limits for the three antecedent soil moisture conditions:

Total 5-day Antecedent Rainfall (inches)

AMC	Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	Over 1.1	Over 2.1

Varying antecedent moisture conditions are used in the design of evaporation ponds in Section 5.4. See Table 4-5.3 for the curve number conversions for different antecedent moisture conditions for the case of Ia = 0.2S. For other conversion, see the SCS National Engineering Handbook No. 4, 1985.

Supplemental Guidelines

Local jurisdictions may wish to restrict the curve numbers used to describe the existing condition and generate the runoff in the predeveloped condition. The lower curve numbers result in lower runoff and mitigate for past changes to the natural drainage patterns. Restricting the allowable curve numbers can also reduce the subjectiveness that is inherent in the selection of curve numbers.

Table 4-5.2
Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas

	CNs for hydrologic soil group			
Cover type and hydrologic condition	A	B	C	D
Open Space (lawns, parks, golf courses, cemeteries, landscaping, etc.): [1]				
Poor condition (grass cover <50% of the area)	68	79	86	89
Fair condition (grass cover on 50% to 75% of the area)	49	69	79	84
Good condition (grass cover on >75% of the area)	39	61	74	80
Impervious Areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	98	98	98	98
Porous Pavers and Permeable Interlocking Concrete (assumed as 85% impervious and 15% lawn):				
Fair lawn condition (weighted average CNs)	95	96	97	97
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, Grassland, or Range-Continuous Forage for Grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed)	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Cultivated Agricultural Lands:				
Row Crops (good) e.g. corn, sugar beets, soy beans	64	75	82	85
Small Grain (good) e.g. wheat, barley, flax	60	72	80	84
Meadow (continuous grass, protected from grazing and generally mowed for hay):	30	58	71	78
Brush (brush-weed-grass mixture with brush the major element):				
Poor (<50% ground cover)	48	67	77	83
Fair (50% to 75% ground cover)	35	56	70	77
Good (>75% ground cover)	30[2]	48	65	73
Woods - grass combination (orchard or tree farm): [3]				
Poor	57	73	82	86
Fair	43	65	76	82
Good	32	58	72	79
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning)	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Herbaceous (mixture of grass, weeds, and low-growing brush, with brush the minor element): [4]				
Poor (<30% ground cover)		80	87	93
Fair (30% to 70% ground cover)		71	81	89
Good (>70% ground cover)		62	74	85
Sagebrush with Grass Understory: [4]				
Poor (<30% ground cover)		67	80	85
Fair (30% to 70% ground cover)		51	63	70
Good (>70% ground cover)		35	47	55
For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).				

[1] Composite CNs may be computed for other combinations of open space cover type.

[2] Actual curve number is less than 30; use CN = 30 for runoff computations.

[3] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

[4] Curve numbers have not been developed for group A soils.

Table 4-5.3
Curve Numbers Conversions for Different Antecedent Moisture Conditions (Case Ia = 0.2 S)

CN for AMC II	CN for AMC I	CN for AMC III		CN for AMC II	CN for AMC I	CN for AMC III
100	100	100		76	58	89
99	97	100		75	57	88
98	94	99		74	55	88
97	91	99		73	54	87
96	89	99		72	53	86
95	87	98		71	52	86
94	85	98		70	51	85
93	83	98		69	50	84
92	81	97		68	48	84
91	80	97		67	47	83
90	78	96		66	46	82
89	76	96		65	45	82
88	75	95		64	44	81
87	73	95		63	43	80
86	72	94		62	42	79
85	70	94		61	41	78
84	68	93		60	40	78
83	67	93		59	39	78
82	66	92		58	38	76
81	64	92		57	37	75
80	63	91		56	36	75
79	62	91		55	35	74
78	60	90		54	34	73
77	59	89		50	31	70

Source: SCS-NEH4. Table 10.1.

Example: The following is an example of how CN values are selected for a sample project.

Select CNs for the following development:

Existing Land Use-- woods (thin stand, poor cover)

Future Land Use -- 80% impervious

Basin Size -- 10 acres

Soil Type -- 80% Garfield, 20% Bonner split between the pervious and impervious areas.

Table 4-5.1 shows that Garfield soil belongs to the "C" hydrologic soil group and Bonner soil belongs to the "B" group. Therefore, for the existing condition, CNs of 77 and 66 are read from Table 4-5.2 and area weighted to obtain a CN value of 75.

For the developed condition with 80 percent impervious the impervious and pervious areas of 8.0 acres and 2.0 acres respectively. The impervious area CN-value is 98. The 2.0 acres of pervious area consists of 70 percent grass landscaping covering the same proportions of Garfield and Bonner soil (80 percent and 20 percent respectively). Therefore, CNs of 79 and 69 are read from Table 4-5.2 fair condition open space and area weighted to obtain a pervious area CN value of 77. The result of this example are summarized below:

On-Site Condition	Existing	Developed
Land use	Woods	Multi-Family
Pervious area	10.0 ac.	2.0 ac.
CN of pervious area	75	77
Impervious area	0 ac	8.0 ac
CN of impervious area	---	98

SCS Curve Number Equations

The rainfall-runoff equations of the SCS curve number method relates a land area's runoff depth (precipitation excess) to the precipitation it receives and to its natural storage capacity. The amount of runoff from a given watershed is solved with the following equations:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \text{ ....(4-1)}$$

$$S = \frac{1000}{CN} - 10 \text{ ....(4-2)}$$

Q = 0 for P < 0.2S

Where,

Q is the actual direct runoff depth (inches)

P is the total storm rainfall depth over the area (inches)

When designing volume based treatment BMPs using Method PM2, note that the 6-month long duration storm precipitation must be used in this equation. To determine 6-month long-duration storm precipitation from the 2-year 24-hour precipitation, multiply the 2-year 24-hour precipitation times Cwqs from Table 4-2.8 times the conversion factor in Table 4-2.11.

For method PM2: P = (P2yr24hr) (Cwqs) (24 to72 Hour Conversion Factor)

For method AM2: P = (P2yr24hr) (Cwqs)

S is the potential abstraction or potential maximum natural detention over the area due to infiltration, storage, etc.(inches)

CN is the runoff curve number

The combination of the above equations allows for estimation of the total runoff volume by computing the total runoff depth, Q, given the total precipitation depth, P.

The following is an example for determining design treatment volume.

The project location is Ellensburg.
The contributing area requiring treatment is 4.5 acres.
The curve number of the area is 98 (which corresponds to paved surfaces).
The value of S is 1000/98 – 10 = 0.20.

The 2-year 24-hour precipitation from Figure 4-3.3 is 0.8 inches.
Cwqs for Region 2 from Table 4-2.8 is 0.66.
24 to 72 Hour Conversion Factor for Region 2 from Table 4-2.11 is 1.19.

For **Preferred Method PM2**, the total amount of rainfall during the long duration storm would be:

P = (0.80 inches) (0.66) (1.19) = 0.63 inches

For **Alternative Method AM2**, the total amount of rainfall during the 24-hour storm would be:

P = (0.80 inches) (0.66) = 0.53 inches

Continuing on with **Method PM2**, the amount of rainfall that would become runoff would be:

Q = [0.63 - 0.2 (0.20)]2 /[0.63 + 0.8 (0.20)] = 0.44 inches

This computed runoff represents inches over the tributary area. Therefore, the total volume of runoff is found by multiplying Q by the area (with necessary conversions):

Total runoff						
Volume	=	3,630	X	Q	X	A
(cu-ft)		(cu-ft/ac-in)		(in)		(ac)

The total runoff volume is:

3,630 cu. ft./acre-in. x 0.44 in. x 4.5 acres = 7,187 cu. ft.

This is the design volume for treatment BMPs for which the design criterion is based on volume of runoff.

When developing the runoff hydrograph, the above equation for Q is used to compute the incremental runoff depth for each time interval from the incremental precipitation depth given by the design storm hyetograph. This time distribution of runoff depth is often referred to as the precipitation excess and provides the basis for synthesizing the runoff hydrograph.

4.6 Single Event Hydrograph Methods

Applicability

Single Event Hydrograph Methods are the required method for designing flow control BMPs. They are an allowable method for computing peak runoff rates and runoff volumes for design of runoff treatment BMPs. Single Event Hydrograph Methods include Soil Conservation Service (SCS) and Santa Barbara Urban Hydrograph (SBUH). Commercially available computer programs for these methods may be used, if the sponsor's engineer acquires acceptance from the local jurisdiction. Said acceptance shall be obtained prior to submittal of plans and calculations.

4.6.1 Hydrograph Design Process

This section presents the general process involved in conducting a hydrologic analysis using hydrograph methods to a) design retention/detention flow control facilities and b) determine water quality treatment volumes. The exact step-by-step method for entering data into a computer model varies with the different models and is not described here. See the documentation or Help module of the computer program. Pre-developed and post-developed site runoff conditions need to be determined and documented in the Stormwater Site Plan.

The process for designing retention/detention flow control facilities is described as follows:

Review the Core Element #6 in Chapter 2 to determine all requirements that will apply to the proposed project.
1. Determine the climate region and Mean Annual Precipitation (MAP). (See Figure 4-3.1)
2. Determine 2 rainfalls for site. (See Figures 4-3.3 and 4-3.5) • 2-year – 24-hour • 25-year – 24-hour
3. Determine pre-developed soils type and hydrologic group (A, B, C, or D) from SCS maps.
4. Determine pre-developed and post-developed drainage basin areas, and determine the subsequent pervious and impervious area for each condition (in acres).
5. Determine curve numbers for pervious and impervious area using hydrologic soil group for both the pre-developed and post-developed condition. (See Table 4-5.2)
6. Determine pre-developed and post-developed time of concentration. (Some computer models will do this calculation if the designer enters length, slope, roughness and flow type.)

7. If modeling the long duration storm, input the long-duration storm (72-hour) hyetographs into model for the climate region (See Tables 4-2.4 to 4-2.7.) (Note this step only needs to be done once.) Since most computer models already include all four SCS storm hyetographs this step is not normally required if modeling the SCS Type II storm. However, the user should check that the hyetograph data matches the desired time step interval.
8. Input data obtained from Steps 3, 5, 6, and 7 into the computer model for each pre-developed and post-developed storm event.
9. Have the computer model compute the hydrographs.
10. Review the peak flow rate for the pre-developed conditions in the 2-year and 25-year design storms. The allowable release rate for the 2-year storm is 50 percent of the pre-developed 2-year peak flow. The allowable release rate for the 25-year storm is equal to the pre-developed 25-year peak flow. Note that in some cases the pre-developed 2-year peak flow rate may be 0 cfs, which means there is no discharge from the site. The 2-year post-developed flows in this situation must be infiltrated or retained for evaporation in dead storage.
11. Review the peak flow rate for post-developed conditions in the 2-year and 25-year storms. Compare the increases in peak flow rates for 2-year and 25-year design storms to determine if the project qualifies for an exemption.
12. Assume the size of the detention facility and input the data into the computer model. Most computer models will allow a vault or a pond detention facility, with or without infiltration. Refer to the volume of the design storm hydrograph computed in Step 10 for a good assumption of the detention volume required.
13. Assume the size of the orifice structure and input the data into the computer model. A single orifice at the bottom of the riser may suffice in some cases. In other projects multiple orifices may result in decreased pond sizes. A good approximation would be to assume a 1 inch diameter orifice per 0.05 cfs outflow for a typical pond. Note that the design engineer should reference Chapter 5 to determine the minimum allowable orifice diameter.
14. Use the computer model to route the post-developed hydrographs through the detention facility and orifice structure. Compare the post-developed peak outflow rates to allowable release rates from Step 11.

15. If the post-developed peak outflow rates exceed the allowable release rates, adjust detention volume, orifice size, orifice height, or number of orifices. Keep running the computer model and adjusting the parameters until the post-developed outflow rates are less than or equal to the allowable release rates.
16. Calculations are complete.

The process for designing water quality treatment volumes or flow rates is described as follows. Note that the data for many of the initial steps matches the data utilized in designing retention/detention flow control facilities described above.

1. Review the Core Element #5 in Chapter 2 to determine all requirements that will apply to the proposed project.
2. Determine the climate region and Mean Annual Precipitation (MAP). (See Figure 4-3.1)
3. Determine one of the following rainfalls for site depending on the treatment BMP. (See Figures 4-3.2 and 4-3.3) • 2-year – 2-hour for flow based treatment BMPs • 2-year – 24-hour for volume based treatment BMPs
4. Multiply the rainfall by the appropriate coefficient to determine the 6-month precipitation. • Csds from Table 4-2.9 for 2-year – 2-hour precipitation • Cwqs from Table 4-2.8 for 2-year – 24-hour precipitation 5. Determine the existing soils type and hydrologic group (A, B, C, or D) from SCS maps. 6. Determine post-developed drainage basin areas, and determine the subsequent pervious and impervious area requiring treatment that contributes flow to the treatment BMP (in acres).
7. Determine curve numbers for pervious and impervious area using hydrologic soil group for the post-developed condition. (See Table 4-5.2)
8. Determine post-developed time of concentration. (Some computer models will do this calculation if the designer enters length, slope, roughness and flow type.)
9. If modeling the short or long duration storm, input the short-duration storm (3-hour) or long-duration storm (72-hour) hyetographs into model for the climate region (See Tables 4-2.3 to 4-2.7.) (Note this step only needs to be done once.) Since most computer models already include all four SCS storm hyetographs this step is not normally required if modeling the SCS Type II storm. However, the user should check that the hyetograph data matches the desired time step interval.

10. Input data obtained from Steps 4, 6, 7, and 8 into the computer model for the post-developed storm event.
11. Have the computer model compute the hydrograph.
12. For the design of flow based treatment BMPs, the computed peak flow form the 6-month – 2-hour hydrograph is the design flow.
13. For the design of volume based treatment BMPs, the computed volume from the 6-month – 24-hour (or long duration design) storm is the design volume.

4.6.2 Hydrograph Parameters

All storm event hydrograph methods require the input of parameters that describe the physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed. This section describes one of the three key parameters used to develop the runoff hydrograph using the SCS or SBUH method. The other two parameters are area and curve number which are described in Section 4.5.

4.6.3 Travel Time and Time of Concentration

The time of concentration for rainfall shall be computed for all overland flow, ditches, channels, gutters, culverts, and pipe systems. When using the SBUH or SCS methods, the time of concentration for the various surfaces and conveyances should be computed using the following methods, which are based on the methods described in Chapter 3, NRCS publication 210-VI-TR-55, Second Ed., June 1986.

Travel time (Tt) is the time it takes water to travel from one location to another in a watershed. Tt is a component of time of concentration (Tc), which is the time for runoff to travel from the hydraulically most distant point of the watershed. Tc is computed by summing all the travel times for consecutive components of the drainage conveyance system. Tc influences the shape and peak of the runoff hydrograph. Urbanization usually decreases Tc, thereby increasing the peak discharge. But Tc can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is best determined by field inspection.

Travel time (Tt) is the ratio of flow length to flow velocity:

$T_t =$ L / 60 V .... (4-3)

where

T_t = travel time (min)

L = flow length (ft)

V = average velocity (ft/s), and

60 = conversion factor from seconds to minutes.

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments.

$$T_c = T_{t_1} + T_{t_2} + \ldots T_{t_m} \quad \text{................ (4-4)}$$

where

T_c = time of concentration (min), and

m = number of flow segments

Sheet Flow: Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (ns) (a modified Manning's effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment) is used. These ns values are for very shallow flow depths of about 0.1 foot and are only used for travel lengths up to 300 feet. Table 4-6.1 gives Manning's ns values for sheet flow for various surface conditions.

For sheet flow up to 300 feet, use Manning's kinematic solution to directly compute Tt:

$$T_t = \frac{0.42 \ (n_s L)^{0.8}}{(P_2)^{0.5} \ (s_o)^{0.4}} \quad \text{................ (4-5)}$$

where

T_t = travel time (min),
n_s = sheet flow Manning's effective roughness coefficient (from Table 4-6.1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), (from Figure 4-3.3) and
s_o = slope of hydraulic grade line (land slope, ft/ft)

Shallow Concentrated Flow: After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. The average velocity for this flow can be calculated using the ks values from Table 4-6.1 in which average velocity is a function of watercourse slope and type of channel. After computing the average velocity using the Velocity Equation below, the travel time (Tt) for the shallow concentrated flow segment can be computed using the Travel Time Equation described above.

Velocity Equation

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

$V = k \sqrt{s_o}$ .... (4-6)

where:

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

"k" values in Table 4-6.1 have been computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$k = (1.49 (R)^{0.667})/n$; .... (4-7)

where

R = an assumed hydraulic radius
n = Manning's roughness coefficient for open channel flow (from Tables 4-6.1 or 4-6.2)

Table 4-6.1
"n" And "k" Values for Use in Computing Time Of Concentration

FOR SHEET FLOW	n_s
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 ft/ft)	0.06
Cultivated soil with crop residue (slope > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
FOR SHALLOW, CONCENTRATED FLOW	k_s
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n =0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.030)	11
Newly-bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
CHANNEL FLOW (INTERMITTENT, R = 0.2)	k_c
Forested swale with heavy ground litter (n=0.10)	5
Forested drainage course/ravine with defined channel bed (n=0.050)	10
Rock-lined waterway (n=0.035)	15
Grassed waterway (n=0.030)	17
Earth-lined waterway (n=0.025)	20
CMP pipe (n=0.024)	21
Concrete pipe (n=0.012)	42
Other waterways and pipes	0.508/n
CHANNEL FLOW (CONTINUOUS STREAM, R =0.4)	k_c
Meandering stream with some pools (n=0.040)	20
Rock-lined stream (n=0.035)	23
Grassed stream (n=0.030)	27
Other streams, man-made channels and pipe	0.807/n

Table 4-6.2
Other Values of the Roughness Coefficient “n” for Channel Flow

Type of Channel and Description	Manning’s “n”*	Type of Channel and Description	Manning’s “n”*
A. Constructed Channels		6. Sluggish reaches, weedy	
a. Earth, straight and uniform		deep pools	0.070
1. Clean, recently completed	0.018	7. Very weedy reaches, deep	
2. Gravel, uniform selection,	0.025	pools, or floodways with	
clean		heavy stand of timber and	
3. With short grass, few	0.027	underbrush	0.100
weeds		b. Mountain streams, no vegetation	
b. Earth, winding and sluggish		in channel, banks usually steep,	
1. No vegetation	0.025	trees and brush along banks	
2. Grass, some weeds	0.030	submerged at high stages	
3. Dense weeds or aquatic		1. Bottom: gravel, cobbles and	
plants in deep channels	0.035	few boulders	0.040
4. Earth bottom and rubble		2. Bottom: cobbles with large	
sides	0.030	boulders	0.050
5. Stony bottom and weedy		B-2 Flood plains	
banks	0.035	a. Pasture, no brush	
6. Cobble bottom and clean		1. Short grass	0.030
sides	0.040	2. High grass	0.035
c. Rock lined		b. Cultivated areas	
1. Smooth and uniform	0.035	1. No crop	0.030
2. Jagged and irregular	0.040	2. Mature row crops	0.035
d. Channels not maintained,		3. Mature field crops	0.040
weeds and brush uncut		c. Brush	
1. Dense weeds, high as flow		1. Scattered brush, heavy	
depth	0.080	weeds	0.050
2. Clean bottom, brush on		2. Light brush and trees	0.060
sides	0.050	3. Medium to dense brush	0.070
3. Same, highest stage of		4. Heavy, dense brush	0.100
flow	0.070	d. Trees	
4. Dense brush, high stage	0.100	1. Dense willows, straight	0.150
B. Natural Streams		2. Cleared land with tree	
B-1 Minor streams (top width		stumps, no sprouts	0.040
at flood stage < 100ft.)		3. Same as above, but with	
a. Streams on plain		heavy growth of sprouts	0.060
1. Clean, straight, full stage		4. Heavy stand of timber, a few	
no rifts or deep pools	0.030	down trees, little	
2. Same as above, but more		undergrowth, flood stage	
stones and weeds	0.035	below branches	0.100
3. Clean, winding, some		5. Same as above, but with	
pools and shoals	0.040	flood stage reaching	
4. Same as above, but some		branches	0.120
Weeds	0.040		
5. Same as 4, but more			
Stones	0.050		

*Note, these “n” values are “normal” values for use in analysis of channels. For conservative design for channel capacity the “maximum” values listed in other references should be considered. For channel bank stability the minimum values should be considered.

Open Channel Flow: Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on United States Geological Survey (USGS) quadrangle sheets. The kc values from Table 4-6.1 used in the Velocity Equation above or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full conditions. After average velocity is computed the travel time (Tt) for the channel segment can be computed using the Travel Time Equation above.

Lakes or Wetlands: Sometimes it is necessary to estimate the velocity of flow through a lake or wetland at the outlet of a watershed. This travel time is normally very small and can be assumed as zero. Where significant attenuation may occur due to storage effects, the flows should be routed using the "level pool routing" technique described in Section 4.7.

Limitations: The following limitations apply in estimating travel time (Tt).

Manning's kinematic solution should not be used for sheet flow longer than 300 feet.

In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate Tc. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.

A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. A hydrograph should be developed to this point and the "level pool routing" technique should be used to determine the outflow rating curve through the culvert or bridge.

Time of Concentration Example: The following is an example of travel time and time of concentration calculations.

Given: An existing drainage basin having a selected flow route composed of the following 4 segments: (Note: Drainage basin has a P2 = 0.8 inches.)

Segment 1: L = 200 ft, Forest with good cover (sheet flow)
s_o = 0.03 ft/ft, n_s = 0.80
Segment 2: L = 300 ft, Pasture (shallow concentrated flow)
s_o = 0.04 ft/ft, k_s = 11
Segment 3: L = 300 ft, Grassed waterway (intermittent channel)
s_o = 0.05, k_c = 17
Segment 4: L = 500 ft, Grass-lined stream (continuous)
s_o = 0.02, k_c = 27

Calculate travel times (Tt's) for each reach and then sum them to calculate the drainage basin time of concentration (Tc).

Segment 1: Sheet flow, (L < 300 feet)

$$T_t = \frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$$

$$T_1 = \frac{(0.42)[(0.80)(200)]^{0.8}}{(0.8)^{0.3}(0.03)^{0.4}} = \underline{106\,\text{minutes}}$$

Segment 2: Shallow concentrated flow

$$V = k_s \sqrt{s_o}$$

$$V_2 = (11)\sqrt{(0.04)} = 2.2 \text{ ft/s}$$

$$T_2 = \frac{L}{60V} = \frac{(300)}{60(2.2)} = \underline{2 \text{ minutes}}$$

Segment 3: Intermittent channel flow

$$V_4 = (17)\sqrt{(0.05)} = 3.8 \text{ ft/s}$$

$$T_4 = \frac{(300)}{60(3.8)} = \underline{1\,\text{minute}}$$

Segment 4: Continuous stream

$$V_5 = (27)\sqrt{(0.02)} = 3.8 \text{ ft/s}$$

$$T_5 = \frac{(500)}{60(3.8)} = \underline{2 \text{ minutes}}$$

$$T_c = T_1 + T_2 + T_3 + T_4$$

$$T_c = 106 + 2 + 1 + 2 = \underline{111 \text{ minutes}}$$

It is important to note how the initial sheet flow segment's travel time dominates the time of concentration computation. This will nearly always be the case for relatively small drainage basins and in particular for the existing site conditions. This also illustrates the significant impact urbanization has on the surface runoff portion of the hydrologic process.

The time of concentration should be calculated for each significantly different slope. Travel time for flow in pipes, ditches and gutters should be computed as a function of the velocity as defined by the Manning formula.

4.6.4 Hydrograph Synthesis

This section presents a description of the Santa Barbara Urban Hydrograph (SBUH) method. This method is used to synthesize the runoff hydrograph from precipitation excess (time distribution of runoff) and time of concentration.

The SBUH method was developed by the Santa Barbara County Flood Control and Water Conservation District, California. The SBUH method directly computes a runoff hydrograph without going through an intermediate process (unit hydrograph) as the SCSUH method does. By comparison, the calculation steps of the SBUH method are much simpler and can be programmed on a calculator or a spreadsheet program. Commercial software is also available that can perform these calculations.

The SBUH method uses two steps to synthesize the runoff hydrograph:

Step 1 - Compute the instantaneous hydrograph, and

Step 2- Compute the runoff hydrograph.

The instantaneous hydrograph, l(t), in cfs, at each time step, dt, is computed as follows:

$$l(t) = 60.5\ R(t)\ A/dt$$

where

R(t) = total runoff depth (both impervious and pervious runoffs) at time increment dt, in inches (also known as precipitation excess)

A = area in acres

dt = time interval in minutes*

Note: *A maximum time interval of 5 minutes will be used for all short-duration design storms. A maximum time interval of 30 minutes will be used for all long-duration design storms.*

The runoff hydrograph, Q(t), is then obtained by routing the instantaneous hydrograph l(t), through an imaginary reservoir with a time delay equal to the time of concentration, Tc, of the drainage basin. The following equation estimates the routed flow, Q(t):

$$Q(t+1) = Q(t) + w[l(t) + l(t+1) - 2Q(t)]$$

where,

$$w = dt/(2T_c + dt)$$

dt = time interval in minutes

Example: To illustrate the SBUH method, Figure 4-6.1 shows a runoff hydrograph computed by this method. These examples were prepared using spreadsheet program. These examples illustrate how the method can be performed with a personal computer. In order to save space, time increments with all values equal to zero have been omitted.

Figure 4-6.1
Example SBUH Runoff Hydrograph

Existing Site Condition
REGION 2, 25-YEAR LONG-DURATION STORM

Given				
Area (ac.) = **5.0**		P_t (inches) = **1.6**	d_t (min.)= **30**	T_c (min)= **40**
w =routing constant =$d_t/(2T_c + d_t)$ = **0.2727**				
Pervious Area (ac.):	Area = **5.0**	CN = **65**	S = (1000/CN) -10 = **5.38**	0.2S = **1.08**
Impervious Area (ac.):	Area = **0.0**	CN = **98**	S = (1000/CN) -10 = **0.20**	0.2S = **0.04**

Column (3) = rainfall distribution
Column (4) = Column (3) x P_t
Column (5) = P = Accumulated sum of Column (4)
Column (6) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where PERVIOUS AREA S value is used
Column (7) = Column (6) of present step – Column (6) of previous step
Column (8) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where IMPERVIOUS AREA S value is used
Column (9) = Column (8) of present step – Column (8) of previous step
Column (10) = [(PERVIOUS AREA/TOTAL AREA) * Column (7)] + [(IMPERVIOUS AREA/TOTAL AREA) x Column (9)]
Column (11) = (60.5 x Column (10) x TOTAL AREA)/d_t
Column (12) = Column (12) of previous time + w[(Column (11) of previous time step + Column (11) of present time step) – (2 x Column (12) of previous time step)] where w = d_t /(2T_c+ d_t)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accumul. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
1	0	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
2	30	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
3	60	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
…											
90	2670	0.06220	0.100	0.934	0.000	0.000	0.495	0.089	0.000	0.0	0.00
91	2700	0.09330	0.149	1.083	0.000	0.000	0.632	0.137	0.000	0.0	0.00
92	2730	0.05275	0.084	1.167	0.001	0.001	0.711	0.079	0.001	0.0	0.00
93	2760	0.04025	0.064	1.232	0.004	0.003	0.772	0.061	0.003	0.0	0.01
94	2790	0.03717	0.059	1.291	0.008	0.004	0.828	0.056	0.004	0.0	0.02
95	2820	0.03483	0.056	1.347	0.013	0.005	0.881	0.053	0.005	0.0	0.03
96	2850	0.03307	0.053	1.400	0.018	0.005	0.931	0.051	0.005	0.1	0.04

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accumul. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
97	2880	0.02893	0.046	1.446	0.024	0.005	0.976	0.044	0.005	0.1	0.05
98	2910	0.02519	0.040	1.486	0.029	0.005	1.015	0.039	0.005	0.1	0.05
99	2940	0.02189	0.035	1.521	0.034	0.005	1.048	0.034	0.005	0.0	0.05
100	2970	0.01906	0.030	1.552	0.039	0.005	1.078	0.029	0.005	0.0	0.05
101	3000	0.01670	0.027	1.579	0.043	0.004	1.103	0.026	0.004	0.0	0.05
102	3030	0.01480	0.024	1.602	0.047	0.004	1.126	0.023	0.004	0.0	0.04
103	3060	0.01336	0.021	1.624	0.050	0.004	1.147	0.021	0.004	0.0	0.04
104	3090	0.01234	0.020	1.643	0.054	0.004	1.166	0.019	0.004	0.0	0.04
105	3120	0.01156	0.018	1.662	0.057	0.003	1.184	0.018	0.003	0.0	0.04
106	3150	0.01096	0.018	1.679	0.061	0.003	1.201	0.017	0.003	0.0	0.04
107	3180	0.01054	0.017	1.696	0.064	0.003	1.217	0.016	0.003	0.0	0.03
108	3210	0.01032	0.017	1.713	0.067	0.003	1.233	0.016	0.003	0.0	0.03
109	3240	0.01028	0.016	1.729	0.070	0.003	1.249	0.016	0.003	0.0	0.03
110	3270	0.01038	0.017	1.746	0.074	0.003	1.265	0.016	0.003	0.0	0.03
111	3300	0.01046	0.017	1.763	0.077	0.004	1.282	0.016	0.004	0.0	0.03
112	3330	0.01046	0.017	1.779	0.081	0.004	1.298	0.016	0.004	0.0	0.04
113	3360	0.01040	0.017	1.796	0.085	0.004	1.314	0.016	0.004	0.0	0.04
114	3390	0.01025	0.016	1.812	0.088	0.004	1.330	0.016	0.004	0.0	0.04
115	3420	0.01004	0.016	1.828	0.092	0.004	1.346	0.016	0.004	0.0	0.04
116	3450	0.00974	0.016	1.844	0.096	0.004	1.361	0.015	0.004	0.0	0.04
117	3480	0.00926	0.015	1.859	0.099	0.003	1.375	0.014	0.003	0.0	0.04
118	3510	0.00868	0.014	1.873	0.102	0.003	1.389	0.014	0.003	0.0	0.04
119	3540	0.00832	0.013	1.886	0.106	0.003	1.402	0.013	0.003	0.0	0.03
120	3570	0.00781	0.012	1.899	0.109	0.003	1.414	0.012	0.003	0.0	0.03
121	3600	0.00500	0.008	1.907	0.111	0.002	1.422	0.008	0.002	0.0	0.03
122	3630	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.02
123	3660	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.01
124	3690	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00
125	3720	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00
…											
145	4320	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00

Developed Site Condition

REGION 2, 25-YEAR LONG-DURATION STORM

Given			
Area (ac.) = **5.0**	P_t (inches) = **1.6**	d_t (min.)= **30**	T_c (min)= **5**
w =routing constant $=d_t/(2T_c + d_t)$ = **0.750**			
Pervious Area (ac.): Area = **0.5**	CN = **65**	S = (1000/CN) -10 = **5.38**	0.2S = **1.08**
Impervious Area (ac.): Area = **4.5**	CN = **98**	S = (1000/CN) -10 = **0.20**	0.2S = **0.04**

Column (3) = rainfall distribution
Column (4) = Column (3) x P_t
Column (5) = P = Accumulated sum of Column (4)
Column (6) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where PERVIOUS AREA S value is used
Column (7) = Column (6) of present step – Column (6) of previous step
Column (8) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where IMPERVIOUS AREA S value is used
Column (9) = Column (8) of present step – Column (8) of previous step
Column (10) = [(PERVIOUS AREA/TOTAL AREA) * Column (7)] + [(IMPERVIOUS AREA/TOTAL AREA) x Column (9)]
Column (11) = (60.5 x Column (10) x TOTAL AREA)/d_t
Column (12) = Column (12) of previous time + w[(Column (11) of previous time step + Column (11) of present time step) – (2 x Column (12) of previous time step)] where w = d_t /(2T_c+ d_t)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accum. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
1	0	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
2	30	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
3	60	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
…											
22	630	0.01669	0.027	0.046	0.000	0.000	0.000	0.000	0.000	0.0	0.00
23	660	0.02831	0.045	0.092	0.000	0.000	0.010	0.010	0.009	0.1	0.07
24	690	0.04680	0.075	0.167	0.000	0.000	0.048	0.038	0.034	0.3	0.29
25	720	0.03120	0.050	0.217	0.000	0.000	0.081	0.033	0.030	0.3	0.34
26	750	0.02549	0.041	0.257	0.000	0.000	0.111	0.030	0.027	0.3	0.26
27	780	0.01451	0.023	0.281	0.000	0.000	0.129	0.018	0.016	0.2	0.20
28	810	0.00445	0.007	0.288	0.000	0.000	0.135	0.006	0.005	0.1	0.06
29	840	0.00202	0.003	0.291	0.000	0.000	0.138	0.003	0.002	0.0	0.02
30	870	0.00192	0.003	0.294	0.000	0.000	0.140	0.002	0.002	0.0	0.02
31	900	0.00172	0.003	0.297	0.000	0.000	0.142	0.002	0.002	0.0	0.02

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accum. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
32	930	0.00152	0.002	0.299	0.000	0.000	0.144	0.002	0.002	0.0	0.02
33	960	0.00132	0.002	0.301	0.000	0.000	0.146	0.002	0.002	0.0	0.02
34	990	0.00112	0.002	0.303	0.000	0.000	0.147	0.001	0.001	0.0	0.01
35	1020	0.00092	0.001	0.305	0.000	0.000	0.149	0.001	0.001	0.0	0.01
36	1050	0.00072	0.001	0.306	0.000	0.000	0.150	0.001	0.001	0.0	0.01
37	1080	0.00052	0.001	0.307	0.000	0.000	0.150	0.001	0.001	0.0	0.01
38	1110	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
39	1140	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
…											
72	2130	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
73	2160	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
74	2190	0.00544	0.009	0.315	0.000	0.000	0.157	0.007	0.006	0.1	0.05
75	2220	0.00856	0.014	0.329	0.000	0.000	0.169	0.011	0.010	0.1	0.10
76	2250	0.01000	0.016	0.345	0.000	0.000	0.182	0.013	0.012	0.1	0.12
77	2280	0.01200	0.019	0.364	0.000	0.000	0.198	0.016	0.015	0.1	0.14
78	2310	0.01300	0.021	0.385	0.000	0.000	0.216	0.018	0.016	0.2	0.16
79	2340	0.01400	0.022	0.407	0.000	0.000	0.235	0.019	0.017	0.2	0.17
80	2370	0.01500	0.024	0.431	0.000	0.000	0.256	0.021	0.019	0.2	0.19
81	2400	0.01600	0.026	0.457	0.000	0.000	0.279	0.023	0.020	0.2	0.20
82	2430	0.01700	0.027	0.484	0.000	0.000	0.304	0.024	0.022	0.2	0.22
83	2460	0.01869	0.030	0.514	0.000	0.000	0.331	0.027	0.024	0.2	0.24
84	2490	0.02281	0.036	0.551	0.000	0.000	0.364	0.033	0.030	0.3	0.29
85	2520	0.02832	0.045	0.596	0.000	0.000	0.406	0.042	0.038	0.4	0.37
86	2550	0.03050	0.049	0.645	0.000	0.000	0.451	0.045	0.041	0.4	0.41
87	2580	0.03350	0.054	0.698	0.000	0.000	0.502	0.050	0.045	0.5	0.45
88	2610	0.03650	0.058	0.757	0.000	0.000	0.557	0.055	0.050	0.5	0.50
89	2640	0.04842	0.077	0.834	0.000	0.000	0.631	0.074	0.067	0.7	0.63
90	2670	0.06220	0.100	0.934	0.000	0.000	0.727	0.096	0.086	0.9	0.84
91	2700	0.09330	0.149	1.083	0.000	0.000	0.871	0.145	0.130	1.3	1.22
92	2730	0.05275	0.084	1.167	0.001	0.001	0.954	0.082	0.074	0.7	0.94
93	2760	0.04025	0.064	1.232	0.004	0.003	1.017	0.063	0.057	0.6	0.52
94	2790	0.03717	0.059	1.291	0.008	0.004	1.075	0.058	0.053	0.5	0.57
95	2820	0.03483	0.056	1.347	0.013	0.005	1.130	0.055	0.050	0.5	0.49
96	2850	0.03307	0.053	1.400	0.018	0.005	1.182	0.052	0.047	0.5	0.49
97	2880	0.02893	0.046	1.446	0.024	0.005	1.227	0.046	0.042	0.4	0.43
98	2910	0.02519	0.040	1.486	0.029	0.005	1.267	0.040	0.036	0.4	0.37
99	2940	0.02189	0.035	1.521	0.034	0.005	1.301	0.034	0.032	0.3	0.33
100	2970	0.01906	0.030	1.552	0.039	0.005	1.331	0.030	0.028	0.3	0.28
101	3000	0.01670	0.027	1.579	0.043	0.004	1.358	0.026	0.024	0.2	0.25
102	3030	0.01480	0.024	1.602	0.047	0.004	1.381	0.023	0.021	0.2	0.22

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accum. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
103	3060	0.01336	0.021	1.624	0.050	0.004	1.402	0.021	0.019	0.2	0.20
104	3090	0.01234	0.020	1.643	0.054	0.004	1.422	0.019	0.018	0.2	0.18
105	3120	0.01156	0.018	1.662	0.057	0.003	1.440	0.018	0.017	0.2	0.17
106	3150	0.01096	0.018	1.679	0.061	0.003	1.457	0.017	0.016	0.2	0.16
107	3180	0.01054	0.017	1.696	0.064	0.003	1.474	0.017	0.015	0.2	0.16
108	3210	0.01032	0.017	1.713	0.067	0.003	1.490	0.016	0.015	0.2	0.15
109	3240	0.01028	0.016	1.729	0.070	0.003	1.506	0.016	0.015	0.2	0.15
110	3270	0.01038	0.017	1.746	0.074	0.003	1.523	0.016	0.015	0.2	0.15
111	3300	0.01046	0.017	1.763	0.077	0.004	1.539	0.017	0.015	0.2	0.15
112	3330	0.01046	0.017	1.779	0.081	0.004	1.556	0.017	0.015	0.2	0.15
113	3360	0.01040	0.017	1.796	0.085	0.004	1.572	0.016	0.015	0.2	0.15
114	3390	0.01025	0.016	1.812	0.088	0.004	1.589	0.016	0.015	0.2	0.15
115	3420	0.01004	0.016	1.828	0.092	0.004	1.604	0.016	0.015	0.1	0.15
116	3450	0.00974	0.016	1.844	0.096	0.004	1.620	0.015	0.014	0.1	0.14
117	3480	0.00926	0.015	1.859	0.099	0.003	1.635	0.015	0.014	0.1	0.14
118	3510	0.00868	0.014	1.873	0.102	0.003	1.648	0.014	0.013	0.1	0.13
119	3540	0.00832	0.013	1.886	0.106	0.003	1.662	0.013	0.012	0.1	0.12
120	3570	0.00781	0.012	1.899	0.109	0.003	1.674	0.012	0.011	0.1	0.12
121	3600	0.00500	0.008	1.907	0.111	0.002	1.682	0.008	0.007	0.1	0.08
122	3630	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.01
123	3660	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
124	3690	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
…											
144	4290	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
145	4320	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00

4.7 Level-Pool Routing Method

4.7.1 Introduction

This section presents a general description of the methodology for routing a hydrograph through an existing retention/detention facility or closed depression, and for sizing a new retention/detention facility using hydrograph analysis.

The "level pool routing" technique presented here is one of the simplest and most commonly used hydrograph routing methods. This method is described in "Handbook of Applied Hydrology," Chow, Ven Te, 1964, and elsewhere, and is based on the continuity equation:

Inflow - Outflow = Change in storage

$$\left[\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2}\right] = \frac{\Delta S}{\Delta t} = S_2 - S_1$$

where

I = Inflow at time 1 and time 2

O = Outflow at time 1 and time 2

S = Storage at time 1 and time 2

Δt = Time interval, time 2 – time 1

The time interval, Δt, must be consistent with the time interval used in developing the inflow hydrograph. The time interval used for the 6-hour storm is 5 minutes while the time interval for the 72-hour storm is 30 minutes. The Δt variable can be eliminated by dividing it into the storage variables to obtain the following rearranged equation:

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

If the time interval, Δt, is in minutes, the units of storage (S) are now [cubic feet/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 O2 and S2 can be solved interactively from the given stage-storage and stage-discharge curves.

The following steps are required in performing level-pool hydrograph routing:

Develop stage-storage relationship, which is a function of inflow and pond geometry.

Develop the routing curve for the hydrograph and pond, which is a graph of outflow from the pond at a given stage versus the quantity O + 2S for the same stage. The outflow is a function of stage (head above the orifice) and the control structure configuration.

Route the inflow hydrograph through the proposed facility by applying the continuity equation above at each time step, where the inflow hydrograph supplies values of I, the stage-storage relationship supplies values of S, and the routing curve supplies values of O.

The commercially available SBUH hydrograph computer models use the level pool routing methodology to shift hydrographs and size infiltration and detention facilities.

Appendix 4A – Background Information on Design Storms

by MGS Engineering Consultants

Overview of Storm Types

There are two storm types of interest for stormwater analyses in eastern Washington. Short-duration thunderstorms can occur in the late-spring through early-fall seasons and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash-flooding and are important where flood peak discharge and/or erosion are design considerations.

Long-duration general storms can occur at anytime of the year, but are more common in the late-fall through winter period, and in the late-spring and early-summer periods. General storms in eastern Washington are characterized by sequences of storm activity and intervening dry periods, often occurring over several days. Low to moderate intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with large runoff volumes and moderate peak discharge. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early-spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

Design storms are constructed utilizing two components: a precipitation magnitude for a specified duration; and a dimensionless storm pattern. The precipitation magnitude for the specified duration is determined based on the desired level of service (return period of the storm, years) and is used to scale the dimensionless storm pattern to produce the design storm. Specifically, the 2-hour precipitation amount for a selected return period is used for scaling the short-duration thunderstorm. The 24-hour precipitation amount for a selected return period is used for scaling the long-duration general storm.

This appendix provides information on the methods and data that were used for analysis and development of design storms for both short-duration thunderstorms and long-duration general storms. The dimensionless storm patterns for the short-duration thunderstorm and long-duration general storm were developed from analyses of historical storms and contain storm characteristics that are representative of the conditions frequently observed in significant storms.

Climatic Regions

Eastern Washington has been divided into four climatic regions to reflect differences in storm characteristics and the seasonality of storms. The four climatic regions (see Figure 4-3.1) include:

Region 1 – East Slopes of Cascade Mountains

This region is comprised of mountain areas on the east slopes of the Cascade Mountains. It is bounded to the west by the Cascade crest and bounded to the east by a generalized contour line of 16-inches mean annual precipitation.

Region 2 – Central Basin

The Central Basin region is comprised of the Columbia Basin and adjacent low elevation areas in central Washington. It is bounded to the west by the generalized contour line of 16-inches mean annual precipitation that forms the east slopes of the Cascade Mountains, and bounded to the north and east by the contour line of 14-inches mean annual precipitation. Many of the larger cities in eastern Washington are in this region including: Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.

Region 3 – Okanogan , Spokane, Palouse

This region is comprised of inter-mountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded to the west by the east slopes of the Cascade Mountains and the Central Basin, bounded to the northeast by the Kettle River Range and Selkirk Mountains, and bounded to the southeast by the Blue Mountains. It generally occupies an area with mean annual precipitation ranging from 14-inches to 22-inches.

Region 4 – Northeastern Mountains and Blue Mountains

This region is comprised of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast, and includes the Blue Mountains in the southeast corner of eastern Washington. Mean annual precipitation ranges from a minimum of 22-inches to over 60-inches. The western boundary of this region is a generalized contour line of 22-inches mean annual precipitation.

Seasonality of Storms

Information on the seasonality of storms is useful in providing information for selection of antecedent conditions to be used with the design storms for rainfall-runoff modeling at undeveloped sites.

Short-duration thunderstorms are warm season events that occur from late-spring through early-fall throughout eastern Washington (Figure 4A-1). Antecedent conditions for rainfall-runoff modeling of thunderstorms should be selected consistent with the conditions expected at the time of year when thunderstorms have historically occurred.

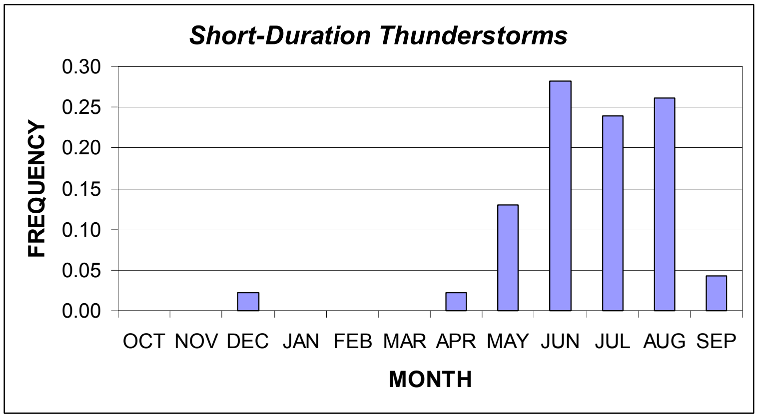


Figure 4A-1 – Seasonality of Short-Duration Thunderstorms in Eastern Washington

The seasonality of long-duration general storms varies across eastern Washington. General storms occur in late-fall and winter on the east slopes of the Cascade Mountains (Figure 4A-2a) and are generally associated with concurrent storm activity in western Washington. In contrast, general storms in the more eastern climatic regions, may or may not be associated with concurrent storms in western Washington. Long-duration general storms occur in both the cool and warm seasons in the Central Basin, Okanogan, Spokane, and Palouse regions. The storm seasons are reasonably well-defined with more frequent storm activity from fall through early-spring, and from late-spring through early-summer (Figure 4A-2b). The seasonality of long-duration general storms in the eastern mountain areas is similar to that for Climatic Regions 2 and 3, except that the winter season is dominant (Figure 4A-2c) with a greater frequency of storm events in the winter season. These seasonalities of storm occurrences should be considered when selecting antecedent conditions for rainfall-runoff modeling.

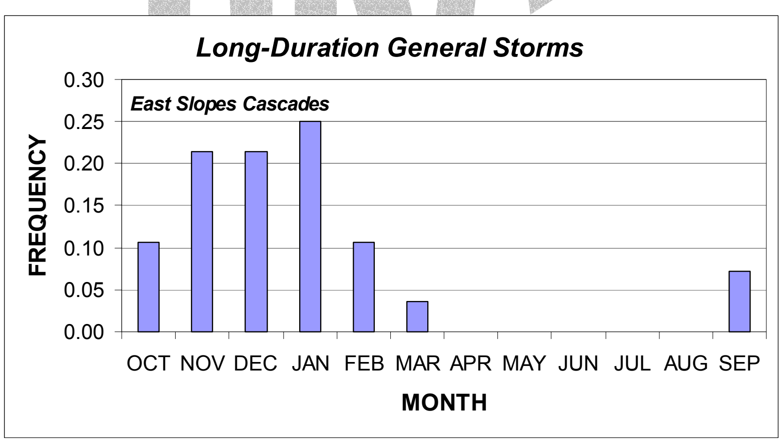


Figure 4A-2a – Seasonality of Long-Duration General Storms for the East Slopes of the Cascade Mountains

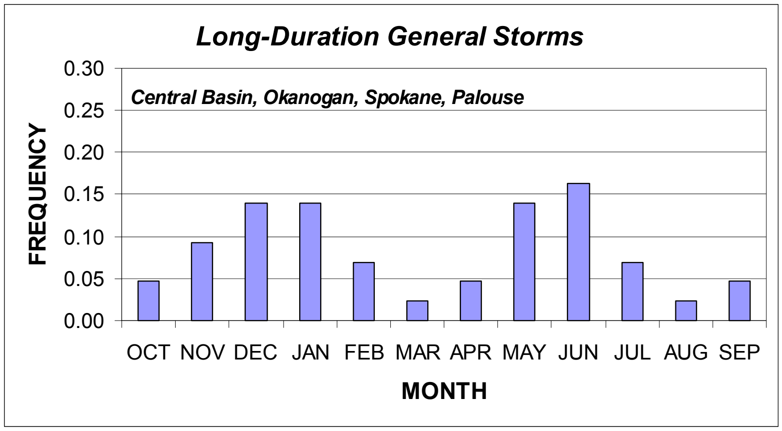


Figure 4A-2b – Seasonality of Long-Duration General Storms for the Central Basin, Okanogan, Spokane, and Palouse

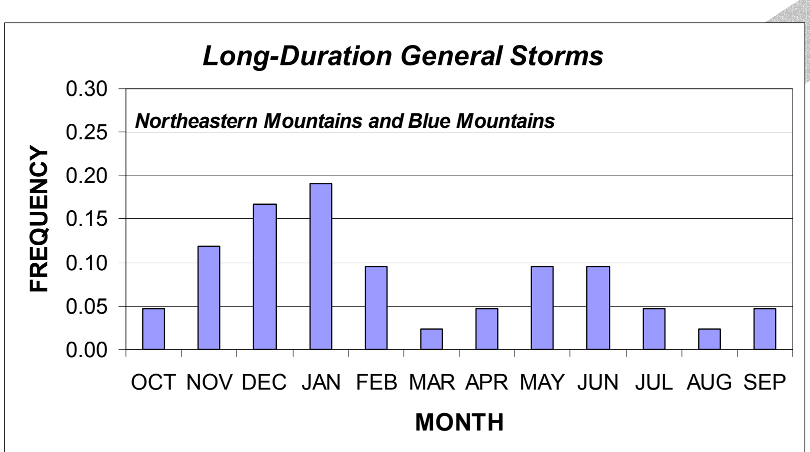


Figure 4A-2c – Seasonality of Long-Duration General Storms for the Northeastern Mountains and Blue Mountains

Dimensionless Design Storm Patterns

The temporal pattern of a design storm is important because it influences the magnitude of the flood peak discharge and runoff volume produced by the storm. Elements of the design storm that are important in rainfall-runoff modeling include: total storm volume; storm duration; maximum intensity during the storm; duration of the high intensity portion(s) of the storm; elapsed time to the high-intensity portion of the storm; and the magnitude, sequencing and temporal pattern of incremental precipitation amounts within the storm. Each of these storm characteristics was examined in the analysis of historical storms in eastern Washington. The storm characteristics were analyzed using a variety of procedures developed by the National Weather Service3,6, Schaefer10, and the US Geological Survey8. A total of 37 short-duration thunderstorms and 59 long-duration general storms were analyzed that occurred in the period from 1940 to 2000. Attachment A contains a listing of storm dates, locations, and precipitation amounts for storms that were analyzed.

Dimensionless design storms for the short-duration thunderstorm and long-duration general storm were developed in a manner to contain storm characteristics that are representative of the conditions observed in historical storms. Specifically, mean values of storm characteristics and commonly occurring temporal patterns were used in assembling the design storm temporal patterns.

Long-Duration General Storms

Long-duration general storms in eastern Washington are associated with organized weather systems that produce low to moderate intensity precipitation over broad areas. General storms are typically comprised of sequences of storm activity and intervening dry periods, often occurring over several days. Each of these important characteristics is preserved in the long-duration dimensionless storm patterns.

While many of the characteristics of general storms are similar throughout eastern Washington, some storm characteristics vary by climatic region. For example, in mountain areas, the duration of precipitation is longer and the length of intervening dry periods is shorter, relative to that in the Central Basin. Thus, separate long-duration design storm patterns were needed for each climatic region.

An example of a scaled long-duration design storm is shown in Figure 4A-3, which was obtained by scaling (multiplying) the incremental ordinates of the dimensionless design storm (see Table 4-2.6) by a 24-hour precipitation value of 0.82-inches. Differences in temporal patterns between the four climatic regions can be seen in Figures 4-2.5 and 4-2.6, which compare long-duration water quality design storms for the four climatic regions.

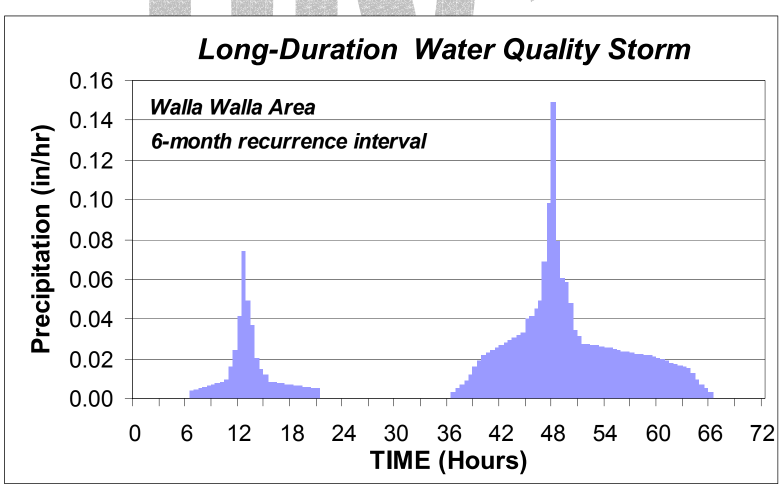


Figure 4A-3 – Example Long-Duration Design Storm

Short-Duration Thunderstorms

Short-duration thunderstorms are characterized by very high-intensity rainfall occurring over isolated areas. The duration of the high-intensity portion of the storm may last from 5-minutes to 30-minutes with a total duration typically ranging from less than an hour to several hours. These storms are convective events, commonly occurring in the late-afternoon and early-evening hours in the summer where atmospheric instabilities are often driven by solar heating. They are frequently accompanied by lightning and thunder.

Analysis of historical storms indicates that short-duration thunderstorms have similar characteristics throughout eastern Washington. Therefore, one dimensionless design storm pattern is applicable to all four climatic regions. An example of a scaled short-duration design storm is shown in Figure 4A-4, which was obtained by scaling (multiplying) the incremental ordinates of the dimensionless design storm (see Table 4-2.1) by a 2-hour precipitation value of 0.50-inches.

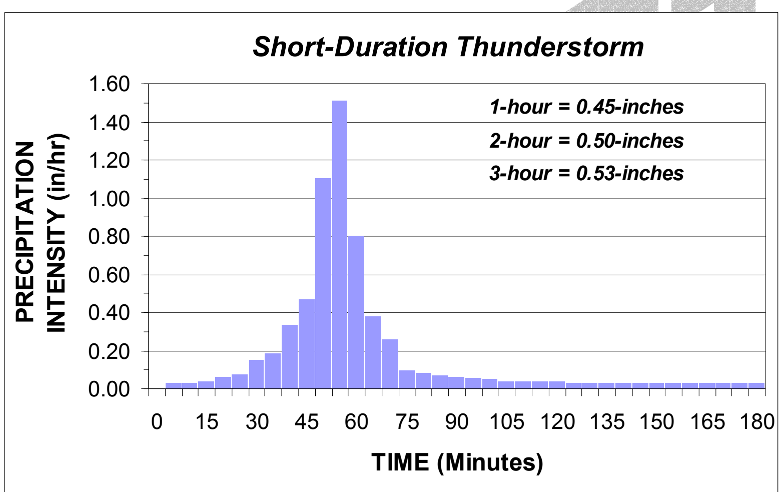


Figure 4A-4 – Example Short-Duration Design Storm

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Attachment 4A-1 – Historical Storms Used for Development of Design Storms in Eastern Washington

Long-Duration General Storms

Region 1 – Cascade Mountains

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Diablo Dam	24-Oct-1945	6.42	9.23
Underwood	11-Dec-1946	4.04	7.27
Hood River Exp Station	6-Jan-1948	3.33	4.53
Diablo Dam	16-Feb-1949	8.12	9.64
Diablo Dam	9-Feb-1951	6.47	12.99
Satus Pass	24-Nov-1960	3.12	4.46
Lucerne 2NNW	19-Nov-1962	3.05	3.45
Mazama	27-Feb-1972	3.80	5.97
Mount Adams RS	13-Jan-1973	6.00	11.39
Satus Pass	15-Jan-1974	3.60	6.05
Lucerne 2NNW	1-Dec-1975	3.17	5.99
Satus Pass	13-Dec-1977	3.30	5.02
Mazama	12-Jan-1980	3.20	3.62
Stehekin 4NW	23-Jan-1982	5.00	6.80
Stevens Pass	3-Dec-1982	6.50	7.40
Carson Fish Hatch	9-Dec-1987	6.20	7.90
Lake Wenatchee	9-Jan-1990	5.30	7.60
Easton	22-Nov-1990	6.40	10.20
Glenwood	27-Oct-1994	3.80	4.10
Easton	8-Feb-1996	4.10	8.90
Glenwood	28-Dec-1998	3.70	4.70

Region 2 – Central Basin

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Lind 3NE	25-Jun-1942	1.53	1.77
Harrington 4ENE	21-Sep-1945	1.52	2.10
Coulee Dam 1SW	28-May-1948	1.66	1.74
Harrington 4ENE	25-Sep-1948	1.51	1.65
Centerville	19-Jan-1953	2.36	2.76
Naches 10NW	14-Jan-1956	1.43	1.60
McNary Dam	2-Oct-1957	3.15	3.17
Yakima	24-Dec-1964	1.40	2.83
Harrington 1NW	23-Dec-1966	1.12	1.28
Ellensburg	4-Dec-1974	1.30	2.00
Chief Joe Dam	18-Sep-1986	1.50	1.70
Wenatchee	10-Dec-1987	1.77	1.82
Yakima	19-Nov-1996	1.40	1.57

Region 3 – Okanogan/Spokane/Palouse

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Pullman 2NW	15-Sep-1947	2.10	2.60
Oroville	16-Nov-1950	1.96	2.04
Spokane WSO AP	18-Dec-1951	1.58	1.67
Spokane WSO AP	25-Nov-1960	1.41	1.86
Pullman 2NW	22-Nov-1961	1.96	2.52
Dixie 4SE	23-Nov-1964	2.70	2.92
Dayton 9SE	22-Dec-1964	3.01	4.70
Dayton 9SE	2-Jan-1966	2.53	3.69
Moscow 5NE ID	23-Dec-1972	1.80	2.70
Moscow 5NE ID	11-Nov-1973	1.70	2.90
Colville Airport	16-Nov-1973	1.55	1.98
Walla Walla WSO	14-Oct-1980	3.08	3.63
Moscow 5NE ID	9-Feb-1996	1.50	3.20
Whitman Mission	19-Nov-1996	2.00	2.40
Ola ID	27-Dec-1996	3.10	5.00
Republic	27-May-1998	2.50	2.80
Spokane WSO AP	13-Apr-2000	1.53	1.73

Region 4 – Northeastern Mountains and Blue Mountains

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Bonners Ferry 1SW	18-Nov-1946	2.78	4.09
Pullman 2NW	15-Sep-1947	2.10	2.60
Pullman 2NW	22-Nov-1961	1.96	2.52
Dayton 9SE	22-Dec-1964	3.01	4.70
Dayton 9SE	2-Jan-1966	2.53	3.69
Moscow 5NE ID	23-Dec-1972	1.80	2.70
Moscow 5NE ID	11-Nov-1973	1.70	2.90
Colville Airport	16-Nov-1973	1.55	1.98
Coeur D Alene RS	15-Jan-1974	1.90	3.70
Dworshak Fish Hatch ID	2-Dec-1977	2.30	2.40
Plummer 3WSW ID	25-Dec-1980	2.10	2.80
Boundary Switchyard	15-Feb-1986	3.10	3.19
Boundary Switchyard	4-Jan-1989	2.30	2.50
Moscow 5NE ID	9-Feb-1996	1.50	3.20
Ola ID	27-Dec-1996	3.10	5.00
Northport	27-May-1998	2.40	2.80

Short-Duration Thunderstorms

All Regions

PRECIPITATION STATION	CLIMATIC REGION	STORM DATE	PRECIPITATION 1-HOUR (in)	PRECIPITATION 2-HOUR (in)
Ellensburg	2	12-May-1943	0.31	0.62
Dayton 1WSW	3	8-Jul-1946	0.78	0.79
Sunnyside	2	7-Jun-1947	1.62	1.62
Oroville	3	16-Jun-1947	1.19	1.25
Methow	2	17-Jun-1950	0.89	0.89
Wilson Creek	2	18-Jun-1950	1.50	1.50
Colville	4	19-Jul-1950	0.92	1.00
Wilson Creek	2	24-Jul-1950	0.80	0.80
Wenatchee Exp Station	2	10-Aug-1952	1.29	1.29
Colville	4	6-Jul-1956	0.81	0.82
Naches 10NW	2	5-May-1957	0.70	0.90
Republic RS	3	5-Jul-1958	1.10	1.10
Methow	2	8-Jul-1958	1.33	1.33
Republic RS	3	9-Aug-1962	1.17	1.26
Pomeroy	3	13-Sep-1966	1.12	1.12
Withrow 4WNW	2	14-Aug-1968	0.64	0.94
Walla Walla WSO	3	26-May-1971	1.64	1.75
Yakima	2	18-Aug-1975	0.70	0.98
Whitman Mission	3	5-Aug-1977	0.94	0.94
Dayton 1WSW	3	7-Jul-1978	1.20	1.20
Boundary Switchyard	4	21-May-1981	0.90	1.10
Naches 10NW	2	7-Jul-1982	1.20	1.20
Chewelah	3	20-Jul-1983	0.90	1.00
Republic RS	3	10-Aug-1983	0.90	1.50
Easton	1	26-Aug-1983	1.80	1.80
Naches 10NW	2	1-Aug-1984	0.80	0.80
Lake Wenatchee	1	11-Feb-1985	0.90	1.10
Mazama	1	16-Jul-1985	1.00	1.10
Diablo Dam	1	20-Jul-1992	0.80	1.10
Chief Joe Dam	2	23-Jul-1992	0.70	1.00
Dixie 4SE	4	7-Aug-1992	0.70	0.90
Boundary Switchyard	4	23-May-1989	1.00	1.00
Chief Joe Dam	2	9-Jul-1993	1.10	1.10
Lind 3NE	2	22-Jul-1993	1.30	1.40
Stevens Pass	1	2-Jun-1998	1.00	1.00
Northport	4	11-Jul-1998	1.10	1.10
Colville	4	3-Jun-1999	1.00	1.90

Appendix 4B – Precipitation Maps

Precipitation maps for eastern Washington are included on the following pages, as listed below:

Figure 4-3.1: Mean Annual Precipitation with Climate Regions

Figure 4-3.2: 2-year 2-hour Isopluvial Map

Figure 4-3.3: 2-year 24-hour Isopluvial Map

Figure 4-3.4: 10-year 24-hour Isopluvial Map

Figure 4-3.5: 25-year 24-hour Isopluvial Map

Figure 4-3.6: 50-year 24-hour Isopluvial Map

Figure 4-3.7: 100-year 24-hour Isopluvial Map