City of Seattle

Appendix A - Definitions

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

- "Agency" means any governmental entity or its subdivision.
- "Agency, City" means "City agency" as defined in Section 25.09.520.
- "Approved" means approved by the Director.
- "Aquatic life use" means "aquatic life use" as defined in WAC 173-201A-200. For the purposes of this subtitle, at minimum the following water bodies are designated for aquatic life use: small lakes, creeks, and fresh designated receiving waters.
- "Arterial" means "arterial" as defined in Section 11.14.035.
- "Basic treatment facility" means a drainage control facility designed to reduce concentrations of total suspended solids in drainage water.
- "Basic treatment receiving water" means:
    - All marine waters, including Puget Sound;
    - Lake Union;
    - Lake Washington;
    - Ship Canal and bays between Lake Washington and Puget Sound; and
    - Duwamish River.
- "Best management practice" (BMP) means a schedule of activities, prohibitions of practices, operational and maintenance procedures, structural facilities, or managerial practice or device that, when used singly or in combination, prevents, reduces, or treats contamination of drainage water, prevents or reduces soil erosion, or prevents or reduces other adverse effects of drainage water. When the Directors develop rules and/or manuals prescribing BMPs for particular purposes, whether or not those rules and/or manuals are adopted by ordinance, BMPs specified in the rules and/or manuals shall be the BMPs required for compliance with this subtitle.
- "Building permit" means a document issued by the Seattle Department of Construction and Inspections authorizing construction or other specified activity in accordance with the Seattle Building Code or the Seattle Residential Code.
- "Capacity-constrained system" means a drainage system or public combined sewer that the Director of SPU has determined to have inadequate capacity to carry existing and anticipated loads, or a drainage system that includes ditches or culverts.
- "Certified Erosion and Sediment Control Lead" (CESCL) means an individual who has current certification through an approved erosion and sediment control training program that meets the minimum training standards established by Ecology.
- "Civil engineer, licensed" means a person who is licensed by the State of Washington to practice civil engineering.
- "City agency" means "City agency" as defined in Section 25.09.520.
- "Combined sewer." See "public combined sewer."
- "Combined sewer basin" or "public combined sewer basin" means the area tributary to a public combined sewer feature, including, but not limited to, a combined sewer overflow outfall, trunk line connection, pump station, or regulator.
- "Compaction" means the densification, settlement, or packing of earth material or fill in such a way that permeability is reduced by mechanical means.

- "Construction Stormwater Control Plan" means a document that explains and illustrates the measures to be taken on the construction site to prevent erosion and discharge of sediment and other pollutants on a construction project.
- "Containment area" means the area designated for conducting pollution-generating activities for the purposes of implementing source controls or designing and installing source controls or treatment facilities.
- "Contaminate" means the addition of sediment, any other pollutant or waste, or any illicit or prohibited discharge.
- "Creek" means a Type S, F, Np or Ns water as defined in WAC 222-16-031, or as defined in WAC 222-16-030 after state water type maps are adopted, and is used synonymously with "stream."
- "Damages" means monetary compensation for harm, loss, costs, or expenses incurred by the City, including, but not limited, to the following: costs of abating or correcting violations of this subtitle; fines or penalties the City incurs as a result of a violation of this subtitle; and costs to repair or clean the public drainage system or public combined sewer as a result of a violation. For the purposes of this subtitle, damages do not include compensation to any person other than the City.
- "Designated receiving waters" means the Duwamish River, Puget Sound, Lake Washington, Lake Union, Elliott Bay, Portage Bay, Union Bay, the Lake Washington Ship Canal, and other receiving waters determined by the Director of SPU and approved by Ecology as having sufficient capacity to receive discharges of drainage water such that a site discharging to the designated receiving water is not required to implement flow control.
- "Detention" means temporary storage of drainage water for the purpose of controlling the drainage discharge rate.
- "Development" means the following activities:

  1. Class IV–general forest practices that are conversions from timberland to other uses;
  2. Land disturbing activity;
  3. The addition or replacement of hard surfaces;
  4. Expansion of a building footprint or addition or replacement of a structure;
  5. Structural development, including construction, installation, or expansion of a building or other structure;
  6. Seeking approval of a building permit, other construction permit, grading permit, or master use permit that involves any of the foregoing activities; and
  7. Seeking approval of subdivision, short plat, unit lot subdivision, or binding site plans, as defined and applied in Chapter 58.17 RCW, or other master use permit.

  Development is a type of project.

- "Director" means the Director of the Department authorized to take a particular action, and the Director's designees, who may be employees of that department or another City department.

- "Director of SDCI" means the Director of the Seattle Department of Construction and Inspections or the designee of the Director of the Seattle Department of Construction and Inspections, who may be employees of that department or another City department.
- "Director of SDOT" means the Director of Seattle Department of Transportation of The City of Seattle or the designee of the Director of Seattle Department of Transportation, who may be employees of that department or another City department.
- "Director of SPU" means the General Manager and Chief Executive Officer of Seattle Public Utilities of The City of Seattle or the designee of the General Manager and Chief Executive Officer of Seattle Public Utilities, who may be employees of that department or another City department.
- "Discharge point" means the location from which drainage water from a site is released.
- "Discharge rate" means the rate at which drainage water is released from a site. The discharge rate is expressed as volume per unit of time, such as cubic feet per second.
- "Drainage basin" means the geographic and hydrologic tributary area or subunit of a watershed through which drainage water is collected, regulated, transported, and discharged to receiving waters.
- "Drainage basin plan" means a plan to manage the quality and quantity of drainage water in a watershed or a drainage basin, including watershed action plans.
- "Drainage control" means the management of drainage water. Drainage control is accomplished through one or more of the following: collecting, conveying, and discharging drainage water; controlling the discharge rate from a site; controlling the flow duration from a site; controlling the quantity from a site; and separating, treating or preventing the introduction of pollutants.
- "Drainage control facility" means any facility, including best management practices, installed or constructed for the purpose of controlling the discharge rate, flow duration, quantity, and/or quality of drainage water.
- "Drainage control plan" means a plan for collecting, controlling, transporting and disposing of drainage water falling upon, entering, flowing within, and exiting the site, including designs for drainage control facilities.
- "Drainage system" means a system intended to collect, convey and control release of only drainage water. The system may be either publicly or privately owned or operated, and the system may serve public or private property. It includes components such as pipes, ditches, culverts, curbs, gutters, and drainage control facilities. Drainage systems are not receiving waters.
- "Drainage water" means stormwater and all other discharges that are permissible pursuant to subsection 22.802.030.A.
- "Earth material" means any rock, gravel, natural soil, fill, or re-sedimented soil, or any combination thereof, but does not include any solid waste as defined by RCW 70.95.
- "Ecology" means the Washington State Department of Ecology.

- “Effective hard surface” means those hard surfaces that are connected via sheet flow or discrete conveyance to a drainage system.
- “Enhanced treatment facility” means a drainage control facility designed to reduce concentrations of dissolved metals in drainage water.
- “Environmentally critical area” (ECA) means an area designated in Section 25.09.012.
- “EPA” means the United States Environmental Protection Agency.
- “Erodible or leachable materials” means wastes, chemicals, or other substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the drainage water. Examples include: erodible soils that are stockpiled; leachable materials that are stockpiled; uncovered process wastes; manure; fertilizers; oily substances; ashes, kiln dust; and garbage dumpster leakage.
- “Erosion” means the wearing away of the ground surface as a result of mass wasting or of the movement of wind, water, ice, or other geological agents, including such processes as gravitational creep. Erosion also means the detachment and movement of soil or rock fragments by water, wind, ice, or gravity.
- “Excavation” means the mechanical removal of earth material.
- “Exception” means relief from a requirement of this subtitle to a specific project.
- “Existing grade” means “existing grade” as defined in Section 22.170.050.
- “Fill” means a deposit of earth material placed by artificial means.
- “Flow control” means controlling the discharge rate, flow duration, or both of drainage water from the site through means such as infiltration or detention.
- “Flow control facility” means a drainage control facility for controlling the discharge rate, flow duration, or both of drainage water from a site.
- “Flow duration” means the aggregate time that peak flows are at or above a particular flow rate of interest.
- “Garbage” means putrescible waste.
- “Geotechnical engineer” or “Geotechnical/civil engineer” means a person licensed by The State of Washington as a professional civil engineer who has expertise in geotechnical engineering.
- “Grading” means excavation, filling, in-place ground modification, removal of roots or stumps that includes ground disturbance, stockpiling of earth materials, or any combination thereof, including the establishment of a grade following demolition of a structure.
- “Green stormwater infrastructure” means distributed BMPs, integrated into a project design, that use infiltration, filtration, storage, or evapotranspiration, or provide stormwater reuse.
- “Groundwater” means water in a saturated zone or stratum beneath the surface of land or below a surface water body. Refer to Ground Water Quality Standards, Chapter 173-200 WAC.
- “Hard surface” means an impervious surface, a permeable pavement, or a vegetated roof.

- "High-use sites" means sites that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. High-use sites include:
    - o An area of a commercial or industrial site subject to an expected average daily traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area;
    - o An area of 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;
    - o An area of a commercial or industrial site subject to parking, storage or maintenance of 25 or more vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.);
    - o 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.
- "Illicit connection" means any direct or indirect infrastructure connection to the public drainage system or receiving water that is not intended, not permitted, or not used for collecting drainage water.
- "Impervious surface" means any surface exposed to rainwater from which most water runs off. Impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, formal planters, parking lots or storage areas, concrete or asphalt paving, areas with underdrains designed to remove stormwater from subgrade (e.g., playfields, athletic fields, rail yards), gravel surfaces subjected to vehicular traffic, compact gravel, 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 minimum requirements are exceeded. Open, uncovered retention/detention facilities shall be considered impervious surfaces for purposes of stormwater modeling.
- "Industrial activities" means 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.
- "Infiltration" means the downward movement of water from the surface to the subsoil. "Infiltration facility" means a drainage control facility that temporarily stores, and then percolates, drainage water into the underlying soil.
- "Integrated Drainage Plan" means a plan developed, reviewed, and approved pursuant to subsection 22.800.080.E.
- "Interflow" means that portion of rainfall and other precipitation 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.

- “Inspector” means a City inspector, their designee, or licensed civil engineer performing the inspection work required by this subtitle.
- “Land disturbing activity” means any activity that results in a change in the existing soil cover, both vegetative and nonvegetative, or the existing topography. Land disturbing activities include, but are not limited to, clearing, grading, filling, excavation, or addition of new or the replacement of hard surface. Compaction, excluding hot asphalt mix, that is associated with stabilization of structures and road construction is also considered a land disturbing activity. Vegetation maintenance practices, including landscape maintenance and gardening, are not considered land disturbing activities. Stormwater facility maintenance is not considered land disturbing activity if conducted according to established standards and procedures.
- “Large project” means a project including:
  1. Five thousand square feet or more of new plus replaced hard surface;
  2. One acre or more of land disturbing activity;
  3. Conversion of 3/4 acres or more of vegetation to lawn or landscaped area; or
  4. Conversion of 2.5 acres or more of native vegetation to pasture.
- “Listed creeks” means Blue Ridge Creek, Broadview Creek, Discovery Park Creek, Durham Creek, Frink Creek, Golden Gardens Creek, Kiwanis Ravine/Wolfe Creek, Licton Springs Creek, Madrona Park Creek, Mee-Kwa-Mooks Creek, Mount Baker Park Creek, Puget Creek, Riverview Creek, Schmitz Creek, Taylor Creek, and Washington Park Creek.
- “Master use permit” means a “master use permit” as defined in subsection 23.84A.025.
- “Maximum extent feasible” means the requirement is to be fully implemented, constrained only by the physical limitations of the site, practical considerations of engineering design, and reasonable considerations of financial costs.
- “Municipal stormwater NPDES permit” means the permit issued to the City under the federal Clean Water Act for public drainage systems within the City limits.
- “Native vegetation” means “native vegetation” as defined in Section 25.09.520.
- “New hard surface” means a surface that is: changed from a pervious surface to a hard surface (e.g., converting lawn to permeable pavement, resurfacing by upgrading from dirt to gravel, a bituminous surface treatment (“chip seal”), asphalt, concrete, or a hard surface structure); or upgraded from gravel to chip seal, asphalt, concrete, or a hard surface structure; or from a hard surface to a hard surface structure. Note that if asphalt or concrete has been overlaid by a chip seal, the existing condition should be considered as asphalt or concrete.
- “New impervious surface” means a surface that is: changed from a pervious surface to an impervious surface (e.g., resurfacing by upgrading from dirt to gravel, a bituminous surface treatment (“chip seal”), asphalt, concrete, or an impervious structure); or upgraded from gravel to chip seal, asphalt, concrete, or an impervious structure; or from a impervious surface to an impervious structure. Note that if asphalt or concrete has been overlaid by a chip seal, the existing condition should be considered as asphalt or concrete.

- "Non-listed creeks" means any creek not identified in the definition of "Listed creeks" in Section 22.801.130.
- "NPDES" means National Pollutant Discharge Elimination System, the national program for controlling discharges under the federal Clean Water Act.
- "NPDES permit" means an authorization, license or equivalent control document issued by the EPA or Ecology to implement the requirements of the NPDES program.
- "Nutrient-critical receiving water" means a surface water or water segment that is determined to be impaired due to phosphorus contributed by stormwater, as specified in rules promulgated by the Director of SPU which shall be based on consideration of water bodies reported by Ecology, and approved by EPA, under Category 5 (impaired) under Section 303(d) of the Clean Water Act for total phosphorus through Ecology's Water Quality Assessment.
- "Oil control treatment facility" means a drainage control facility designed to reduce concentrations of oil in drainage water.
- "On-site BMP" means a best management practice identified in subsection 22.805.070.D.
- "Owner" means any person having title to and/or responsibility for, a building or property, including a lessee, guardian, receiver or trustee, and the owner's duly authorized agent.
- "Parcel-based project" means any project that is not a roadway project, single-family residential project, sidewalk project, or trail project. The boundary of the public right-of-way shall form the boundary between the parcel and roadway portions of a project.
- "Person" means an individual, receiver, administrator, executor, assignee, trustee in bankruptcy, trust estate, firm, partnership, joint venture, club, company, joint stock company, business trust, municipal corporation, the State of Washington, political subdivision or agency of the State of Washington, public authority or other public body, corporation, limited liability company, association, society or any group of individuals acting as a unit, whether mutual, cooperative, fraternal, nonprofit or otherwise, and the United States or any instrumentality thereof.
- "Pervious surface" means a surface that is not impervious. See also "impervious surface."
- "Phosphorus treatment facility" means a drainage control facility designed to reduce concentrations of phosphorus in drainage water.
- "Plan" means a graphic or schematic representation, with accompanying notes, schedules, specifications and other related documents, or a document consisting of checklists, steps, actions, schedules, or other contents that has been prepared pursuant to this subtitle, such as a site plan, drainage control plan, construction stormwater control plan, stormwater pollution prevention plan, or integrated drainage plan.
- "Pollution-generating activity" means any activity that is regulated by the joint SPU/SDCI Directors' Rule titled "Seattle Stormwater Manual" at "Volume 4 – Source Control" or any activity with similar impacts on drainage water. These activities include, but are not limited to: cleaning and washing activities; transfer of liquid or solid material; production and application activities; dust, soil, and sediment control;

commercial animal care and handling; log sorting and handling; boat building, mooring, maintenance, and repair; logging and tree removal; mining and quarrying of sand, gravel, rock, peat, clay, and other materials; cleaning and maintenance of swimming pool and spas; deicing and anti-icing operations for airports and streets; maintenance and management of roof and building drains at manufacturing and commercial buildings; maintenance and operation of railroad yards; maintenance of public and utility corridors and facilities; and maintenance of roadside ditches.

- "Pollution-generating hard surface" means those hard surfaces considered to be a significant source of pollutants in drainage water. See definition of pollution-generating impervious surface in this Section 22.801.170 for surfaces that are considered significant sources of pollutants in drainage water. In addition, permeable pavement subject to vehicular use or other pollutants as described in the definition for pollution-generating impervious surfaces is a pollution-generating hard surface.
- "Pollution-generating impervious surface" means those impervious surfaces considered to be a significant source of pollutants in drainage water. Such surfaces include those that are subject to any of the following: vehicular use; industrial activities; storage of erodible or leachable materials, wastes, or chemicals, and that receive direct rainfall or the run-on or blow-in of rainfall. Such surfaces also include roofs subject to venting of significant sources of pollutants and metal roofs unless coated with an inert, non-leachable material (e.g., baked-on enamel coating).
    - A surface, whether paved or not, shall be considered subject to vehicular use 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; rail lines and railways; and airport runways.
    - The following are not considered regularly used by motor vehicles: sidewalks and trails not subject to drainage from roads for motor vehicles; paved bicycle pathways separated from and not subject to drainage from roads for motor vehicles; fenced fire lanes; and infrequently used maintenance access roads with recurring routine vehicle use of no more than once per day.
- "Pollution-generating pervious surface" means any pervious surface subject to any of the following: vehicular use; industrial activities; storage of erodible or leachable materials, wastes, or chemicals, and that receive direct rainfall or run-on or blow-in of rainfall; use of pesticides and fertilizers; or loss of soil. Typical pollution-generating pervious surfaces include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields (natural and artificial turf).
- "Pre-developed condition" means the vegetation and soil conditions that are used to determine the allowable post-development discharge peak flow rates and flow durations, such as pasture or forest.
- "Private drainage system" means a drainage system that is not a public drainage system.
- "Project" means any proposed action to alter or develop a site. Development is a type of project.
- "Project site" means that portion of a property, properties, or rights-of-way subject to land-disturbing activities, new hard surfaces, or replaced hard surfaces.

- "Public combined sewer" means a publicly owned and maintained system which carries drainage water and wastewater and flows to a publicly owned treatment works.
- "Public drainage system" means a drainage system owned or operated by The City of Seattle.
- "Public place" means and includes streets, avenues, ways, boulevards, drives, places, alleys, sidewalks, and planting (parking) strips, squares, triangles and right-of-way for public use and the space above or beneath its surface, whether or not opened or improved.
- "Public sanitary sewer" means the sanitary sewer that is owned or operated by The City of Seattle.
- "Public storm drain" means the part of a public drainage system that is wholly or partially piped, owned or operated by a City agency and designed to carry only drainage water.
- "Real property" means "real property" as defined in Chapter 3.110.
- "Receiving water" means the surface water, such as a creek, stream, river, lake, wetland or marine water, or groundwater, receiving drainage water. Drainage systems and public combined sewers are not receiving waters.
- "Repeat violation" means a prior violation of this subtitle within the preceding 5 years that became a final order or decision of the Director or a court. The violation does not need to be the same nor occur on one site to be considered repeat.
- "Replaced hard surface" or "replacement of hard surface" means, for structures, the removal down to the foundation and replacement; and, for other hard surfaces, the removal down to existing subgrade or base course and replacement.
- "Replaced impervious surface" or "replacement of impervious surface" means, for structures, the removal down to the foundation and replacement; and, for other impervious surfaces, the removal down to existing subgrade or base course and replacement.
- "Responsible party" means all of the following persons:
    1. Owners, operators, and occupants of property; and
    2. Any person causing or contributing to a violation of the provisions of this subtitle.
- "Right-of-way" means "right-of-way" as defined in Section 23.84A.032.
- "Roadway" means "roadway" as defined in Section 23.84A.032.
- "Roadway project" means a project located in the public right-of-way that involves the creation of a new or replacement of an existing roadway or alley. The boundary of the public right-of-way shall form the boundary between the parcel and roadway portions of a project.
- "Runoff" means the portion of rainfall or other precipitation that becomes surface flow and interflow.
- "Sanitary sewer" means a system that conveys wastewater and is not designed to convey drainage water.
- "SDCI" means the Seattle Department of Construction and Inspections.

- "SDOT" means the Seattle Department of Transportation.
- "Service drain" means "service drain" as defined in Section 21.16.030.
- "Side sewer" means "side sewer" as defined in Section 21.16.030.
- "Sidewalk" means "sidewalk" as defined in Section 23.84A.036.
- "Sidewalk project" means a project for the creation of a new sidewalk or replacement of an existing sidewalk, including any associated planting strip, apron, curb ramp, curb, or gutter, and necessary roadway grading and repair. If the total new plus replaced hard surface in the roadway exceeds 10,000 square feet, the entire project is a roadway project.
- "Single-family residential project" means a project that constructs one Single-family Dwelling Unit as defined in subsection 23.84A.032, and any associated accessory dwelling unit located in land classified as being Single-family Residential 9,600 (SF 9600), Single-family Residential 7,200 (SF 7200), or Single-family Residential 5,000 (SF 5000) pursuant to Section 23.30.010, and the total new plus replaced hard surface is less than 5,000 square feet.
- "Site" means the area defined by the legal boundaries of a parcel or parcels of land subject to development. For roadway projects, the length of the project site and the right-of-way boundaries define the site.
- "Slope" means an inclined ground surface.
- "Small lakes" means Bitter Lake, Green Lake and Haller Lake.
- "Small project" means a project with:
  1. Less than 5,000 square feet of new and replaced hard surface; and
  2. Less than one acre of land disturbing activities.
- "SMC" means the Seattle Municipal Code.
- "Soil" means naturally deposited non-rock earth materials.
- "Solid waste" means "solid waste" as defined in Section 21.36.016.
- "Source controls" means structures or operations that prevent contaminants from coming in contact with drainage water through physical separation or careful management of activities that are known sources of pollution.
- "SPU" means Seattle Public Utilities.
- "Standard design" is a design pre-approved by the Director for drainage and erosion control available for use at a site with pre-defined characteristics.
- "Standard Plans and Specifications" means the City of Seattle Standard Plans and Specifications for Road, Bridge, and Municipal Construction in effect on the date of permit application.
- "Storm drain" means both public storm drain and service drain.
- "Stormwater" means runoff during and following precipitation and snowmelt events, including surface runoff, drainage and interflow.

- “Stream” means a Type S, F, Np or Ns water as defined in WAC 222-16-031, or as defined in WAC 222-16-030 after state water type maps are adopted, and is used synonymously with “creek.”
- “Topsoil” means the weathered surface soil, including the organic layer, in which plants have most of their roots.
- “Trail” means a path of travel for recreation and/or transportation within a park, natural environment, or corridor.
- “Trail project” means a project for the creation of a new trail or replacement of an existing trail, and which does not contain pollution-generating hard surfaces.
- “Treatment facility” means a drainage control facility designed to remove pollutants from drainage water.
- “Wastewater” means “wastewater” as defined in Section 21.16.030.
- “Water Quality Standards” means Surface Water Quality Standards, Chapter 173-201A WAC, Ground Water Quality Standards, Chapter 173-200 WAC, and Sediment Management Standards, Chapter 173-204 WAC.
- “Watercourse” means the route, constructed or formed by humans or by natural processes, generally consisting of a channel with bed, banks or sides, in which surface waters flow. Watercourse includes small lakes, bogs, streams, creeks, and other receiving waters but does not include designated receiving waters.
- “Watershed” means a geographic region within which water drains into a particular river, stream, or other body of water.
- “Wetland” means a wetland designated under Section 25.09.020.
- “Wetland function” means the physical, biological, chemical, and geologic interactions among different components of the environment that occur within a wetland. Wetland functions can be grouped into three categories: functions that improve water quality; functions that change the water regime in a watershed, such as flood storage; and functions that provide habitat for plants and animals.
- “Wetland values” means wetland processes, characteristics, or attributes that are considered to benefit society.

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City of Seattle

Appendix B - Additional Submittal Requirements

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

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B-1. Preliminary Drainage Control Review Submittal Requirements for Master Use Permits

Preliminary Drainage Control Review is required for certain Master Use Permit (MUP) applications per SMC 22.807.020.A (refer to *Volume 1, Section 8.1*). The general submittal requirements are described in *Volume 1, Section 8.1*. However, different types of MUPs require different levels of drainage review and detail.

The following describes the specific submittal requirements and drainage review process for the most common types of MUP that will typically require drainage review.

B-1.1. Subdivisions and Short Plats

B-1.1.1. Subdivisions

"Full" Subdivisions per SMC 23.22 require a high level of detail for approval of Preliminary Drainage Control Review. Prior to Preliminary Plat Approval, a Preliminary Drainage Control Plan, Preliminary Drainage Report (Report), and all supporting documents as described in *Volume 1, Section 8.1* must be submitted and approved. The Preliminary Drainage Control Plan and Report shall identify all BMPs necessary to meet the minimum requirements (e.g., on-site stormwater management, flow control, water quality treatment, etc.) including size and location. The level of detail required is the same as required for Standard and Comprehensive Drainage Control Review.

The Preliminary Drainage Control Plan approval does not constitute approval for construction. A Standard or Comprehensive Drainage Control Plan and Report must be submitted with a construction permit. Depending on the scope and location, required construction permit will be a Grading Permit, Building Permit, or a Seattle Department of Transportation (SDOT) Street Improvement Plan (SIP) Permit.

Subsequent construction permits in the subdivision must demonstrate with Standard or Comprehensive Drainage Control Plans that they are compliant with the intent of the approved Preliminary Drainage Control Plan.

Note: Additional requirements apply to permitting and construction of drainage control facilities and drainage systems that will be shared by multiple parcels, lots, tracts, etc., within the Subdivision. Refer to *Section B-1.1.3*.

B-1.1.2. Short Plats

Short Plats (a.k.a. Short Subdivisions) per SMC 23.24 require a similar level of detail as Full Subdivisions for approval of Preliminary Drainage Control Review.

Deferred Drainage Plans for Some Projects: The requirement for a Preliminary Drainage Control Plan and Report may be deferred until the construction permit by the Director if all of the following conditions are met:

1. The full development potential in the Short Plat, including all lots, parcels, and tracts, does not exceed the thresholds established for flow control or water quality treatment or require a mainline extension,
2. The project has an approved offsite discharge point for drainage (e.g., public storm drain),
3. The downstream drainage system has adequate capacity,
4. Drainage Condition #1 in *Section B-1.1.4* is placed on the first sheet of the recorded plat.

Otherwise, a Preliminary Drainage Control Plan and Report, and all supporting documents as described in *Volume 1, Section 8.1* must be submitted and approved prior to approval of the Short Plat. Depending on the scope and location, this will require a Grading Permit, Building Permit, or an SDOT SIP Permit.

Subsequent construction permits in the short subdivision must demonstrate with Standard or Comprehensive Drainage Control Plans that they are compliant with the intent of the approved Preliminary Drainage Control Plan.

Note: Additional requirements apply to permitting and construction of drainage control facilities and drainage systems that will be shared by multiple parcels, lots, tracts, etc., in the Subdivision. Refer to *Section B-1.1.3*.

B-1.1.3. Shared Drainage Control Facilities and Systems for Subdivisions and Short Plats

Drainage control facilities and systems proposed on Preliminary Drainage Control Plans that will serve multiple parcels, lots, tracts, etc., in a Subdivision or Short Plat are subject to the following code requirement.

Stormwater Code Language	References
SMC 22.805.010.E. Construction of drainage control facilities and drainage systems for plats. *1. In the case of a subdivision under Chapter 23.22, drainage control facilities or drainage systems that are identified on the associated preliminary drainage control plan or the approved preliminary plat and will serve multiple proposed lots, parcels, tracts, or rights-of-way shall be constructed prior to approval of the final plat unless a bond is provided according to subsection 23.22.070.C. If a bond is provided in lieu of construction prior to approval of the final plat, the construction permit for the facilities or systems must be issued prior to issuance of any building permit for any other construction within the subdivision and construction of the facilities or systems shall be completed and final inspection approved prior to final inspection approval of any building permit for any other construction within the subdivision and prior to occupancy of any buildings, but in no event later than two years after final plat approval.* *2. In the case of a short plat under Chapter 23.24 with shared drainage control facilities or drainage systems that are identified on the preliminary drainage control plan and will serve multiple proposed lots, parcels, tracts, or rights-of-way, the following shall occur:*	• *Volume 1, Section 8.1* – Preliminary Drainage Control Review • SMC 22.807.020.A – Thresholds for Drainage Control Review • SMC, Chapter 23.22 – Subdivisions • SMC, Chapter 23.24 – Short Plats

Stormwater Code Language	References
a. The construction permit for the shared facilities or systems shall be issued prior to issuance of any building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities or systems; and *b. Construction of the shared facilities or systems shall be completed and final inspection approved prior to final inspection approval of any building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities, and prior to occupancy of any buildings on these lots, parcels, or tracts.*	

In addition, shared drainage control facilities and shared service drains require a joint use and maintenance agreement (JUMA) between the parcels, lots, tracts, etc. that are served by the shared feature per the requirements of the Side Sewer Code (SMC, Section 21.16.250.C).

B-1.1.4. Typical Drainage Conditions for Subdivisions and Short Plats

Subdivisions and Short Plats will require one or more drainage conditions. The applicable drainage conditions must be placed on the first sheet of the plat that will be recorded. The following are some of the typical drainage conditions that may apply. The conditions may require modifications per the reviewer and additional drainage conditions may apply as required by the Director.

Typical Drainage Condition #1. (Required on all Subdivisions and Short Plats): The subdivision of the property will not reduce the requirements of the Seattle Stormwater Code and the Seattle Side Sewer Code. The proposed parcels within this [Subdivision/Short Plat] will meet the standards required by the higher area threshold of the entire property being subdivided rather than the standards required for each of the proposed parcels individually.

Typical Drainage Condition #2. (Required for all Subdivisions or Short Plats that require submittal of Preliminary Drainage Control Plans): Approval of the Preliminary Drainage Control Plans and Report reviewed with this Subdivision/Short Subdivision is preliminary. A Standard or Comprehensive Drainage and Wastewater Control Plan, a Construction Stormwater Control and Soil Management Plan, a Drainage Report (if triggered), and all supporting documents will be required for all future construction permits within this Subdivision/Short Subdivision to demonstrate compliance with the approved Preliminary Drainage Control Plan.

Typical Drainage Condition #3 (Required if the Preliminary Drainage Control Plan shows drainage control facilities that will serve multiple lots, parcels, or tracts within the Subdivision/Short Subdivision): The construction permit for the shared facilities or systems shown on the preliminary drainage plan shall be issued prior to issuance of the any building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities or systems; and construction of the shared facilities or systems shall be completed and final inspection approved prior to final inspection approval of any building permit for any other construction within the lots, parcels, tracts, or rights-of-way served by the shared facilities, and prior to occupancy of any buildings of these lots, parcels, or tracts. [*for full subdivisions*: but in no event later than two years after final plat approval.]

Typical Drainage Condition #4 (Required if a Public Storm Drain mainline extension is required.): The public storm drain shall be extended across the full street frontage of the Subdivision/Short Plat per SMC 22.805.020.L-N unless an adjustment or exception is approved by the Director of Seattle Public Utilities per SMC 22.800.040.B or C. The permits for the public storm drain extension must be issued prior to issuance of the first building permit in the subdivision, and construction of the public storm drain must be completed before final approval of any building permit within the subdivision.

B-1.1.5. Easements for Subdivisions and Short Plats

All lots, parcels, tracts must be demonstrated to have access through easements for the proposed drainage features or conveyance systems that must cross the other lots, parcels, tracts within the subdivision or short plat and for all shared drainage facilities. Easements must be either established in the plat; or the previously recorded easement shall be shown and called out on the plat, including the King County recording number.

Note: Per SPU Policy DWW-160 "The City does not allow the use of an easement in lieu of an extension of the public storm or sewer system (i.e., public sanitary sewer [PSS], public combined sewer [PS], public storm drain [PSD]). Any adjustments or exceptions to this restriction must be authorized by the SPU General Manager/CEO or a designee." A mainline extension may be required if there are any proposed lots that abut a public street right-of-way where there is no existing public piped storm drain. Refer to the Public Drainage System Requirements Director's Rule (SPU Director's Rule DWW-210).

B-1.1.6. Determining Minimum Requirements for Subdivisions and Short Plats

The steps to determine the minimum requirements that apply to Subdivisions and Short Plats are described in *Volume 1*, *Chapter 2*. The project type for Subdivisions and Short Plats is parcel-based, regardless of the land use zoning; and the boundaries of the project site include the full area of the Subdivision or Short Plat. The following code section includes requirements for calculating the new plus replaced hard surface for a Subdivision or Short Plat.

Stormwater Code Language	References
SMC 22.805.010.D *In the case of a subdivision under Chapter 23.22 and short plat under Chapter 23.24, unless an adjustment pursuant to subsection 22.800.040.B is approved by the Director, for the purposes of applying the thresholds in Chapter 22.805, the hard surface coverage is the maximum lot coverage allowed per Subtitle III of Title 23, Land Use Code, plus required and proposed pedestrian and vehicular access and amenities, including driveways, walkways, plazas, and patios identified on the preliminary drainage control plan and associated preliminary site plan.*	• *Volume 1, Section 2.5* – Step 5 – Calculate Land-Disturbing Activity and New Plus Replaced Hard Surface • *Volume 1*, *Section 2.6* – Calculate New Plus Replaced Pollution Generating Surface • SMC 22.800.040.B – Adjustments • SMC, Chapter 23.22 – Subdivisions • SMC, Chapter 23.24 – Short Plats

B-1.2. Unit Lot Subdivisions

Unit Lot Subdivisions per SMC 23.22.062 and 23.24.045 typically have a building permit that is already issued or is being reviewed simultaneously with the Unit Lot Subdivision. If Standard or Comprehensive Drainage Review is already completed or in process for a Building Permit that includes all proposed development in the Unit Lot Subdivision, then the Drainage Control Plan and Drainage Report are not required to be submitted with the Unit Lot Subdivision submittal.

In the case where an application for a Building Permit that covers all development in the Unit Lot Subdivision has not been made, a Preliminary Drainage Plan and Drainage Report (if required), and all supporting documents must be submitted with the Unit Lot Subdivision application (similar to Short Plats and Subdivisions).

Easements

All unit lots must be demonstrated to have access through easements for the proposed drainage features or conveyance systems that must cross the other unit lots within the subdivision and for all shared drainage facilities. Easements must be either established in the Unit Lot Subdivision or the previously recorded easement shall be shown and called out on the Unit Lot Subdivision plat, including the King County recording number.

B-1.3. Lot Boundary Adjustments

Preliminary Drainage Review for Lot Boundary Adjustments (LBA) per SMC 23.28 is required. A separate Preliminary Drainage Control Plan is not required with the Master Use Permit (MUP) submittal if:

1. Drainage infrastructure is accessible to each adjusted lot, and
2. All lots that abut the public place (i.e., street right-of-way) have a public drainage system in their street frontage or access directly to a receiving water.

If the adjusted lots that abut the public place (i.e., street right-of-way) do not have a public piped storm drain (PSD) in their street frontage or access directly to a receiving water, then the following LBA Drainage Adequacy Note #1 must be added to the first page of the recorded LBA plat.

LBA Drainage Adequacy Note #1

There is no available public piped storm drain (PSD) in the street frontage of one or more of the adjusted lots. An extension of the public storm drain may be required across the full street frontage of the adjusted lot/s if required per SMC 22.805.020.L unless an alternative is allowed by the SPU Public Drainage System Requirements Director's Rule DWW-210 (e.g., use of a ditch, culvert, public piped combined main; curb weep or on-site infiltration for small projects). Note: the thresholds for determining requirements include all "Closely Related Projects" as described in the SMC 22.805.010.B/Seattle Stormwater Manual Volume 1, Section 2.1.2.

If an extension of a public drainage system is infeasible as determined by the Director, a Preliminary Drainage Control Plan and associated documents must be submitted to demonstrate that the potential development on each lot can be constructed with infiltration or dispersion BMPs to meet the requirements of *Volume 1*, *Section 4.3.2*. In this scenario, LBA Drainage Adequacy Note #2 must be added to the first page of the recorded LBA plat.

LBA Drainage Adequacy Note #2

A Preliminary Drainage Control Plan was submitted to demonstrate adequacy of drainage for potential development on the adjusted lots using [_________] (onsite infiltration or dispersion BMPs). Approval of this plan is preliminary. A Drainage and Wastewater Control Plan, a Construction Stormwater Control and Soil Management Plan, a Drainage Report, and all supporting documents will be required for all future construction permits within each of the lots and must comply with the provisions of the Preliminary Drainage Control Plan.

The level of detail required on the Preliminary Drainage Control Plan must include a Site Plan showing the proposed or potential development and the sizes and possible locations of stormwater BMPs that will manage the runoff fully on site.

Easements

All adjusted lots must be demonstrated to have legal access for the proposed drainage features or conveyance systems that must cross the other lots to reach street frontage where drainage infrastructure is located or will be extended or have access to a receiving water. Easements must be either established in the LBA; or the previously recorded easement shall be shown and called out on the LBA plat, including the King County recording number.

Note: Per SPU Policy DWW-160, "*The City does not allow the use of an easement in lieu of an extension of the public storm or sewer system (i.e., public sanitary sewer [PSS], public combined sewer [PS], public storm drain [PSD]). Any adjustments or exceptions to this restriction must be authorized by the SPU General Manager/CEO or a designee.*" A mainline extension may be required if there are any adjusted lots that abut a public street right-of-way where there is no existing public piped storm drain (PSD). Refer to the Public Drainage System Requirements Director's Rule (SPU Director's Rule DWW-210).

B-2. Drainage Report Format/Content Requirements

Drainage Reports are a required part of many Drainage Control Plans as indicated in *Volume 1, Chapter 8*. The following table describes the typical, required elements and recommended format for Drainage Reports. Elements that are not applicable to a particular project may be indicated as "not applicable" in the Drainage Report. Additional information that is not included in this table may be as described in *Volume 1*, *Section 8.4*.

Drainage Report Section		**Stormwater Manual Reference**	**Submittal Notes (if applicable)**
1. Introduction	1.1. Project overview	*Volume 1, Chapter 8*	Narrative describing the project.
	1.2. Existing and Proposed Conditions		Describe the existing and proposed conditions including a summary of existing hard surface area.
2. Determining minimum requirements	2.1. Define the boundaries of the project site	*Volume 1, Section 2.1*	Include a vicinity map highlighting the project area
			Include a description of the drainage basin(s) where the project is located and a map highlighting the areas in the project that are in different drainage basins (if applicable).
			If there are multiple basins, include a table with area calculations and identification of drainage basins.
	2.2. Identify the type of project	*Volume 1, Section 2.2*	The project will be classified as a specific project type; this will determine the minimum requirements.
	2.3. Identify the receiving water and downstream conveyance	*Volume 1, Section 2.3*	Include at least one map that shows the existing drainage infrastructure per basin.
			Include a table or narrative describing the type of receiving water/s and types downstream conveyance systems per basin.
	2.4. Perform site assessment and planning	*Volume 1, Section 2.4*	The Drainage Report shall contain, at a minimum, the evaluation and conclusion of each of these items (Section 2.4.1 through 2.4.11) when applicable.
	2.4.1. Project boundaries	*Volume 1, Section 7.2*	
	2.4.2. Setbacks		
	2.4.3. Location of buildings		
	2.4.4. Foundation and footing drains		
	2.4.5. Soil condition assessment and infiltration feasibility analysis	*Volume 1, Section 7.3; Volume 3, Section 3.2*	

Drainage Report Section		Stormwater Manual Reference	Submittal Notes (if applicable)
2. Determining minimum requirements (continued)	2.4.6. Environmentally critical areas (ECAs)	*Volume 1, Section 7.4*	
	2.4.7. Dewatering (Temporary and Permanent)	*Volume 1, Section 7.5*	Identify any temporary or permanent groundwater that the project will discharge and include estimates of the discharge rates from a licensed professional.
	2.4.8. Topography	*Volume 1, Section 7.6*	
	2.4.9. Site Assessment	*Volume 1, Section 7.7*	
	2.4.10. Landscaping principles	*Volume 1, Section 7.8*	
	2.4.11. Site design considerations and dispersion feasibility	*Volume 1, Section 7.9* *Volume 3, Section 3.2*	
	2.5. Calculate land disturbing activity and new plus replaced hard surface	*Volume 1, Section 2.5*	Provide a map highlighting the project's new plus replaced hard surface and limits of disturbance per basin. Provide a color map that identifies different types of surfaces (i.e., hard vs. pervious) and area calculations.
	2.6. Calculate new plus replace pollution generating surface	*Volume 1, Section 2.6*	If water quality treatment is required, provide a map highlighting the pollution generating hard and pervious areas per basin and delineate the areas tributary to each Water Quality BMP.
	2.7. Determine which minimum requirements apply	*Volume 1, Section 2.7*	Include a summary of all minimum requirements that apply.
3. Minimum requirements for all projects	3.1. Maintaining natural drainage patterns	*Volume 1, Section 3.1*	The Drainage Report shall contain, at a minimum, an evaluation and conclusion of each of these items (*Section 3.1* through *3.12*) when applicable.
	3.2. Discharge point	*Volume 1, Section 3.2*	
	3.3. Flood-prone areas	*Volume 1, Section 3.3*	

Drainage Report Section		Stormwater Manual Reference	Submittal Notes (if applicable)
3. Minimum requirements for all projects (continued)	3.4. Construction site stormwater pollution prevention control	*Volume 1, Section 3.4; Volume 1, Chapter 8; Volume 2, Chapter 2*	Include small- or large-project CSC checklist and CSC plan. A narrative is also required and a short narrative describing the selected BMPs and the results of any required calculations.
	3.5. Protect wetlands	*Volume 1, Section 3.5*	
	3.6. Protect streams and creeks	*Volume 1, Section 3.6*	
	3.7. Protect shorelines	*Volume 1, Section 3.7*	
	3.8. Ensure sufficient capacity	*Volume 1, Section 3.8*	
	3.9. Install source control BMPs	*Volume 1, Section 3.9; Volume 4, Section 1.6*	Include the Worksheet for Identifying Applicable Source Control BMPs (*Volume 4*, Table 1)
	3.10. Do not obstruct watercourses	*Volume 1, Section 3.10*	
	3.11. Comply with side sewer code	*Volume 1, Section 3.11*	Side sewers in ROW shall be shown on SIP plans but require a separate permit.
	3.12. Extension of public drainage system	*Volume 1, Section 3.12*	
	3.13. Public drainage system requirements	*Volume 1, Section 3.13*	
	3.14. Maintenance and inspection	*Volume 1, Section 3.14*	

Drainage Report Section			Stormwater Manual Reference	Submittal Notes (if applicable)
4. Minimum requirements based on project type	4.1. Soil amendment		*Volume 1, Section 5.1*	Include site plans highlighting the area requiring soil amendment (disturbed area)
	4.2. On-site Stormwater management		*Volume 1, Section 5.2; Volume 3, Chapter 3*	Include a narrative with a summary of the BMPs selected and describe any modeling required for the sizing of the BMPs or special considerations such as presettling. Describe in the infeasibility criteria for On-site Stormwater Management BMPs that were not selected. Reference the appropriate Appendix of the Report for the On-site Stormwater Management Calculator and any other required infeasibility documentation.
	4.3. Flow control	5.3.1. Wetland protection standards	*Volume 1, Section 5.3; Volume 3, Sections 3.4 and 4.1*	When using hydrologic modeling software, provide conclusions for each simulation to explain how the proposed flow control BMP complied with SMC, Section 22.805.080. Include a map identifying the tributary area connected to the flow control BMP that specifies the amount of area been collected.
		5.3.2. Pre-developed forest standard		
		5.3.3. Pre-developed pasture standard		
		5.3.4. Existing condition standard		
		5.3.5. Peak control standard		
	4.4. Water quality treatment	5.4.1. Basic treatment	*Volume 1, Section 5.4; Volume 3, Section 3.5*	
		5.4.2. Oil treatment		
		5.4.3. Phosphorus treatment		
		5.4.4. Enhanced treatment		
5. Conclusion				Describe the project and how each of the requirements were met, giving a summary of the problems and solutions proposed for this project.

Drainage Report Section		Stormwater Manual Reference	Submittal Notes (if applicable)
Appendix A	Figures and Maps		
Appendix B	Construction Stormwater Control and Temporary Dewatering Calculations		
Appendix C	On-site Stormwater Management Workbook and any related documentation or calculations		Include the full workbook and any required documentation to justify infeasibility criteria selected (e.g., financial infeasibility criteria, rainwater demand analysis for rainwater harvesting, Geotechnical Engineering analysis and recommendations, etc.).
Appendix D	Flow Control Calculations (if required)		
Appendix E	Water Quality Calculations (if required)		
Appendix F	Landscape Management Plan (if required)		
Appendix G	Source Control Calculations (if required)		
Appendix H	Infiltration Checklist and Documentation		
Appendix I	Soil and Infiltration Investigation Documentation		Infiltration checklists and documentation. Groundwater investigation and estimated flowrate documentation. Geotechnical Report
Appendix J	Inspections and Operations and Maintenance (O&M) Requirements and schedule		

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Appendix C - On-site Stormwater List BMP Infeasibility Criteria

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

This appendix provides infeasibility criteria for use in evaluating BMPs to meet the On-site Stormwater Management Requirement using the On-Site List approach (SMC, Section 22.805.070.D.2) to manage new and replaced hard surfaces. Refer to *Volume 1*, *Section 5.2.2* to determine which On-site BMPs require evaluation for a project. Evaluation is based on project type, discharge location, and other criteria. Step-by-step instructions for using the On-site List Approach are provided in *Volume 3*, *Section 3.3.1*.

Prior to evaluating On-site BMPs, review the site design consideration in *Volume 1*, *Chapter 7 — Site Assessment and Planning* to conserve natural areas, retain native vegetation, reduce impervious surfaces, and integrate stormwater controls into the existing site layout to the maximum extent feasible. The infeasibility criteria provided in this appendix apply to BMPs if the area proposed for the BMP is the only available area for the BMP, after all reasonable efforts to regrade the site and allow for alternative placement of the BMP have been made.

When using the On-site List approach, an on-site BMP is considered infeasible if an infeasibility criterion in Tables C.1 through C.6 is met.

Table C.1. On-site List Infeasibility Criteria: All Dispersion and Infiltration BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
All BMPs	• Installation requires removal of an existing tree. To use this infeasibility criterion, the tree must be in good health and meet minimum size requirements: deciduous trees must have trunks at least 1.5 inches in diameter measured 6 inches above the ground, and evergreen trees must be at least 4 feet tall. In addition, the existing tree must be in an area that will be protected throughout construction. • Where BMP installation is prohibited per Regulations for Environmentally Critical Areas (SMC Chapter 25.09). • Where BMP installation would require pumping to a designated point of discharge, but failure of the pump may destabilize a steep slope. • Where unable to maintain a desired access of 36 inches in a required building setback from a property line, except when using the Soil Amendment BMP (*Volume 3, Section 5.1*). • Where unable to maintain clearance for required ingress, egress, or ADA pathways. • Where BMP installation would require a pump when a pump is not already required to provide site storm drainage. Requiring a pump as the result of using the Rainwater Harvesting BMP does not make this BMP infeasible.	

Table C.1 (continued). On-site List Infeasibility Criteria: All Dispersion and Infiltration BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
All Dispersion BMPs	• A licensed professional (as defined in *Appendix D*, *Section D-1*) recommends dispersion not be used anywhere within project site due to reasonable concerns of erosion, slope failure, or flooding (requires a signed and stamped written determination based on site-specific conditions from a licensed professional). • The dispersion flow path area does not provide positive drainage. • The dispersion flowpath area is within a landslide-prone area (SMC, Section 25.09.080). • The dispersion flowpath area is within 100 feet of a contaminated site or landfill (active or closed). • The dispersion flowpath area is in a steep slope area (SMC, Section 25.09.020) or within a setback to a steep slope area (calculated as 10 times the height of the steep slope to a 500-foot maximum setback). • The dispersion flowpath area is within 10 feet of a proposed or existing septic system or drainfield.	
All Infiltration BMPs	The following criteria each establish that the BMP is infeasible but only if based on an evaluation of site-specific conditions and documented within a signed and stamped written determination from a licensed professional (as defined in *Appendix D*, *Section D-1*): • Infiltration is not recommended due to reasonable concerns about erosion, slope failure, or flooding. • The area available for siting would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, pre-existing structures, or pre-existing road or parking lot surfaces or subgrades. • The area available for siting would threaten shoreline structures such as bulkheads. The following criteria each establish that the BMP is infeasible, without further justification, though some criteria evaluation require professional services: • Evaluation of infiltration is not required per the "Infiltration Investigation Map." • The area available for siting does not allow for overflow conveyance to an approved point of discharge per *Volume 3*, *Section 4.3.2*. • The area available for siting is within a steep slope area or land-slide prone area (or setback) (refer to *Volume 3*, *Section 3.2).* • The area available for siting does not meet the minimum horizontal setback requirements (refer to *Volume 3*, *Section 3.2).* • The area available for siting does not meet the minimum vertical setback requirements (refer to *Volume 3*, *Section 3.2*, and *Appendix D).* • Infiltration is restricted due to contaminated soil or groundwater (refer to *Volume 3*, *Section 3.2).*	

Table C.2. On-site List Infeasibility Criteria: Category 1 BMPs.

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Full Dispersion	• One or more of the infeasibility criteria for "All BMPs" or "All Dispersion BMPs" (Table C.1) apply. • The site has less than a 65 to 10 ratio of the native vegetation area to the impervious area. • The minimum native vegetation flowpath length is less than 100 feet.	
Infiltration Trenches	• One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. • Field testing indicates potential infiltration trench site(s) have a measured underlying soil infiltration rate less than 5 inches per hour (*Volume 3*, *Section 5.4.2*). • Where the site cannot be reasonably designed to locate a catch basin between the infiltration trench and point of connection to the public system.	
Drywells	• One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. • Field testing indicates potential drywell site(s) have a measured underlying soil infiltration rate less than 5 inches per hour (*Volume 3*, *Section 5.4.3*). • Where the site cannot be reasonably designed to locate a catch basin between the drywell and point of connection to the public system.	

Table C.3. On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Rain Gardens	• One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. • In the right-of-way, the longitudinal road slope exceeds 4 percent. • The rain garden would have a linear geometry with a longitudinal slope greater than 8 percent. • The minimum bottom width of the rain garden (12-inch average) cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s) or minimum setbacks to structures, utilities, or property lines. • The infiltration area is within the minimum vertical or horizontal clearance from utilities, according to clearances required by the utility owner. • Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour.	
Infiltrating Bioretention Facilities	• One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. • The infiltrating bioretention facility would have a linear geometry with a longitudinal slope greater than 8 percent. • The minimum bottom width of the infiltrating bioretention facility (2 feet for facilities with vertical sides and 18-inch average for facilities with sloped sides) cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s) or minimum setbacks to structures, utilities, or property lines. • The infiltration area is within the minimum vertical and horizontal clearance from utilities, according to clearances required by the utility owner. • Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. • Field testing indicates soils have a measured underlying soil infiltration rate less than 0.6 inch per hour and an underdrain cannot be installed per the design criteria. • The facility with an underdrain would route underdrained water to a nutrient-critical receiving water. • In the right-of-way, installation requires a vertical walled facility.	
Rainwater Harvesting	• One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. • Project lacks non-pollution-generating roof from which to harvest rainwater. • Non-potable water demand is insufficient to meet the On-site Performance Standard per modeling conducted in accordance with *Volume 3, Section 5.5.1.6*. • Installation is not economically feasible based on reasonable consideration of financial cost (e.g., roof area is less than 20,000 sf or the ratio of roof area to average daily rainwater demand is less than 10,000 square feet/gpm) (refer to *Appendix H*). Documentation is required.	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Permeable Pavement Facilities	• One or more of the infeasibility criteria for "All BMPs" or "All Infiltration BMPs" (Table C.1) apply. The following criteria each establish that the BMP is infeasible but only if based on an evaluation of site-specific conditions and a written recommendation from a licensed professional (as defined in *Appendix D*, *Section D-1*): • Infiltrating or ponding water below pavement area would compromise adjacent pavements. • Fill soils are used that can become unstable when saturated. • The permeable pavement design does not provide sufficient strength to support heavy loads in areas with "industrial activity" as identified in 40 CFR 122.26(b)(14). The following criteria each establish that the BMP is infeasible, without further justification, though some criteria require professional services: • The subgrade slope exceeds 6 percent after reasonable efforts to grade. • The permeable pavement wearing course slope exceeds 6 percent after reasonable efforts to grade. • For projects in the right-of-way, the permeable pavement surface area would be less than 2,000 square feet of contiguous pavement and the project discharges to: o A designated receiving water body, or o A combined system, or o A capacity constrained system which does not drain to a creek wetland or small lake. • The anticipated mature tree spread (based on tree species) would overhang more than 50 percent of permeable pavement area. • The pavement is over a structure, such as, but not limited to: parking garages, box culverts, and bridges. • The pavement is subject to long-term excessive sediment deposition (e.g., construction and landscaping material yards). • Underlying soils are unsuitable for supporting traffic loads when saturated (e.g., a residential access road has a California Bearing Ratio of 5 percent or less). • Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour. • Pavement is replacing an existing pollution-generating hard surface in the right-of-way. • The street type is classified as arterial or collector rather than local access. Refer to RCW 35.78.010, RCW 36.86.070, and RCW 47.05.021. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces associated with the collector or arterial.	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Permeable Pavement Facilities (continued)	● Streets that receive more than very low traffic volumes, and areas having more than very low truck traffic. Streets with a projected average daily traffic volume of 400 vehicles or less are very low volume roads (AASHTO, 2001) (U.S. Dept. of Transportation 2013). Areas with very low truck traffic volumes are streets and other areas not subject to through truck traffic but may receive up to weekly use by utility trucks (e.g., garbage, recycling), daily school bus use, and multiple daily use by pick-up trucks, mail/parcel delivery trucks, and maintenance vehicles. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces. ● The pavement area is defined as a “high use site” in SMC, Section 22.801.090. ● In areas with “industrial activity” as identified in 40 CFR 122.26(b)(14). ● Where the risk of concentrated pollutant spills is more likely, including, but not limited to, gas stations, truck stops, and industrial chemical storage sites. ● In areas where routine, heavy roadway applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation, including sidewalks within 7 feet of driving lanes with sand application. ● Where runon from unstabilized erodible areas would occur without presettling. ● The areas contributing runoff to the permeable pavement facilities exceed the maximum run-on limits: o Pollution-generating impervious surfaces (e.g., roadways, parking lots) exceed the maximum run-on area ratio of 2:1 o Non-pollution generating impervious surfaces (e.g., roofs, sidewalks) and stabilized pervious surfaces exceed the maximum run-on area ratio of 5:1 ● Where the Director has determined that permeable pavement in active zones of a skate park, bike park, or sport court violates safety standards	

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

<table>
<tr><th>BMP</th><th>On-site List Infeasibility Criteria</th><th>Additional Information from Applicant</th></tr>
<tr><td>Permeable Pavement Surfaces</td><td>

One or more of the infeasibility criteria provided for permeable pavement facilities apply. (Note, however, that for permeable pavement surfaces, the infeasibility criteria for “All Infiltration BMPs” are not applicable).
Field testing indicates soils have a measured underlying soil infiltration rate less than 0.3 inch per hour (Note: field infiltration tests are not required for permeable pavement surfaces, but must be used to demonstrate infeasibility).
The site is a contaminated site or abandoned landfill.
Installation is within 10 feet of a petroleum, chemical, or liquid hazardous waste storage tank or connecting underground pipes.
Run-on from an adjacent impervious area is greater than 10 percent of the permeable pavement surface area.
A licensed professional (as defined in Appendix D, Section D-1) recommends permeable pavement not be used anywhere within the project site due to reasonable concerns of erosion, slope failure, or flooding (requires a signed and stamped written determination based on site-specific conditions from a licensed professional).
Where the Director has determined that permeable pavement in active zones of a skate park, bike park, or sport court violates safety standards.
Based on subsurface investigation,[a] groundwater or hydraulically-restrictive layer is too shallow per the following Minimum Vertical Separation table.

<table>
<tr><th colspan="4">Permeable Pavement Surfaces</th></tr>
<tr><th rowspan="2">Season</th><th rowspan="2">Minimum Investigation Depth (ft)[b]</th><th colspan="2">Minimum Vertical Separation, ft[a]</th></tr>
<tr><th>Ground-water</th><th>Hydraulically-Restrictive Layer</th></tr>
<tr><td>Wet Season (November – March)</td><td>2</td><td>1</td><td>1</td></tr>
<tr><td>Dry Season (April – October)</td><td>3</td><td>2</td><td>1</td></tr>
</table>
[a] Subsurface investigation is not required for permeable pavement surfaces, but subsurface investigation must be performed to demonstrate infeasibility due to lack of vertical separation.
[b] The minimum investigation depth and vertical separation shall be measured from the bottom of the BMP. The bottom of the BMP is defined as the deepest portion of proposed BMP where water is expected to move into the underlying soil (i.e., at the aggregate subbase or Water Quality Treatment Course [if required]).
</td><td></td></tr>
</table>

Table C.3 (continued). On-site List Infeasibility Criteria: Category 2 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Sidewalk/ Trail Compost-Amended Strip	• One or more of the infeasibility criteria for "All BMPs," "All Dispersion BMPs," or "All Infiltration BMPs" (Table C.1) apply. • The flowpath downstream of the Sidewalk/Trail Compost-Amended Strip is within 10 feet of a proposed or existing septic system or drainfield, as measured from the toe of the Sidewalk/Trail Compost-Amended Strip slope. • The sidewalk or trail to be dispersed exceeds a lateral slope of 5 percent or a longitudinal slope of 8 percent. • The sidewalk or trail to be dispersed has a lateral slope of less than 1 percent. • Field testing indicates underlying soils have a design soil infiltration rate less than 0.15 inch per hour. Note that field infiltration tests are not required for the Sidewalk/Trail Compost-Amended Strip, but must be used to demonstrate infeasibility. • The minimum Sidewalk/Trail Compost-Amended Strip design criteria cannot be met.	

[a] Category references Parcel-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

Table C.4. On-site List Infeasibility Criteria: Category 3 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Sheet Flow Dispersion	• One or more of the infeasibility criteria for “All BMPs” or “All Dispersion BMPs” (Table C.1) apply. • The area to be dispersed (e.g., driveway, patio) exceeds a slope of 15 percent. • The minimum vegetated flow path for sheet flow dispersion cannot be met. Note: A 10-foot flowpath is required to disperse runoff from a contributing flow length of up to 20 feet. An additional 10 feet of flow path is required for each additional 20 feet of contributing flow path or fraction thereof. Refer to *Volume 3*, *Figure 5.5*. • The flowpath does not meet the minimum horizontal setback requirements to property lines, structures and other flowpaths (refer to *Volume 3*, *Section 5.3.5*).	
Concentrated Flow Dispersion	• One or more of the infeasibility criteria for “All BMPs” or “All Dispersion BMPs” (Table C.1) apply. • There are no concentrated flows to disperse. • The minimum dispersion trench length of 10 feet cannot be met. • The vegetated flow path for the dispersion trench is less than 25 feet • The vegetated flow path for a rock pad is less than 50 feet. • Greater than 700 square feet of surface area drains to the BMP. • The flowpath does not meet the minimum horizontal setback requirements to property lines, structures and other flowpaths (refer to *Volume 3*, *Section 5.3.6*).	
Splashblock Downspout Dispersion	• One or more of the infeasibility criteria for “All BMPs” or “All Dispersion BMPs” (Table C.1) apply. • There are no downspouts. • The vegetated flowpath is less than 50 feet. • Greater than 700 square feet of surface area drains to the BMP. • The flowpath does not meet the minimum horizontal setback requirements to property lines, structures and other flowpaths (refer to *Volume 3*, *Section 5.3.3*).	
Trench Downspout Dispersion	• One or more of the infeasibility criteria for “All BMPs” or “All Dispersion BMPs” (Table C.1) apply. • There are no downspouts. • The minimum dispersion trench length of 10 feet for every 700 square feet of drainage area cannot be met. • The vegetated flowpath is less than 25 feet. • The flowpath is within the setbacks to property lines, structures and other flowpaths (refer to *Volume 3*, *Section 5.3.4*).	

[a] Category references Single Family Residential-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

Table C.5. On-site List Infeasibility Criteria: Category 4 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Non-Infiltrating Bioretention	• One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. • The minimum bottom width of the non-infiltrating bioretention facility (2 feet) cannot be met due to, but not limited to: encroachment within the critical root zone of an existing tree(s), minimum setbacks to structures/utilities, or project limits/planting strip too small. • Minimum vertical and horizontal clearances from utilities are unachievable as required by utility owner. • The facility would route underdrained water to a nutrient-critical receiving water. • The area available for siting is within a setback equal to the height of the slope to a maximum of 50 feet from the top of steep slope and known landslide area. • The BMP would be located on a structure or roof that cannot provide sufficient structural support for the BMP without reasonable effort to increase the strength of the roof design. • Less than 1 foot between the liner and seasonal high groundwater elevation.	
Rainwater Harvesting	See On-site List Infeasibility Criteria in Table C.3.	
Vegetated Roof Systems	• One or more of the infeasibility criteria for "All BMPs" (Table C.1) apply. • Project does not include a roof. • Roof design has a slope less than 1 degree (0.2:12) or greater than 10 degrees (2:12). • Installation is not economically feasible based on reasonable consideration of financial cost (refer to *Appendix H*). Documentation is required. • The portion of the roof is an amenity area subject to pedestrian use (e.g., balcony, patio, walkway, pet runs, etc.). • The portion of the roof is required for HVAC equipment and/or maintenance access ways (e.g., window washing, HVAC maintenance, etc.). • The portion of the roof is completely covered with solar panels.	

[a] Category references Single Family Residential-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

Table C.6. On-site List Infeasibility Criteria: Category 5 BMPs.[a]

BMP	On-site List Infeasibility Criteria	Additional Information from Applicant
Perforated Stub-out Connections	• One or more of the infeasibility criteria for “All BMPs” or “All Infiltration BMPs” (Table C.1) apply. • The location for the perforated pipe portion of the system is under impervious or heavily compacted (e.g., driveways and parking areas) surfaces. • The minimum perforated stub-out length of 10 feet per 5,000 square feet of contributing roof area cannot be met. • Where the site cannot be reasonably designed to locate a catch basin between the perforated stub-out and point of connection to the public system.	
Trees	• The mature height, size, and/or rooting depth is not compatible with Medium and Large trees listed in the reference materials posted on SDCI’s website.	
Single Family Residential (SFR) Cistern	• One or more of the infeasibility criteria for “All BMPs” (Table C.1) apply. • Project does not include non-pollution generating surfaces. • The SFR cistern would be within restricted setbacks.	

[a] Category references Single Family Residential-based Project list. Refer to SMC, Section 22.805.070.D and *Volume 1 Section 5.2.2* for categories relevant to other types of projects.

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Appendix D - Subsurface Characterization and Infiltration Testing for Infiltration BMPs

City of Seattle

Stormwater Manual

July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

Table of Contents

D-1. Roles and Responsibilities of Licensed Professionals

This appendix provides the minimum investigation requirements for infiltration best management practices (BMPs). This information does not preclude the use of professional judgment to evaluate and manage risk associated with design, construction, and operation of infiltration BMPs.

When a licensed professional is required to perform a subsurface investigations and/or infiltration testing, that professional shall be an engineer, engineering geologist, geologist, hydrogeologist, or soil scientist licensed by the State of Washington who has experience in infiltration and or groundwater testing and infiltration BMP design, except in the following cases:

- The licensed professional shall be either a geotechnical engineer or hydrogeologist licensed by the State of Washington when:
  - A Comprehensive Subsurface Investigation is required.
  - A correction factor for a Comprehensive Subsurface Investigation is required to be determined.
  - Infiltration is proposed in an Environmentally Critical Area (ECA) steep slope or landslide-prone areas or within a setback of 10 times the height of the steep slope area to a maximum of 500 feet above a steep slope area.
- The licensed professional shall be a hydrogeologist licensed in the State of Washington when:
  - Runoff from 5,000 square feet or more of impervious surface area will be infiltrated within 500 feet up-gradient or 100 feet down-gradient of a contaminated site or landfill (active or closed).
  - Groundwater mounding and/or seepage analysis is required.
  - A deep subsurface infiltration test is required.

Acceptance testing shall be performed by a licensed professional from the same category as was required for the design investigations.

Recommendations that deviate from the minimum investigation requirements specified in this appendix shall be contained in a stamped and signed letter from a licensed professional, and must provide rationale and specific data supporting their professional judgment. For more information on the role of the geotechnical engineer or hydrogeologist, refer to City of Seattle Director's Rule 5-2016, *General Duties and Responsibilities of Geotechnical Engineers*.

D-2. Subsurface Investigation

D-2.1. Description

Subsurface investigations consist of any type of excavation that allows for the collection of soil samples and the observation of subsurface materials and groundwater conditions, including hand-auger holes, test pits, and drilled boreholes.

This section includes general subsurface investigation requirements followed by specific information regarding four types of subsurface investigations:

- Simple subsurface investigation
- Standard subsurface investigation
- Comprehensive subsurface investigation
- Deep infiltration subsurface investigation

D-2.2. General Subsurface Investigation Requirements

This section includes requirements for subsurface investigation locations, timing, alternatives, investigation depth and vertical separation requirements, and subsurface reports.

D-2.2.1. Subsurface Investigation Locations

For Single-Family Residential (SFR) and Parcel-based projects, the site is defined as the project area. For Trail, Sidewalk, or Roadway projects, the site is defined by one intersection to the other and blocks may vary in length. In many cases, subsurface investigations should be performed at the site of the infiltration BMP or as close as possible, but no more than 50 feet away, to obtain relevant subsurface information. Subsurface investigations can be conducted at the same location as the infiltration tests (refer to *Section D-3*).

D-2.2.2. Subsurface Investigation Timing

Subsurface investigations should be performed in the wet season (November through March) if possible, when soils may contain a higher water content and groundwater levels are typically higher. Refer to *Sections D-2.3* through *D-2.5* for wet season and dry season requirements for the different types of subsurface investigations.

D-2.2.3. Alternatives to Subsurface Investigation

In some cases, available data and the licensed professional's interpretation of subsurface material characteristics can be used to demonstrate that infiltration is infeasible on a site and precludes the need for all of the subsurface investigation or infiltration testing. Examples of these instances include, but are not limited to:

- Groundwater monitoring data that meets the requirements of the groundwater monitoring section (refer to *Section D-5*), at the site of the proposed BMP showing groundwater elevations not meeting the vertical separation requirements (refer to *Section D-2.2.4)*.
- Identification by the licensed professional of hydraulically-restrictive materials beneath the proposed BMP and within the vertical separation requirements (refer to *Section D-2.2.4*).
- To support these instances, the licensed professional must submit a stamped and signed letter that provides rationale and specific data supporting their professional judgment for each area deemed infeasible for infiltration.

D-2.2.4. Investigation Depth and Vertical Separation Requirements

Investigation depth is measured below the bottom of the proposed infiltration BMP. The bottom of the infiltration BMP is defined as the deepest portion of proposed BMP where infiltrating water is expected to move into the underlying soil.

The vertical separation requirements depend upon the type of subsurface investigation required and the seasonal timing of the geotechnical exploration conducted to evaluate clearance and are typically one foot less than the minimum investigation depths summarized in *Sections D-2.3* through *D-2.5*. If groundwater or a hydraulically-restrictive material is encountered within the vertical separation depth, then no further investigation is required.

Examples of materials that may be interpreted as hydraulically-restrictive include:

- Glacially consolidated soils that have greater than 50 percent fines
- Glacially unconsolidated soils that have greater than 70 percent fines
- Bedrock

D-2.2.5. Subsurface Report

Projects that are required to perform subsurface investigations per *Volume 3*, *Section 3.2*, shall prepare a report documenting results of the subsurface investigations described in *Sections D-2.3* through *D-2.6* and infiltration tests described in *Section D-3*.

D-2.3. Simple Subsurface Investigation

This section summarizes the minimum requirements of a Simple Subsurface Investigation. Refer to Table 3.1 in *Volume 3*, *Section 3.2* to determine the minimum subsurface investigation requirements for a project.

A simple subsurface investigation report can be used to document the investigation and testing results. This report shall include the following, as applicable:

- Map of investigation and testing location
- Soil characteristics
- Depth to groundwater (if encountered)
- Results of subsurface investigations as required in Table 3.1 of *Volume 3, Section 3.2* and evaluation of vertical separation results.

Simple Subsurface Investigation Elements

Minimum Investigation Depth and Vertical Separation Requirements

All BMPs			
		Minimum Vertical Separation, ft [a]	
Season	Minimum Investigation Depth (ft)[a]	Groundwater	Hydraulically-Restrictive Layer
Wet Season (November – March)	2	1	1
Dry Season (April – October)	3	2	1

Soil Characteristics

Type and texture of soil

[a] The bottom of the BMP is defined as the deepest portion of proposed BMP where infiltrating water is expected to move into the underlying soil.

D-2.4. Standard Subsurface Investigation

This section summarizes the minimum requirements of a Standard Subsurface Investigation. Refer to Table 3.1 in *Volume 3*, *Section 3.2* to determine the minimum subsurface investigation requirements for a project.

A standard subsurface investigation report shall be used to document the investigation and testing results. This report shall include the following, as applicable:

- Map of investigation and testing location
- Soil characteristics for each soil and/or rock unit encountered
- Depth to groundwater (if encountered)
- Detailed logs for each investigation
- Results of subsurface investigations as required in Table 3.1 of *Volume 3, Section 3.2* and evaluation of vertical separation results.

If a small pilot infiltration test (PIT) is required, the report shall be signed and stamped by a licensed professional.

Standard Subsurface Investigation Elements

Minimum Investigation Depth and Vertical Separation Requirements

Season	Minimum Investigation Depth (ft)[a]	Minimum Vertical Separation (ft)[a]	
		Groundwater	Hydraulically-Restrictive Layer
Infiltration Basins			
Wet Season (November – March)	6	5	5
Dry Season (April – October)	7	6	5
All Other Infiltration BMPs			
Wet Season (November – March)	2	1	1
Dry Season (April – October)	4	3	1

Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type)

- USCS classification or textural class
- Material texture, color/mottling, density and type
- Relative moisture content
- Grain size distribution, including fines content determination
- Presence of stratification or layering
- Presence of groundwater
- Iron oxide staining or mottling that may provide an indication of high water level
- Cation exchange capacity (refer to *Volume 3*, *Section 4.5.2*)

Detailed logs for each investigation

- Map showing the location of the test pits or borings
- Depth of investigations
- Investigation methods (hand augers, test pits, or drilled borings), material descriptions
- Depth to water (if present)
- Presence of stratification
- Existing boring or groundwater information

The report shall document how the information collected relates to the infiltration feasibility of the site based on the setbacks provided in *Volume 3*, *Section 3.2* and this appendix. If more than 2,000 sf of the site infiltration will occur within a single BMP, the Standard Subsurface Investigation report shall be prepared by a licensed professional.

[a] The bottom of the BMP is defined as the deepest portion of proposed BMP where infiltrating water is expected to move into the underlying soil. For Small PITs, sampling of distinct materials below the bottom of the BMP and within the vertical separation depth is required. Beyond this depth, samples should be collected every 2.5 feet.

D-2.5. Comprehensive Subsurface Investigation

This section summarizes the minimum requirements of a Comprehensive Subsurface Investigation. Refer to Table 3.1 in *Volume 3*, *Section 3.2* to determine the minimum subsurface investigation requirements for a project. The comprehensive subsurface investigation report shall be prepared, signed and stamped by a geotechnical engineer or hydrogeologist.

A comprehensive subsurface investigation report shall be used to document the investigation and testing results. This report shall include the following, as applicable:

- Map of investigation and testing location
- Soil characteristics for each soil and/or rock unit encountered
- Depth to groundwater (if encountered)
- Detailed logs for each investigation
- Results of subsurface investigations as required in Table 3.1 of *Volume 3, Section 3.2* and evaluation of vertical separation results.

Comprehensive Subsurface Investigation Elements

Minimum Investigation Depth

Season	Minimum Investigation Depth (ft)[a,b]	Minimum Vertical Separation (ft)	
		Groundwater	Hydraulically-Restrictive Layer
Infiltration Basins			
Wet Season (November – March)	6	5	5
Dry Season (April – October)	10	8	5
Permeable Pavement Facilities			
Wet Season (November – March)	2	1	1
Dry Season (April – October)	4	3	1
Infiltrating Bioretention with Underdrain			
Wet Season (November – March)	2	1	1
Dry Season (April – October)	10	8	1
Infiltrating Bioretention without Underdrain and all Other Infiltration BMPs			
Wet Season (November – March)	4	3	3
Dry Season (April – October)	10	8	3

Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type)

Same as Standard Subsurface Investigation (*Section D-2.4*)

Detailed logs for each investigation

Same as Standard Subsurface Investigation (*Section D-2.4*)

[a] The bottom of the BMP is defined as the deepest portion of proposed BMP where infiltrating water is expected to move into the underlying soil. For Small PITs, sampling of distinct materials below the bottom of the BMP and within the vertical separation depth is required. Beyond this depth, samples should be collected every 2.5 feet.

[b] If the bottom of the BMP is not known, the minimum investigation depth shall be 16 feet below grade. Investigations that will also serve as groundwater monitoring wells shall not be less than 20 feet below the bottom of proposed BMP and the criteria for vertical separation to groundwater or hydraulically-restrictive materials listed above shall apply.

D-2.6. Deep Infiltration Subsurface Investigation

This section summarizes the minimum requirements of a Deep Infiltration Subsurface Investigation. Refer to Table 3.2 in *Volume 3*, *Section 3.2*, to determine the minimum subsurface investigation requirements for a project. The deep infiltration subsurface investigation report shall be prepared by a licensed geotechnical engineer or hydrogeologist.

Deep Infiltration Subsurface Investigation Elements
Minimum Investigation Depth At least 10 feet below regional groundwater table or into aquitard underlying target soil
Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type) Same as Standard Subsurface Investigation *(Section D-2.4)*
Detailed logs for each investigation Same as Standard Subsurface Investigation *(Section D-2.4)*

D-3. Infiltration Tests

D-3.1. Description

Step 4 in *Volume 3, Section 3.2*, is Conduct Infiltration Testing. This section provides procedures for the following infiltration testing methods:

- Simple Infiltration Test (Small-scale infiltration test)
- Small Pilot Infiltration Test (PIT)
- Large PIT
- Deep infiltration test

To determine which infiltration test method is required for a project, refer to Table 3.1 and Table 3.2 in *Volume 3*, *Section 3.2*.

If possible, perform infiltration testing at the location of the proposed infiltration BMP. Infiltration testing results from a nearby location within 50 feet of the proposed infiltration BMP may be approved at the discretion of the licensed professional. If greater than 5,000 sf is infiltrated on the site, then acceptance testing is required (refer to *Volume 3, Section 3.2*).

If variable soil conditions are observed at the site, multiple infiltration tests are recommended in the different soil types.

After the measured infiltration rates are determined using the procedures provided in this section, correction factors must be applied to calculate the design infiltration rate used for BMP sizing (refer to *Section D-4*).

The test method may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the report. Any modifications to the proposed test method should be approved by the City.

D-3.2. Simple Infiltration Test

The Simple Infiltration Test is a small-scale infiltration test procedure adapted from the Washington State Department of Ecology (Ecology) Rain Garden Handbook for Western Washington (https://fortress.wa.gov/ecy/publications/SummaryPages/1310027.html).

The Simple Infiltration Test does not require a licensed professional.

The Simple Infiltration Test is not allowed for projects with no off-site point of discharge (*Volume 3, Section 4.3.2*). These projects shall use a Small PIT.

Procedure

If testing is performed during the wet season (November through March), only one test is required. If the test is performed during the dry season (April through October), two tests must be performed in same hole within 2 days, with the beginning of each test spaced 24 hours apart.

1. Dig a hole a minimum of 2 feet deep. Preferably, the depth of the hole should be measured from the bottom of the facility but at a minimum shall be measured from the proposed site finished grade. The hole shall be at least 2 feet in diameter.
2. Record the type and texture of the soil. If the soil is primarily fine-grained such as silt or clay, or is glacial till, infiltration may not be feasible.
3. At the same time that you dig your test hole, check for high groundwater by using a post hole digger to excavate a hole to the minimum subsurface investigation depth, as provided in *Section D-2.3*, approximately 5 feet from the test hole. If standing water or seeping water is observed in the hole, measure the depth to the standing water or seepage.
4. Pre-soak period: Add 12 inches of water to the hole. This can be measured using a ruler, scale, or tape measure. Be careful to avoid splashing, which could erode the sides of the hole or disturb the soil at the base of the hole.
5. Record the depth of water in the hole in inches.
6. Record the time water was added to the hole.
7. Check and record the time and depth of water in the hole on an hourly basis for up to two hours. Estimate the infiltration rate in inches per hour by calculating the drop in water level in inches for each hour. Based on the lowest of these measurements, determine which time interval to use for the infiltration test by following these guidelines:
    - >3 inch per hour fall, check at 15-minute intervals
    - 3 inch to 1 inch per hour fall, check at 30-minute intervals
    - <1 inch per hour fall, check at hourly intervals
8. Infiltration Test: Fill the hole back up to a depth of 12 inches. Check and record the time and depth of water in the hole at regular intervals based on the time interval determined during the presoak period for a total of six measurements. If the hole empties prior to the six measurements, refill and continue recording until you have recorded six measurements.

9. Calculate measured infiltration rate. Refer to Table 3.3 in *Volume 3*, *Section 3.2*, for minimum infiltration rates for each type of infiltration BMP. Using the collected data, estimate the infiltration rate in inches per hour by calculating the drop in water level in inches for each hour data was collected during the infiltration test. There should be a total of six values. The lowest calculated value is the measured infiltration rate in inches per hour
10. Mark test locations on site map.

D-3.3. Small Pilot Infiltration Test (Small PIT)

The testing procedure and data analysis requirements for the Small PIT are provided below. The report for this test shall include documentation of the testing procedure, analysis and results to assess infiltration feasibility and an explanation of the correction factor used to determine the design infiltration rate.

The Small PIT report shall be prepared by a licensed professional. The test method may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the report.

Procedure

1. Excavate the test pit to the depth of the bottom of the proposed infiltration BMP. In the case of bioretention, excavate to the lowest estimated elevation at which the imported soil mix will contact the underlying soil. For permeable pavement, excavate to the elevation at which the imported subgrade materials, or the pavement itself, will contact the underlying soil. If the underlying soils (road subgrade) will be compacted, compact the underlying soils prior to testing. Note that the permeable pavement design guidance recommends compaction not exceed 90 to 92 percent.
2. Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.
3. The size of the bottom of the test pit shall be a minimum of 12 square feet (sf). Document the size and geometry of the test pit.
4. Install a device capable of measuring the water level in the pit during the test. This may be a pressure transducer (automatic measurements) or a vertical measuring rod (minimum 5 feet long) marked in half-inch increments in the center of the pit bottom (manual measurements).
5. Use a rigid pipe with a splash plate or some other device on the bottom to convey water to the bottom of the pit and reduce side-wall erosion and excessive disturbance of the pit bottom. Excessive erosion and bottom disturbance may result in clogging of the infiltration receptor and yield lower than actual infiltration rates.
6. Pre-soak period: Add water to the pit so that there is standing water for at least 6 hours. Maintain the pre-soak water level at least 12 inches above the bottom of the pit.
7. Steady state period:
    a. At the end of the pre-soak period, add water to the pit at a rate that will maintain a depth of 12 inches above the bottom of the pit over a full hour.

b. Every 15 minutes during the steady state period, record the cumulative volume and instantaneous flow rate (in gallons per minute) necessary to maintain the water level at the same point (the design ponding depth) on the measuring rod or pressure transducer readout.

8. Falling head period: After 1 hour, turn off the water and record the rate of infiltration (the drop rate of the standing water) in inches per hour every 15 minutes using the pressure transducer or measuring rod data, for a minimum of 1 hour or until the pit is empty.

9. Within 24 hours after the falling head period, over-excavate the pit to determine if the test water is mounded on shallow restrictive layers or if it has continued to flow deep into the subsurface. The investigation depth varies depending on the type of subsurface investigation required (refer to Table 3.1 in *Volume 3*, *Section 3.2*) and the seasonal timing of the geotechnical exploration conducted to evaluate clearance. Minimum investigation depths are provided in *Section D-2*.

Data Analysis

Using the established steady state flow rate, calculate and record the measured infiltration rate in inches per hour. Use the falling head data to confirm the measured infiltration rate calculated from the steady state data.

Adjust the measured infiltration rate using the correction factor (CF) described in *Section D-4* to estimate the design infiltration rate.

D-3.4. Large Pilot Infiltration Test (Large PIT)

A Large PIT will more closely simulate actual conditions for the infiltration BMP than a Small PIT and may be preferred at the discretion of the licensed professional if not already required per Table 3.1 in *Volume 3*, *Section 3.2*. The testing procedure and data analysis requirements for the Large PIT are provided below. The report for this test shall include documentation of the testing procedure, analysis and results to assess infiltration feasibility and an explanation of the correction factor used to determine the design infiltration rate.

The Large PIT report shall be prepared by a licensed professional. The test method may be modified due to site conditions if recommended by the licensed professional and the reasoning is documented in the report.

Procedure

1. Excavate the test pit to the depth of the bottom of the proposed infiltration BMP. In the case of bioretention, excavate to the lowest estimated elevation at which the imported soil mix will contact the underlying soil. For permeable pavement, excavate to the elevation at which the imported subgrade materials will contact the underlying soil. If the underlying soils (road subgrade) will be compacted, compact the underlying soils prior to testing. Note that the permeable pavement design guidance recommends compaction not exceed 90 to 92 percent.

2. Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.

3. The size of the bottom of the test pit should be as close to the size of the planned infiltration BMP as possible, but not less than 32 square feet in area (100 square feet is

recommended). Where water availability is an issue, smaller areas may be considered, as determined by the licensed professional. Document the size and geometry of the test pit.

Refer to Steps 4 through 9 as described in the Small PIT procedure above.

Data Analysis

Refer to the data analysis guidance for small PITs in *Section D-3.3*.

D-3.5. Deep Infiltration Test

The design infiltration capacity for deep infiltration shall be determined by performing a constant-rate infiltration test followed by a falling-head infiltration test. The Deep Infiltration Test report shall include documentation of the testing procedure, analysis and results to assess infiltration feasibility and an explanation of the correction factor used to determine the design infiltration capacity of the proposed BMP.

The Deep Infiltration Test report shall be prepared by a licensed professional. The test method may be modified due to site conditions if recommended by the licensed geotechnical engineer or hydrogeologist and the reasoning is documented in the report.

Procedure

1. Perform the test by adding water (obtained from a potable water source) to the test well to maintain a constant hydraulic head in the well. The specific target hydraulic head will depend on the subsurface conditions, the design and construction of the test well, and the project goals. As a starting point, it is recommended to saturate the entire screened portion of the test well that is within the target soil zone.
2. Monitor the flow rate with a flow meter or other method that is capable of measuring flow to within 5 percent of the total flow rate.
3. Monitor water levels in the test well with a pressure transducer and datalogger on a maximum of 5-minute intervals.
4. Add water until the rate of water added is constant, or for a minimum of 4 hours.
5. Once a constant rate is achieved, the test is complete. Begin the falling head portion of the test. Monitor water levels during the falling head test until the water level has fallen to a minimum of 5 percent of the total head targeted during the constant rate portion of the test.
6. In addition to the required wells, monitor groundwater elevations in nearby monitoring wells as available.

Data Analysis

The test data shall be evaluated by a licensed hydrogeologist experienced in the analysis of well hydraulics and well testing data. As a result of the likely variability in soil conditions, specific methods for analysis of the data are not provided. It is the responsibility of the professional analyzing the data to select the appropriate methodology.

D-4. Infiltration Rate Correction Factor

Measured infiltration rates described in *Section D-3* shall be reduced using correction factors to determine the design infiltration rates. The determination of a design infiltration rate from in-situ infiltration test data involves a considerable amount of engineering judgment. Therefore, when determining the final design infiltration rate, the licensed professional shall consider the results of both soil subsurface material conditions and in-situ infiltration tests results. In no case shall the design infiltration rate exceed 10 inches per hour.

Design Infiltration Rate = Measured Infiltration Rate x CF

A correction factor (CF) is applied to the measured infiltration rate to calculate the design infiltration rate. The design infiltration rate shall be used when sizing infiltration BMPs using the design criteria outlined in *Volume 3*, *Section 5.4*.

D-4.1. Simple Infiltration Test

A CF of 0.5 shall be applied to the measured infiltration rate to calculate the design infiltration rate.

D-4.2. Small and Large PITs

A CF of 0.5 must be used for all projects unless a lower value is warranted by site conditions, as recommended and documented by a licensed professional, and shall not be less than 0.2. In determining an appropriate CF, the following criteria shall be considered and are described below:

- Site variability and number of locations tested
- Uncertainty of test method
- Degree of influent control to prevent siltation and bio-buildup

<u>Site variability and number of locations tested</u> — This criterion depends on the level of uncertainty that adverse subsurface conditions may exist. The number of locations tested must be sufficient to represent the conditions throughout the BMP site. The following are examples of how site variability and number and locations of the tests may affect uncertainty:

- The subsurface conditions are known to be uniform based on previous exploration and site geological factors, one PIT may be adequate to justify that the uncertainty for that site is low.
- High variability may exist due to subsurface conditions (such as buried stream channels) identified on previous explorations and site geological factors. In these cases, even with many explorations and several PITs, the level of uncertainty may still be high.
- High uncertainty could also be assigned where conditions have a more typical variability, but few explorations and only one PIT is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Uncertainty of test method — This criterion represents the accuracy of the infiltration test method used. Larger scale tests are assumed to produce more reliable results (i.e., the Large PIT is more certain than the Small PIT).

Degree of influent control to prevent siltation and bio-buildup — High uncertainty for this criterion may be justified under the following circumstances:

- If the infiltration BMP is located in a shady area where moss buildup or litter fall buildup from the surrounding vegetation is likely and cannot be easily controlled through long-term maintenance.
- If there is minimal pre-treatment, and the influent is likely to contain moderately high total suspended solids (TSS) levels.

If influent into the BMP can be well controlled such that the planned long-term maintenance can easily control siltation and biomass buildup, then low uncertainty may be justified for this criterion.

D-5. Groundwater Monitoring

Groundwater monitoring wells (including the minimum subsurface investigation depth) shall be installed as determined in *Sections D-2.3* through *D-2.6* under the direct supervision of a licensed professional. The minimum number of groundwater monitoring wells, duration of monitoring, and frequency of monitoring are summarized in Table 3.1 and Table 3.2 in *Volume 3*, *Section 3.2*. A report shall be developed that is prepared by a licensed professional and includes a map detailing the locations of the monitoring wells relative to the project site and a description of the groundwater levels relative to the investigation depth and vertical separation requirements provided in *Section D-2*.

Groundwater monitoring is not required in the following situations when using shallow infiltration BMPs:

- Elevation data measured at project monitoring wells shows groundwater levels within the investigation depth and vertical separation requirements summarized in Section D-2
- Available groundwater elevation data within 50 feet of the proposed infiltration BMP shows the highest measured groundwater level to be at least 10 feet below the bottom of the proposed infiltration BMP or if the initial groundwater measurement is more than 15 feet below the bottom of the proposed infiltration facility

In these situations, no further investigation is required to meet on-site, flow control, or water quality treatment requirements. These exceptions do not apply to deep infiltration BMPs.

D-6. Characterization of Infiltration Receptor

The infiltration receptor is the unsaturated and saturated soil receiving stormwater from an infiltration BMP. Thresholds for triggering characterization of the infiltration receptor are summarized in Table 3.1 and Table 3.2 in *Volume 3*, *Section 3.2*.

Assessment and documentation by a licensed hydrogeologist characterizing the infiltration receptor shall include the following elements:

- Depth to groundwater and to hydraulically-restrictive material
- Seasonal variation of groundwater table based on well water levels and observed mottling of soils

- Existing groundwater flow direction and gradient
- Approximation of the lateral extent of infiltration receptor
- Volumetric water holding capacity of the infiltration receptor soils. The volumetric water holding capacity is the storage volume in the soil layer directly below the infiltration BMP and above the seasonal high groundwater mark, or hydraulically-restrictive material.
- Horizontal hydraulic conductivity of the saturated zone to assess the aquifer's ability to laterally transport the infiltrated water

Note: As part of the infiltration receptor characterization for deep infiltration wells, the pretreatment requirements shall be evaluated as in the UIC Guidance Manual (Ecology 2006).

D-7. Groundwater Mounding and Seepage Analysis

Infiltration of large volumes of water may result in a rise in the water table or development of a shallow water table on hydraulically-restrictive materials that slow the downward percolation of water. If this mounding of water is excessive, the infiltration BMP may become less effective and/or adjacent structures or facilities may be impacted by the rising water table. In addition, if the infiltration BMP is adjacent to a slope, slope stability may be decreased.

Thresholds for triggering groundwater mounding and seepage analysis are summarized in Table 3.1 and Table 3.2 in *Volume 3, Section 3.2*.

The mounding analysis shall evaluate the impact of the infiltration BMP on local groundwater flow direction and water table elevations and determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites. If the results of the mounding analysis indicate that adverse conditions could occur, as determined by a licensed professional, the infiltration BMP shall not be built.

If infiltration on the site may result in shallow lateral flow (interflow), the conveyance and possible locations where that interflow may re-emerge shall be assessed by a licensed hydrogeologist.

For deep infiltration BMPs, the following shall also be evaluated:

- Extent of groundwater mounding under the design flow rate
- Potential impacts from the groundwater mounding to:
  - Deep infiltration BMP performance
  - Surrounding infrastructure, including, but not limited to, infiltration BMPs, drainage facilities, foundations, basements, utility corridors, or retaining walls
  - Offsite slope stability
  - Down-gradient existing contamination plumes

Several analytical tools are available to evaluate potential groundwater mounding beneath infiltration BMPs. These include both analytical and numerical groundwater flow software. In general, public domain software programs shall be used (such those initially authored by the United States Geological Survey (USGS) or the Environmental Protection Agency).

The software program MODRET is considered a standard tool for evaluating infiltration BMPs, and is recommended in Ecology's Stormwater Management Manual for Western Washington. Although MODRET is a proprietary computer program, it is readily available for purchase and is based on USGS software. However, MODRET is limited to evaluation of a single BMP at a time, and generally will not be suitable for evaluating clustered BMPs.

The preferred program for simulating groundwater mounding beneath infiltration BMPs is the USGS-based program MODFLOW. MODFLOW can be used to simulate a wide range of aquifer conditions and geometries. The primary limitation with MODFLOW is that most versions of the program do not simulate the movement of water through the unsaturated zone, which would normally be expected to slow the downward movement of water and allow for lateral spreading of water before reaching the water table. Instead, infiltrating water is input directly to the water table. For a shallow water table or perching layer this limitation should not greatly influence the overall results of the mounding simulation and represents a more conservative approach to simulating mounding.

Licensed hydrogeologists with formal training and experience in developing groundwater flow models shall conduct these analyses. It should also be noted that groundwater models do not provide specific answers, but are tools to help understand the behavior of groundwater systems under a variety of conditions. The results of any model should be used in the context of the overall goal of the project and be applied as warranted by the risk tolerance of the owner.

D-7.1. Data Requirements

Data requirements for development of a groundwater mounding model include:

- Soil and groundwater conditions
- Aquifer parameters (e.g., hydraulic conductivity and specific yield)
- Aquifer geometry
- Pre-infiltration hydraulic gradient
- Flow rate from infiltration BMPs

Many of the data inputs for the groundwater mounding model should be available in the vicinity of the infiltration BMPs from the subsurface investigation and infiltration testing performed for design of the BMPs. Outside the area of the infiltration BMPs, data may be sparse and may need to be interpolated from regional data. The extent of the modeled area should be such that the edges of the model do not influence the data unless an actual boundary exists, such as Elliott Bay or Lake Washington.

In the absence of local information regarding the groundwater gradient and/or the distribution of hydraulic restrictive layers, mounding analyses should consider the general slope of the site and surrounding sites, as the general slope is likely indicative of the direction of interflow originating from infiltration BMPs and the regional hydraulic gradient.

Aquifer parameters shall be estimated based on knowledge of local soil types and from grain size distribution of the soil samples collected as part of the subsurface investigation and testing program. In general, groundwater flow models tend to be most sensitive to variations in hydraulic conductivity values. Obtain hydraulic conductivity values from field testing of the infiltration receptor soils using standard industry methods.

D-7.2. Analysis Procedures

The initial step for any groundwater modeling analysis is the development of a conceptual model of the groundwater system. The conceptual model should describe the anticipated groundwater flow system including the data requirements described above, direction and rate of groundwater flow, potential model boundaries, and approach for simulating infiltration. The conceptual model provides the basis for constructing the computer model.

Because of the limited available data necessary for model inputs, a parametric analysis shall be performed whereby model inputs, especially aquifer parameters, are varied over a range of values to evaluate the potential impact on the mounding results. The range values shall be based on known variability in the parameter and experience with similar soils in the area by the licensed professional developing the model.

The following ranges of aquifer parameters shall be used in the parametric analysis:

- Hydraulic conductivity: one order of magnitude (e.g., + and – a power of 10) for each receptor soil
- Aquifer thickness: plus or minus 50 percent of the known values
- Specific yield: minimum range of 0.05 to 0.2

If known field conditions warrant, increase the above ranges as necessary.

In general, multiple infiltration scenarios will need to be simulated to evaluate potential mounding below the infiltration BMPs. For example, both short-term peak storm events and long-term seasonal precipitation should be evaluated. Additional scenarios may include a series of short-term high precipitation events. Although the actual events that need to be simulated will depend on subsurface conditions, number and types of infiltration BMPs, and potential risk factors, as a minimum the following scenario is required:

- A typical wet season (November through April) based on average monthly precipitation followed by a single-event rainfall modeling of the back-loaded long-duration storm for the 100-year recurrence interval, using data from the closest rain gage.

The licensed hydrogeologist performing the mounding analysis should use professional judgment and experience to potentially modify the above scenario or add additional scenarios on a project specific basis, as needed.

As additional soil and groundwater information is collected during construction, testing, and operation of the infiltration BMP, the mounding analysis should be revised and refined to incorporate any new information. If groundwater monitoring indicates results inconsistent with the findings of the mounding analysis, in the opinion of a licensed hydrogeologist, the model should be re-evaluated. The re-evaluation should include simulation of the precipitation events prior to the observed groundwater monitoring data.

D-8. Acceptance Testing

Acceptance testing is required for shallow infiltration BMPs receiving runoff from greater than 5,000 square feet of impervious surface area, including:

- Infiltration Trenches
- Drywells

- Infiltration Bioretention (with and without underdrains)
- Infiltration Basins
- Infiltration Chambers

It may also be required for infiltration BMPs receiving runoff from a smaller contributing area, if required by the Director. Refer to *Volume 3*, *Section 3.2*.

All permeable pavement facilities and surfaces are required to perform acceptance testing per Wearing Course Subsection in *Volume 3, Section 5.4.6.5*. Acceptance testing of deep infiltration BMPs shall consist of the infiltration testing for deep infiltration wells described in *Section D-3.5* performed on the completed permanent wells.

D-8.1. Acceptance Criteria Definitions

The purpose of acceptance testing is to confirm the constructed infiltration BMP will perform in accordance with design. Infiltration acceptance criteria include:

1. **Subsurface Condition Observations:** The observed soil and groundwater conditions in the excavated BMP shall exhibit no adverse conditions that will result in:
    a. The maximum pool drawdown time to be exceeded. Refer to Criterion 4 (Pool Drawdown Time).
    b. For BMPs intended to provide flow control or onsite stormwater management, a long-term infiltration rate lower than the design rate.
    c. For BMPs intended to provide water quality treatment, a long-term infiltration rate that is higher than the design rate.

    Observation and confirmation of the subsurface conditions shall be conducted by a licensed professional who is familiar/experienced with the field infiltration testing performed during design.

2. **Underlying Soil Infiltration Rate:** For BMPs without underdrains which rely on soil infiltration, the underlying soil infiltration rate achieved after construction of the infiltration BMP and adjusted to determine a long-term rate using correction factors shall be:
    a. High enough to ensure that the maximum pool drawdown time is not exceeded. Refer to Criterion 4 (Pool Drawdown Time).
    b. Equal to or greater than the design infiltration rate, where flow control or onsite stormwater management is intended.
    c. Less than or equal to the design infiltration rate where water quality treatment is intended.
3. **Bioretention Soil Infiltration Rate:** When water is applied to the infiltration BMP, it shall readily infiltrate into the bioretention soil and drain downward. If water ponds and does not drain downward, compaction or otherwise compromised bioretention soil is indicated.
4. **Pool Drawdown Time:** The surface pool drawdown time for maximum ponding depth shall be less than 24 hours after water has ceased being added to the BMP.

D-8.2. Acceptance Testing Requirements

Acceptance testing is intended to evaluate the post-construction infiltration performance of the BMP; therefore, timing of the testing during construction is important and shall be performed after all construction activities that could impact the targeted infiltration soil are completed. Activities such as compaction and contamination by finer soil particles can reduce the infiltration rate of bioretention and underlying soil. Water that runs off into the BMP that is not clear and contains sediment can reduce the infiltration rate of the BMP.

Infiltration acceptance testing shall be performed up to three steps. Steps 1 and 2 are recommended but optional. Step 3 is required.

Step 1. Observation of the Subsurface Conditions (optional)

During construction of the BMP, it is recommended that a licensed professional who is familiar/experienced with the field infiltration testing performed during design be on site to observe subsurface soil conditions and confirm the underlying soil conditions are consistent with those observed during the design infiltration testing. Refer to Criterion 1 (Subsurface Condition Observations) in *Section D-8.1*. If the soil conditions are observed to be consistent with design observations and testing, proceed to Step 3. If soil conditions are not consistent with design observations and testing, it is recommended to proceed to Step 2.

Step 2. Infiltration Testing of Differing Soil Conditions (optional)

If the subsurface soil conditions are observed to be different than design observations and testing, and the BMP is designed to rely on infiltration into the underlying soil, infiltration testing is recommended immediately (prior to backfilling the BMP) to determine if the underlying soil meets the design infiltration rate. For BMPs with multiple cells, one test in a representative cell per soil type shall be required. Although it is preferred that acceptance testing be performed in a similar manner as the design infiltration testing, specific procedures can be based on the professional judgement of the licensed professional who performed the testing during design. If the infiltration rate adjusted to a long-term rate using correction factors meets Criterion 2 (Underlying Soil Infiltration Rate) in *Section D-8.1*, proceed to Step 3. If the rate adjusted to a long-term rate does not meet Criterion 2 (Underlying Soil Infiltration Rate) in *Section D-8.1*, retesting or redesign and reconstruction of the BMP shall be required.

Step 3. Acceptance Testing of Backfilled BMP (required)

Testing in this step shall be performed once the BMP has been backfilled, but prior to planting, if applicable:

- For BMPs without underdrains which rely on underlying soil infiltration, the acceptance test shall consist of testing the drawdown time to confirm it is less than or equal to the design ponding criteria. Refer to Criterion 4 (Pool Drawdown Time) in *Section D-8.1*. For BMPs with multiple cells, one test in a representative cell per soil type shall be required. If the acceptance test fails and the BMP performance is not equal to or better than the performance required by the design (refer to Criteria 3 and 4 [Bioretention Soil Infiltration Rate and Pool Drawdown

Time] in *Section D-8.1*), then retesting or redesign and reconstruction of the BMP shall be required.

- For BMPs with an underdrain, acceptance testing shall verify the surface pool drawdown time for the maximum ponding depth meets the ponding criteria of the design or better. Refer to Criteria 3 and 4 (Bioretention Soil Infiltration Rate and Pool Drawdown Time) in *Section D-8.1*. If the acceptance test fails and the BMP performance is not equal to or better than the performance required by the design, then retesting or redesign and reconstruction of the BMP shall be required.

A monitoring well or piezometer is needed for Step 3 to observe water levels within the BMP if the BMP does not have an underdrain. For drywells, infiltration trenches and bioretention with an underdrain, the cleanout or observation port may be used to observe water levels if it allows accurate measurement of underlying soil infiltration. Drilling rigs or other mechanical methods are prohibited within the BMP footprint during construction; therefore, wells or piezometers must be placed using hand methods. The base of the well or piezometer shall be placed at the bottom of the BMP directly on top of the infiltrating soil.

D-8.3. Acceptance Testing Plan

An acceptance testing plan shall be prepared and submitted to the City signed and stamped by a licensed professional. The acceptance testing plan shall include, but is not limited to:

- A site plan showing and listing the proposed infiltration BMPs requiring acceptance testing.
- Measured infiltration rates, correction factors and infiltration testing backup data relied on for design.
- Infiltration testing procedures and specifications including an estimate of the amount of water, duration, rate to apply water to the BMP required for conducting the test and potential source of water.
- Specifications for monitoring wells, piezometer, and/or observation ports to be install for testing and observation.
- Procedure for submittal and acceptance of results.

The acceptance testing plan shall be updated and resubmitted as required based on review by the City.

D-8.4. Acceptance Testing Submittal

The results of the acceptance testing shall be summarized in a memorandum signed and stamped by a licensed professional and submitted for final approval. The memorandum shall include:

- The infiltration rates, correction factors and infiltration testing backup data relied on for the design.
- The measured infiltration rates, correction factors and infiltration testing backup data resulting from the acceptance testing.
- A discussion of subsurface soil condition observations performed in Step 1. State why additional testing of subsurface conditions were or were not required.

- A discussion comparing the results of the Step 2 acceptance infiltration test (if performed) to the results of the design infiltration test. State whether the results of this test indicate the BMP will perform as intended during design.
- A discussion comparing the results of the Step 3 acceptance infiltration test to the results of the design infiltration test. State whether the results of this test indicate the BMP will perform as intended during design.
- If the acceptance testing is performed during the dry season, the licensed professional shall make a statement regarding the expected impact to the measured infiltration rate and how the BMP is expected to perform in the wet season.

City of Seattle

Appendix E - Additional Design Requirements and Plant Lists

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

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Tables

Figures

Appendix E includes additional design requirements for the following:

- Flow Control Structures (*Section E-1*)
- Flow Splitters (*Section E-2*)
- Flow Spreaders (*Section E-3*)
- Level Spreaders (*Section E-4*)
- Pipe Slope Drains (*Section E-5*)
- Outlet Protection (*Section E-6*)
- Liners (*Section E-7*)
- Geotextiles (*Section E-8*)
- Plant Lists for Bioretention, Biofiltration Swales, Sand Filters, and Wet Ponds (*Section E-9*)
- Drywell Sizing Tables (*Section E-10*)

E-1. Flow Control Structures

Flow control structures are catch basins or maintenance holes with a restrictor device for controlling outflow from a BMP to meet the desired performance.

The flow control device usually consists of two or more orifices and/or a weir section sized to meet performance requirements. Standard flow control device details are shown in Figures E.1, E.2, and E.3 and in City of Seattle Standard Plan 272a.

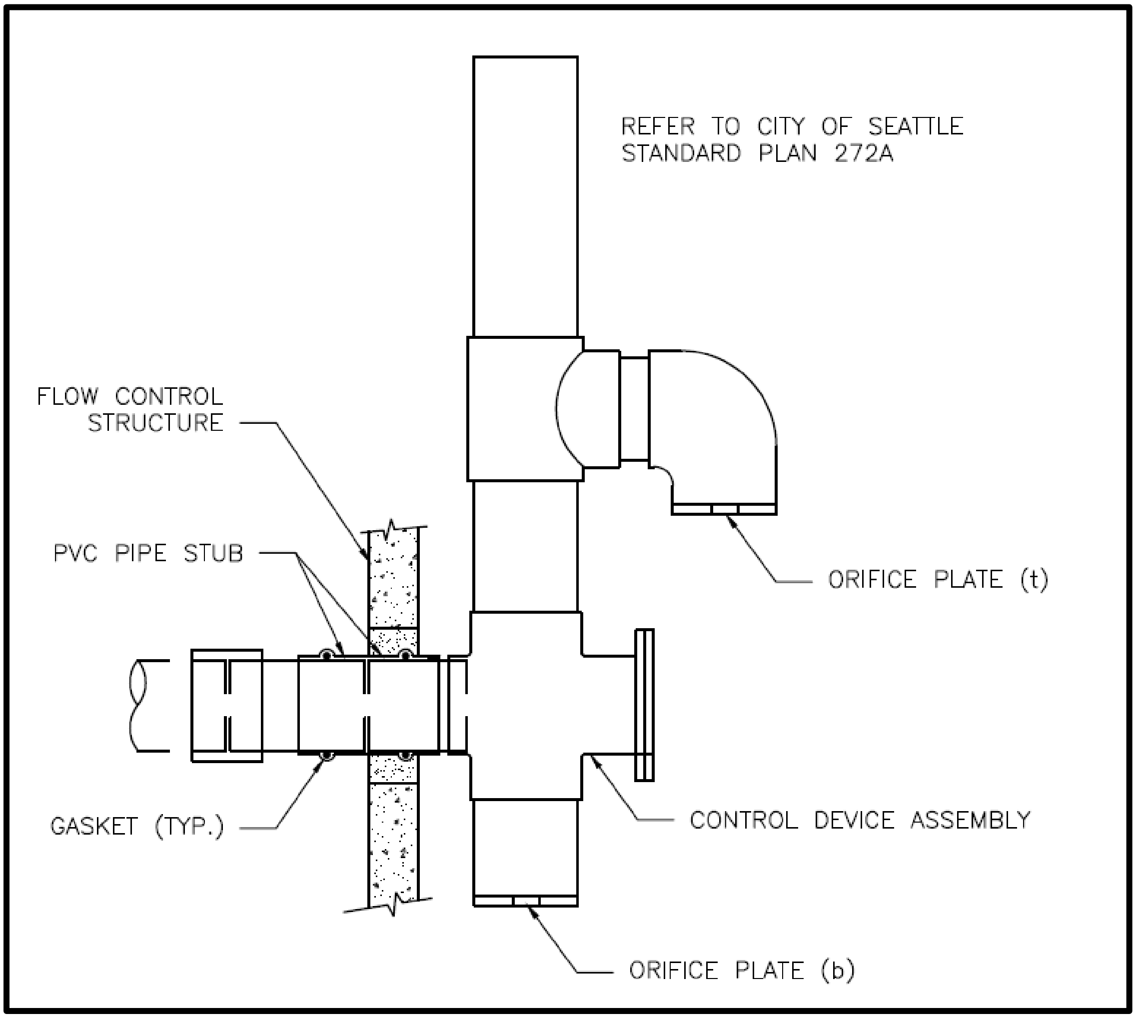
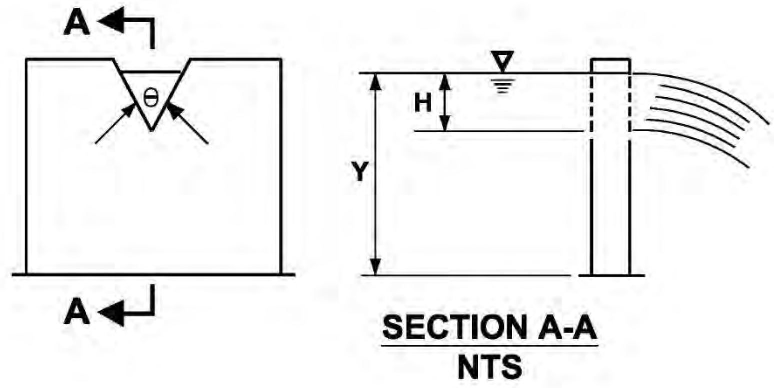


Figure E.1. Simple Orifice.



$$Q = C_d(\mathrm{Tan}\ \theta / 2)Y^{\frac{5}{2}}, \text{ in cfs}$$

Where values of C_d may be taken from the following chart:

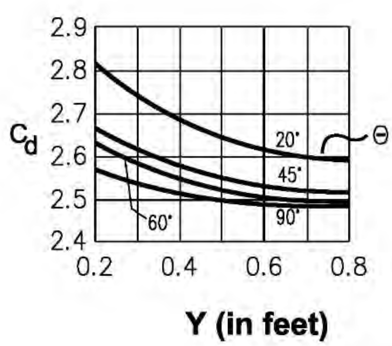
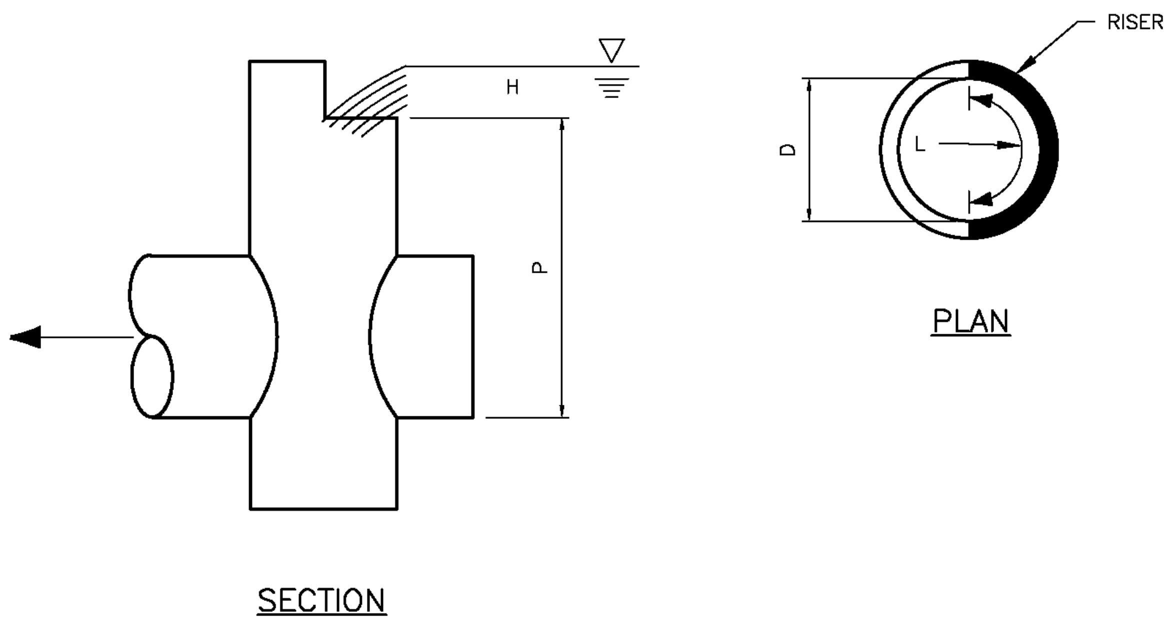


Figure E.2. V-Notch, Sharp-Crested Weir.



Q = C (L − 0.2H)H^3/2
WHERE
Q = FLOW (CFS)
C = 3.27 + 0.40 H/P (FT)
H, P ARE AS SHOWN ABOVE
L = LENGTH (FT) OF THE PORTION OF THE RISER CIRCUMFERENCE
AS NECESSARY NOT TO EXCEED 50% OF THE CIRCUMFERENCE
D = INSIDE RISER DIAMETER (FT)
NOTE THAT THIS EQUATION ACCOUNTS FOR SIDE CONTRACTIONS BY
SUBTRACTING 0.1H FROM L FOR EACH SIDE OF THE NOTCH WEIR.

Figure E.3. Rectangular Notch, Sharp-Crested Weir.

General Requirements

Flow control structures shall comply with the specifications outlined in the City of Seattle's Standard Plans No. 270 and 272A. Additional general requirements are presented below.

Plans submitted for a permit shall include:

- Flow control structure rim elevation
- Storage pipe invert elevation
- Outlet pipe invert elevation
- Elevation at the top of the storage pipe
- Elevation at the top of the overflow pipe
- Orifice diameter(s)
- Orifice elevation(s)

For ponding BMPs, backwater effects shall be included in designing the height of the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

For regionally sized detention BMPs, non-standard orifice orientation and orifice/weir and gate combinations for flow throttling may be used to meet both stormwater and operational requirements. These general requirements are not meant to be restrictive when a flow control need beyond what is discussed here can be demonstrated.

Access

The following access requirements apply to control structures:

- Access shall be provided to the flow control structure from the ground surface with a three-bolt locking maintenance hole ring and cover (refer to SDCI Director's Rule 2011-4, Requirements for Design & Construction of Side Sewers). Rim elevations shall match proposed finish grade. A rectangular cover, or a cover that allows water to enter through the top of the flow control structure, shall not be used. The ring and cover shall be set so the flow control device or the ladder is visible at the edge of the access opening.
- The inside diameter of the flow control structure shall be at least 4 feet to allow maintenance and repair access, and to accommodate stormwater overflow.
- Maintenance holes and catch basins shall meet the OSHA and WISHA confined space requirements, which include, but are not limited to, clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser under the access lid.
- The flow control device shall not be Corrugated Metal Pipe (CMP). The mounting straps and the outlet adapter shall be installed in a manner that will make the flow control device easily removable for maintenance, repair, or replacement. The flow control device shall be designed and located under the maintenance hole ring and cover for inspection from the surface. The outlet pipe adapter may be a plastic, bell-end pipe, or a plastic coupling with rubber gaskets. The outside of the pipe or coupling shall be sanded, epoxy coated, and sand impacted to bond with the flow control structure.

Design Criteria

Multiple Orifice Restrictor

In most cases, control structures only need two orifices: one at the bottom and one near the top of the riser, oriented horizontally. Additional orifices may best utilize detention storage volume in a few cases.

Design requirements for multiple orifice flow restrictors are presented below.

- The minimum allowable orifice diameter is 0.5 inch for underground tanks or vaults and 0.25 inch for aboveground cisterns. In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, underground weirs or orifices shall not be reduced to less than 0.5-inch length or diameter in an attempt to meet the performance standards.

- In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements.

Weir Restrictor

Design requirements for weir flow restrictors are presented below.

- A sharp crested overflow weir shall be used to provide for overflow of the detention BMP and should be analyzed for the developed 100-year peak flow discharge (Figure E.4).
- A notch weir may be used to restrict flows and replace a top orifice.

Flow Control Device Sizing

Orifices

Flow-through orifice plates in the standard tee section or down-turned elbow may be approximated by the general equation:

$$Q = CA\sqrt{2gh}$$

where Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = gravity (32.2 ft/sec^2)

Figure E.4 illustrates this simplified application of the orifice equation.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches.

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}}$$

where *d* = orifice diameter (inches)
Q = flow (cfs)
h = hydraulic head (ft)

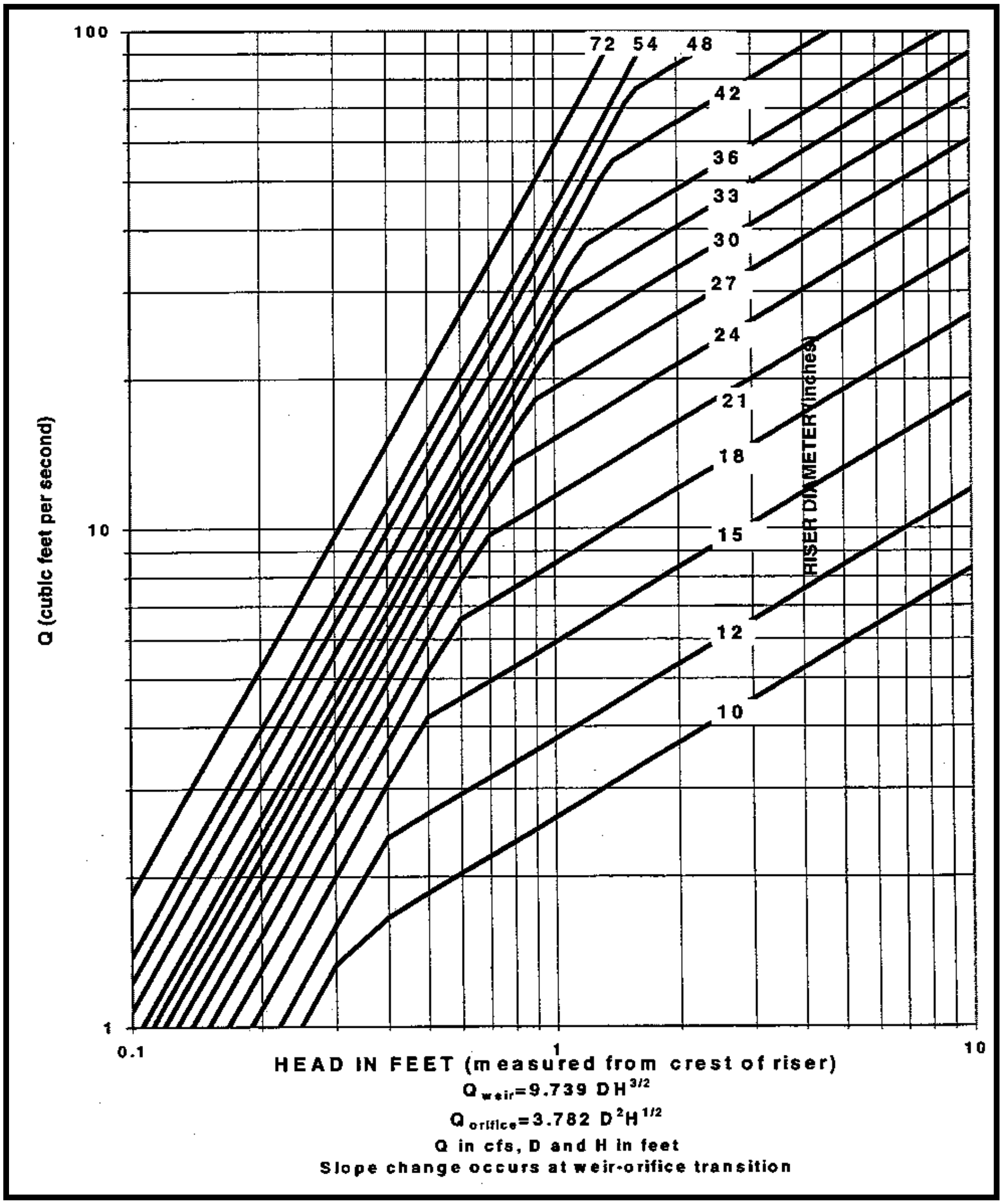


Figure E.4. Riser Inflow Curves.

Riser Overflow

The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design shall still provide for overflow of the developed 100-year peak flow assuming all orifices are plugged. The nomograph in Figure E.4 can be used to determine the head (in feet) above a riser of given diameter and for a given flow. For design requirements on overflows, refer to *Volume 3, Section 4.3.4*.

E-2. Flow Splitters

Flow splitters are typically structures with baffles, weirs, or orifice controls. Two examples of maintenance hole flow splitters are shown in Figure E.5 and Figure E.6. Other equivalent designs for splitting flows may also be acceptable.

General Design Criteria

The top of the weir shall be located at the water surface for the design flow. Flows modeled using a continuous simulation model shall be at a 15-minute time step or less.

The maximum head shall be minimized for flow in excess of the water quality design flow. Specifically, flow to the treatment BMP at the 100-year water surface shall not increase the design water quality flow by more than 10 percent.

As an alternative to using a solid top plate in Figure E.6, a full tee section may be used with the top of the tee at the 100-year water surface. This alternative would route emergency overflows (if the overflow pipe were plugged) through the treatment BMP rather than generate back up from the maintenance hole.

Backwater effects shall be included in the design of standpipe height in the maintenance hole.

Materials

- The splitter baffle may be installed in a maintenance hole or vault.
- The baffle wall shall be made of reinforced concrete or another suitable material resistant to corrosion, and have a minimum 4-inch thickness.
- All metal parts shall be corrosion resistant. Examples of required materials include aluminum, stainless steel, and plastic. Zinc and galvanized materials are prohibited because of aquatic toxicity. Painted metal parts shall not be used because of poor longevity.

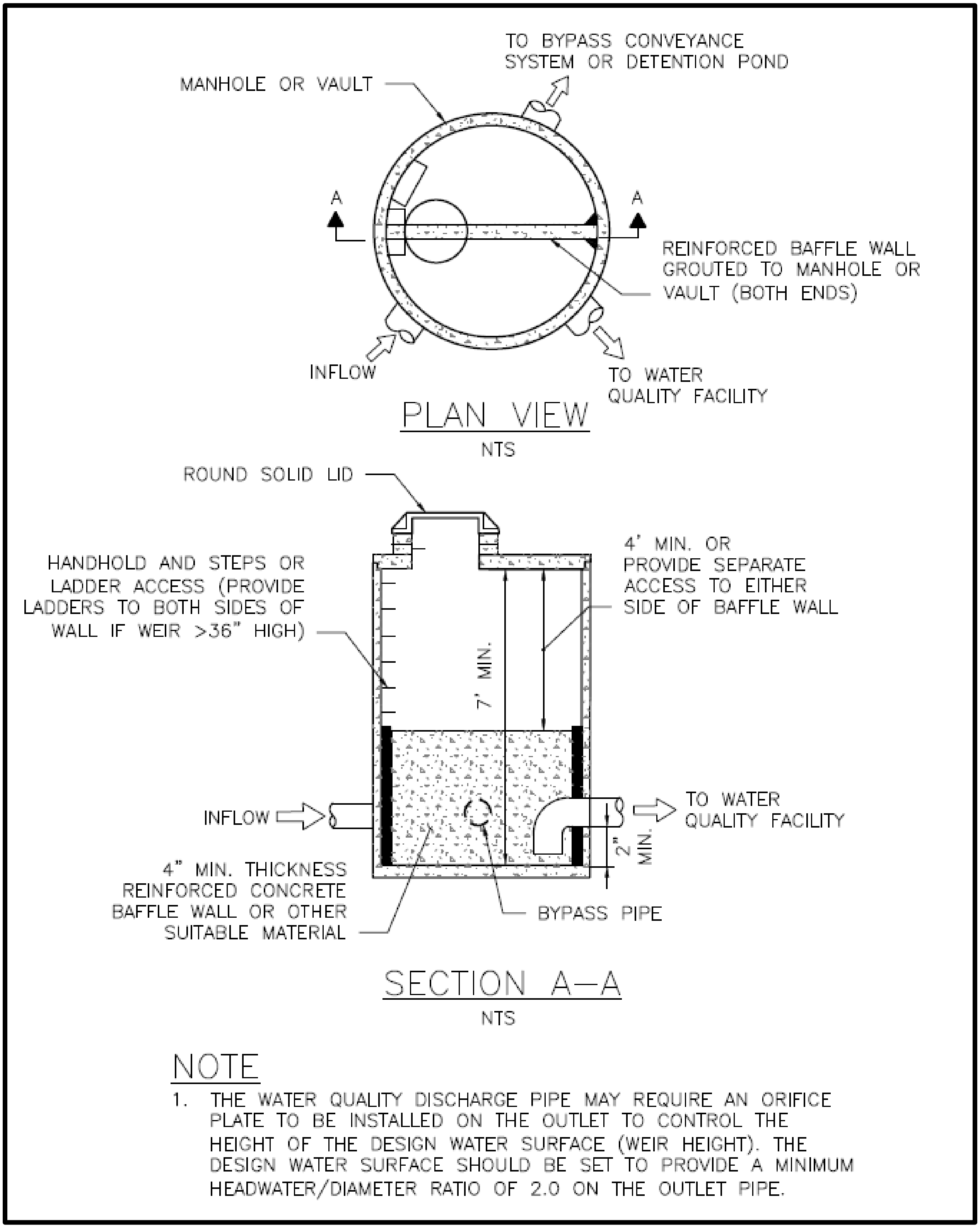


Figure E.5. Flow Splitter Example A.

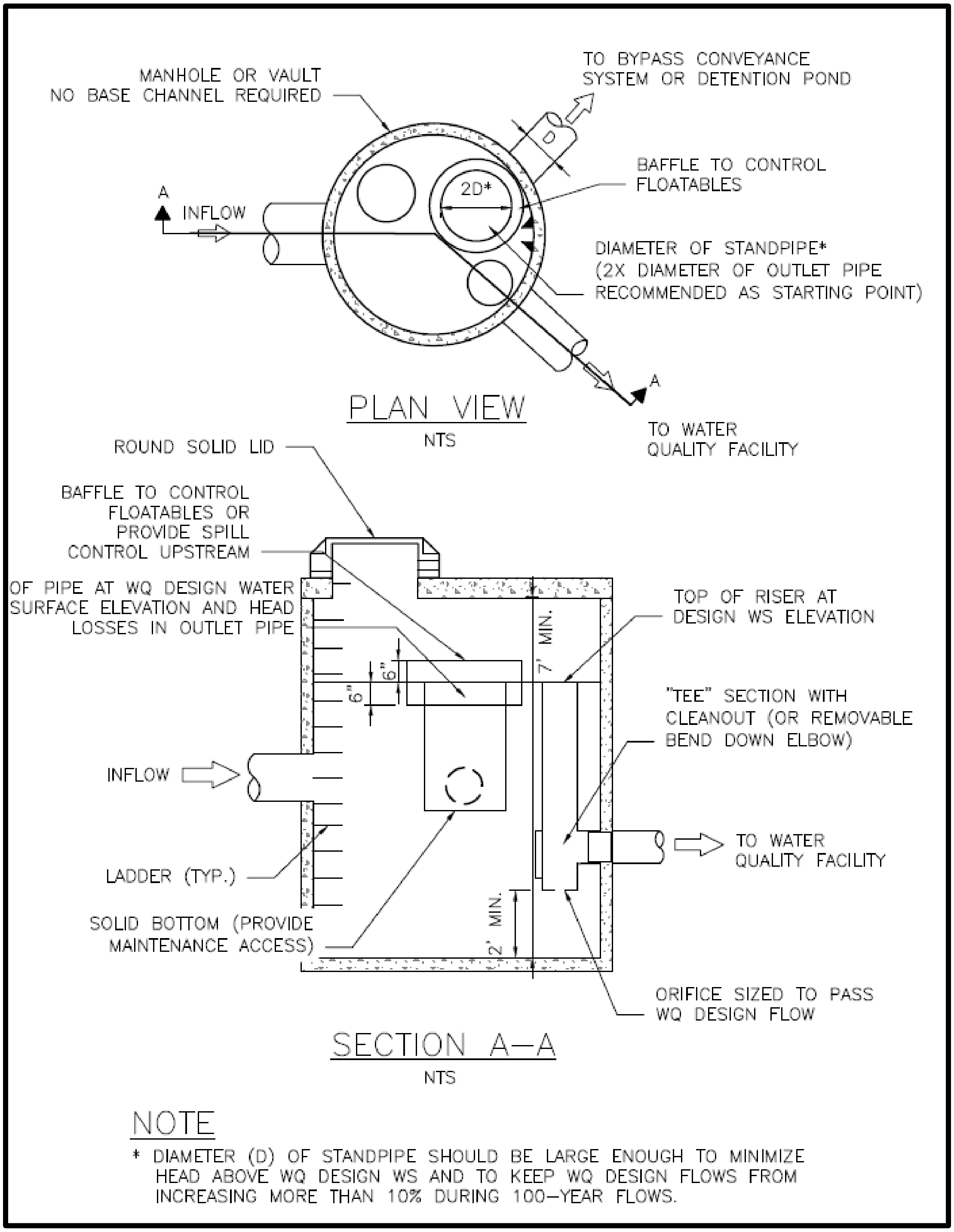


Figure E.6. Flow Splitter Example B.

E-3. Flow Spreaders

Flow spreaders uniformly spread flows across the inflow portion of non-infiltrating BMPs (e.g., sand filter, biofiltration swale, or filter strip). There are five flow spreader options presented in this section:

- Option A — Anchored plate
- Option B — Concrete sump box
- Option C — Notched curb spreader
- Option D — Through-curb ports
- Option E — Interrupted curb

Options A through C can be used for spreading flows that are concentrated. Any one of these options can be used when spreading is required by the BMP design criteria. Options A through C can also be used for unconcentrated flows, and in some cases shall be used, such as to correct for moderate grade changes along a filter strip.

Options D and E can only be used for flows that are already unconcentrated and enter a filter strip or continuous inflow biofiltration swale. Other flow spreader options are possible with prior approval by the Director.

General Design Criteria

- Where flow enters the flow spreader through a pipe, it is recommended that the pipe be submerged to the extent practical to dissipate energy as much as possible.
- For higher inflows (greater than 5 cfs for the 100-year storm), a Type 1 catch basin should be positioned in the spreader and the inflow pipe should enter the catch basin with flows exiting through the top grate of the catch basin. The top of the grate should be lower than the flow spreader plate, or if a notched spreader is used, lower than the bottom of the v-notches.

Option A – Anchored Plate

- An anchored plate flow spreader shall be preceded by a sump having a minimum depth of 8 inches and minimum width of 24 inches. If not otherwise stabilized, the sump area shall be lined to reduce erosion and to provide energy dissipation.
- The top surface of the flow spreader plate shall be level, projecting a minimum of 2 inches above the ground surface of the treatment BMP, or v-notched with notches 6 to 10 inches on center and 1 to 6 inches deep (use shallower notches with closer spacing). Alternative designs may also be considered.
- A flow spreader plate shall extend horizontally beyond the bottom width of the BMP to prevent water from eroding the side slope. The horizontal extent shall be such that the bank is protected for all flows up to the 100-year flow, or the maximum flow that will enter the treatment BMP.
- Flow spreader plates shall be securely fixed in place.

- Flow spreader plates may be made of either wood, metal, fiberglass reinforced plastic, or other durable material. If wood, pressure treated 4- by 10-inch lumber or landscape timbers are acceptable.
- Anchor posts shall be 4-inch square concrete, tubular stainless steel, or other material resistant to decay. Refer to Volume V of the Stormwater Management Manual for Western Washington (SWMMWW) for an example of an anchored plate flow spreader.

Option B – Concrete Sump Box

- The wall of the downstream side of a rectangular concrete sump box shall be level and shall extend a minimum of 2 inches above the inlet to the treatment BMP. This serves as a weir to spread the flows uniformly across the BMP inlet.
- The downstream wall of a sump box shall have "wing walls" at both ends. Side walls and returns shall be slightly higher than the weir so that erosion of the side slope is minimized.
- Concrete for a sump box can be either cast-in-place or precast, but the bottom of the sump shall be reinforced with wire mesh for cast-in-place sump boxes.
- Sump boxes shall be placed over bases that consist of 4 inches of crushed rock, 5/8-inch minus to help assure the sump box remains level. Refer to Volume V of the SWMMWW for an example of a concrete sump box flow spreader.

Option C – Notched Curb Spreader

Notched curb spreader sections shall be made of extruded concrete laid side-by-side and level. Typically, five "teeth" per 4-foot section provides good spacing. The space between adjacent teeth forms a v-notch.

Option D – Through-Curb Ports

Unconcentrated flows from paved areas entering filter strips or continuous inflow biofiltration swales can use through-curb ports (Option D) or interrupted curbs (Option E) to allow flows to enter the BMP. Through-curb ports use fabricated openings that allow concrete curbing to be poured or extruded while still providing an opening through the curb to admit water to the BMP.

Openings in the curb shall be at regular intervals and at least every 6 feet. The width of each opening shall be a minimum of 8 inches for non-right-of-way applications and a minimum of 10 inches in the right-of-way. Approximately 15 percent or more of the curb section length should be in open ports, and no port should discharge more than about 10 percent of the flow. Refer to Volume V of the SWMMWW for an example of a through-curb port flow spreader.

Option E – Interrupted Curb

Interrupted curbs are sections of curb placed to have gaps spaced at regular intervals along the total width (or length, depending on the BMP) of the treatment area. At a minimum, gaps shall be every 6 feet to allow distribution of flows into the treatment BMP before they become too concentrated. The opening shall be a minimum of 8 inches for non-right-of-way applications and a minimum of 10 inches in the right-of-way. As a general rule, no opening should discharge more than 10 percent of the overall flow entering the BMP.

E-4. Level Spreaders

Definition

A level spreader is constructed at zero percent grade and can be used to distribute concentrated runoff to sheet flow. Level spreaders can be used as either a temporary or a permanent BMP.

Purpose

To convert concentrated runoff to a thin layer of sheet flow to promote release onto a stable receiving area. For example, an existing vegetated area or a vegetated strip.

Condition Where Practice Applies

None identified for this BMP.

Planning Considerations

When properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stabilized or undisturbed area.

Particular care shall be taken to ensure that the lower downslope side (or the lip) of the structure is level and on grade. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gravel lip over which the runoff shall flow when exiting the spreader. Regular maintenance is essential for this practice.

Level spreaders shall be constructed on undisturbed areas that are stabilized by existing vegetation, or areas that have been properly stabilized in accordance with the requirements of the Construction Stormwater and Erosion Control section of this manual (*Volume 2*), and where concentrated flows will be dissipated at zero percent grade (Figure E.7).

Design Criteria

- The grade of the pipe and/or ditch for the last 20 feet before entering the level spreader shall be less than or equal to 1 percent, if feasible. If the grade is steeper, provide a flow dissipation device. The grade of the level spreader shall be zero percent to ensure uniform spreading of stormwater runoff.
- An 8-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2- to 4-inch or 0.75-inch to 1.5-inch size.

- The temporary level spreader length shall be calculated by one of the following methods:
  - o Single Event Hydrograph Method: The peak volumetric flow rate from a 10-year, 24-hour design storm with a 10-minute time step, and selecting the appropriate length from Table E-1.
  - o Continuous Simulation Method:
    - The 10-year peak flow rate as determined by an approved continuous runoff model with a 15-minute time step or less.
    - If the level spreader will be permanent, level spreader length will be determined by estimating the flow expected from the 25-year, 24-hour design storm (Q25). Alternatively, an approved continuous runoff model should be used to model the 25-year recurrence interval.
- Use multiple spreaders for higher flows.
- The depth of the spreader as measured from the lip should be at least 8 inches and should be uniform across the entire length.
- The area below the level spreader outlet shall be stabilized and have a slope of less than 11 percent.

Figure E.7. Level Spreader Prior to Backfill and Downstream Stabilization.

Table E.1. Spreader Length Based on 10-Year, 24-Hour Storm.

Q_{10} in cfs	Minimum Length (in feet)
0 to 0.1	15
0.1 to 0.2	25
0.2 to 0.3	35
0.3 to 0.4	45
0.4 to 0.5	55

cfs = cubic feet per second

Q_{10} = 10-year, 24-hour design storm

Maintenance

The spreader should be inspected regularly to ensure that it is functioning correctly. Do not place any material on the level spreader and prevent traffic from crossing over the level spreader. If the level spreader is damaged, it shall be immediately repaired.

E-5. Pipe Slope Drains

Definition

A slope drain consists of a pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized watercourse or a sediment trapping device or onto a stabilization area. It can also be used for water discharging from a flow control or treatment BMP, or to safely convey water past the toe of the slope. Pipe slope drains can be used as a temporary BMP.

Purpose

To convey concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of landslide-prone soils (Figure E.8).

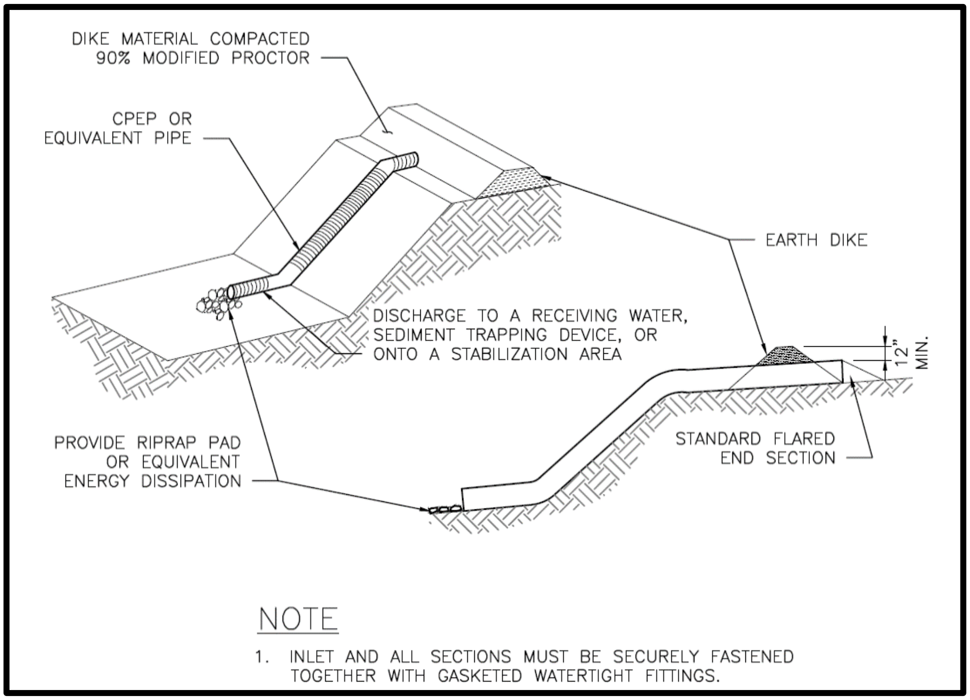


Figure E.8. Pipe Slope Drain Details.

Conditions Where Practice Applies

Pipe slope drains shall be used when conveying concentrated runoff down a steep slope has the potential to cause erosion.

Planning Considerations

There is often a lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is usually not stabilized and is particularly vulnerable to erosion. Temporary slope drains can provide valuable protection of exposed slopes until permanent drainage structures can be installed. The entrance section shall be securely entrenched, all connections shall be watertight, and the conduit shall be staked securely.

Additional protection requirements for steep slopes are included in the Environmentally Critical Area Ordinance (SMC, Section 25.09.180).

Design Criteria

- Permanent slope drains shall be designed by a licensed engineer and may have additional criteria for flow and water quality treatment requirements. Variations or alterations to the minimum BMP requirements outlined below require a licensed engineer's approval.
- Size the pipe to convey the projected flow. The capacity for temporary drains shall be sufficient to handle the flows calculated by one of the following methods:
    - Single Event Hydrograph Method: The peak volumetric flow rate calculated using a 10-year, 24-hour design storm with a 10-minute time step.
    - Continuous Simulation Method: The 10 percent annual probability flow (10-year peak flow rate) using a 15-minute time step or less, indicated by an approved continuous runoff model.

  The hydrologic analysis shall use the existing land cover condition for predicting flow rates from tributary areas outside the project limits. For tributary areas on the project site, the analysis shall use the temporary or permanent project land cover condition, whichever will produce the highest flow rates. If using WWHM, bare soil areas should be modeled as "landscaped area." Refer to *Appendix F* for additional information on stormwater modeling.

- Re-establish cover immediately on areas disturbed by installation.
- Ensure that the entrance area is stable and large enough to direct flow into the pipe.
- The entrance shall consist of a standard flared end section for culverts 12 inches and larger with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance shall be at least 3 percent.
- Pipe slope drain size should be no greater than 6 inches. Intercept flow frequently by using multiple pipe slope drains. Multiple pipes should be no closer than 10 feet.
- The soil around and under the pipe and entrance section shall be thoroughly compacted to prevent undercutting.
- The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.
- Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.
- Thrust blocks should be installed any time 90 degree bends are utilized. Depending on size of pipe and flow, these can be constructed with sand bags, straw bales staked in place, "t" posts and wire, or ecology blocks.

- Pipe needs to be secured along its full length to prevent movement. This can be done with steel "t" posts and wire. Install a post on each side of the pipe and wire the pipe to them. This should be done every 10 to 20 feet of pipe length, depending on the size of the pipe and quantity of water diverted.
- Earth dikes shall be used to direct runoff into a pipe slope drain. The height of the dike shall be at least 12 inches higher at all points than the top of the inlet pipe.
- The area below the outlet shall be stabilized with a riprap apron (refer to *Section E-6* for outlet protection).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into a sediment trapping BMP.
- Refer to the City of Seattle Standard Specifications for all material specifications (http://www.seattle.gov/util/Engineering/StandardSpecsPlans/index.htm).

Maintenance

- Check inlet and outlet points regularly, especially after heavy storms. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, reinforce the headwall with compacted earth or sand bags. The outlet point should be free of erosion and installed with appropriate outlet protection.
- For permanent installations, inspect the pipe periodically for vandalism and physical distress such as slides and wind-throw. Clean the pipe and outlet structure at the completion of construction.
- Normally the pipe slope is so steep that clogging is not a problem with smooth wall pipe; however, debris may become lodged in the pipe or at the inlet.

E-6. Outlet Protection

Definition

Energy dissipating materials or devices placed at concentrated flow outlets, such as the outlets of pipes or paved channel sections. Outlet protection can be used as either a temporary or a permanent BMP.

Purpose

To prevent scour at stormwater outlets, and to minimize the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

Condition Where Practice Applies

Outlet protection is required wherever concentrated runoff could cause scour or erosion.

Planning Considerations

None identified for this BMP.

Design Criteria

- Permanent BMPs shall be designed by a licensed engineer and may have additional criteria for flow and water quality treatment requirements. Variations and/or alterations to the minimum BMP requirements require a licensed engineer's approval.
- Protect culvert outlets from erosion by rock lining the downstream and extending up the channel sides above the maximum tailwater elevation.
- Standard wing walls, tapered outlets, and paved channels should also be considered when appropriate for permanent outlet protection.
- With low flows, grass-lined channels (refer to Ecology BMP C201) can be an effective alternative for lining material.
- Blankets (refer to BMP E1.15: Mulching, Matting, and Compost Blankets in *Volume 2*) or riprap channel lining (refer to Ecology BMP C202) provide suitable options for lining materials.
- The following guidelines shall be used for outlet protection with riprap:
  - For outlets at the base of steep slope pipes (pipe slope greater than 10 percent), use an engineered energy dissipater
  - Filter fabric or erosion control blankets should be used under riprap to prevent scour and channel erosion. Refer to BMP E1.15: Mulching, Matting, and Compost Blankets in *Volume 2*.

Maintenance

Check for evidence of erosion, scour, or channeling. Rock may need to be added if sediment builds up in the pore spaces of the outlet pad. Vegetation, erosion control blankets, or rock pads may need replacement. Partial blocking of an outlet with a protective measure is not allowed unless designed by a licensed engineer.

E-7. Liners

Liners discussed in this section are intended to reduce the likelihood that pollutants in stormwater will reach groundwater when treatment BMPs are constructed or protect surrounding areas from seepage when necessary. In addition to groundwater protection considerations, some facility types require permanent standing water for proper functioning. An example is the first cell of a wet pond.

There are three types of liners:

1. **Treatment liners** amend the soil with materials that treat stormwater before it reaches more freely draining soils. They have slow rates of infiltration, generally less than 2.4 inches per hour, but not as slow as low permeability liners. Treatment liners may use in-place native soils or imported soils, provided that the design criteria outlined below are met.
2. **Low permeability liners** reduce infiltration to a very slow rate, generally less than 0.02 inch per hour. These types of liners are often used for industrial or commercial sites with a potential for high pollutant loading in the stormwater runoff. Low permeability liners may be constructed from compacted till, clay, or concrete. Till liners are preferred because of their general resilience and ease of maintenance.
3. **Impermeable liners** prevent the transmission of water between the BMP and native soils. Impermeable liners shall be used when BMPs are constructed in areas where infiltration is not permitted or is discouraged (e.g., landslide-prone areas or in contaminated soils). Impermeable liners shall be constructed from geomembrane.

Table E-2 shows the type of liner required for use with various treatment BMPs (detention, non-infiltrating, and pretreatment BMPs). Other liner configurations may be used with prior approval from the Director.

Liners shall be placed over the bottom and/or sides of the BMP as indicated in Table E-2.

When placing a liner for water quality treatment, areas above the treatment volume that are required to pass flows greater than the water quality treatment flow (or volume) need not be lined. However, the lining shall be extended to the top of the interior side slope and be anchored if it cannot be permanently secured by other means.

Table E.2. Lining Types Required by BMP Type.

BMP	Area to be Lined	Type of Liner Required
Presettling basin	Bottom and sides	Low permeability liner, treatment liner, or impermeable liner
Wet pond	First cell: bottom and sides to WQ design water surface	Low permeability liner, treatment liner, or impermeable liner
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Combined detention/non-infiltrating BMP	First cell: bottom and sides to WQ design water surface	Low permeability liner, treatment liner, or impermeable liner
	Second cell: bottom and sides to WQ design water surface	Treatment liner
Stormwater wetland	Bottom and sides, both cells	Low permeability liner or impermeable liner
Sand filter basin	Required if over a critical aquifer recharge area, otherwise not required. Refer to *Volume 3, Section 5.8.5*.	Low permeability line, treatment liner, or impermeable liner
Sand filter vault	Not applicable	No liner needed
Linear sand filter	Not applicable if in vault	No liner needed
	Bottom and sides of presettling cell if not in vault	Low permeability liner, treatment liner, or impermeable liner
Media filter (in vault)	Not applicable	No liner needed
Wet vault	Not applicable	No liner needed
Non-infiltrating bioretention	Bottom and sides	Low permeability liner or impermeable liner
Open bottom or open sided detention products (e.g., arch pipe, modular plastic tanks, etc.)	Bottom and sides	Low permeability liner or impermeable liner

Notes

[a] The Director may approve native soils as a low permeability liner based on measured infiltration rates and the recommendation of a licensed professional.

[b] The Director may also require impermeable liner based on infiltration setbacks or site constraints.

Design Criteria for Treatment Liners

This section presents the design criteria for treatment liners.

- A 2-foot-thick layer of soil with a minimum organic content of 1 percent AND a minimum cation exchange capacity (CEC) of 5 milliequivalents/100 grams can be used as a treatment layer beneath a water quality or detention BMP.
- To demonstrate that in-place soils meet the above criteria, one sample per 1,000 square feet of BMP area shall be tested. Each sample shall be a composite of subsamples collected throughout the depth of the treatment layer (usually 2 to 6 feet below the expected BMP invert).

- Typically, side wall seepage is not a concern if the seepage flows through the same stratum as the bottom of the treatment BMP. However, if the treatment soil is an engineered soil or has very low permeability, the potential to bypass the treatment soil through the side walls may be significant. In those cases, the treatment BMP side walls should be lined with at least 18 inches of treatment soil, as described above, to prevent untreated seepage. This lesser soil thickness is based on unsaturated flow as a result of alternating wet-dry periods. Approved continuous simulation models must be run using the "No infiltration" option through the sidewalls if one sidewall is impervious unless the model can limit infiltration only to the unlined portion of the perimeter.
- Organic content shall be measured on a dry weight basis using ASTM D2974.
- Cation exchange capacity (CEC) shall be tested using EPA laboratory method 9081.
- Certification by a soils testing laboratory that imported soil meets the organic content and CEC criteria above shall be provided to the City.
- The liner shall extend vertically to the water quality design water surface elevation plus 6 inches at the minimum.

Design Criteria for Low Permeability Liners

This section presents the design criteria for each of the following four low permeability liner options: compacted till liners, clay liners, and concrete liners. For low permeability liners, the following criteria apply:

- Where the seasonal high groundwater elevation is likely to contact a low permeability liner, liner buoyancy may be a concern. In these instances, use of a low permeability liner shall be designed by a geotechnical engineer.
- Where grass is planted over a low permeability liner per the BMP design, a minimum of 6 inches of topsoil of sufficient organic content and depth or compost-amended native soil shall be placed over the liner in the area to be planted. Native underlying soils may be suitable for planting if amended per Soil Amendment BMP requirements in *Volume 3, Section 5.1*. Twelve inches of cover is preferred.
- Low permeability liners shall extend vertically to the design water surface elevation plus 6 inches at a minimum. For bioretention, the design water surface elevation shall be the 25-year water surface elevation.

Compacted Till Liners

- Liner thickness shall be 18 inches after compaction.
- Soil shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to slow the infiltration rate to 2.4×10^{-5} inches per minute may also be used instead of the above criteria if designed by a geotechnical engineer.
- Soil shall be placed in maximum 6-inch lifts.
- Soils shall meet the gradation outlined in Table E-3 unless otherwise designed by a geotechnical engineer.

Table E.3. Compacted Till Liners.

Sieve Size	Percent Passing
6-inch	100
4-inch	90
#4	70 – 100
#200	20

Clay Liners

- Liner thickness shall be 12 inches after compaction.
- Clay shall be compacted to 95 percent minimum dry density, modified proctor method (ASTM D-1557).
- A different depth and density sufficient to slow the infiltration rate to 2.4 x 10^{-5} inches per minute may also be used instead of the above criteria, if designed by a geotechnical engineer and approved by the Director.
- Plasticity index shall not be less than 15 percent (ASTM D-423, D-424).
- Liquid limit of clay shall not be less than 30 percent (ASTM D-2216).
- Clay particles passing shall not be less than 30 percent (ASTM D-422).
- The slope of clay liners shall be restricted to 3H:1V for all areas requiring soil cover; otherwise, the soil layer shall be stabilized by another method so that soil slippage into the BMP does not occur. Any alternative soil stabilization method shall take maintenance access into consideration.

Concrete Liners

- Concrete liners may also be used for sedimentation chambers, for sedimentation and filtration basins less than 1,000 square feet in area, and non-infiltrating bioretention. Concrete shall be 5-inch thick Class 3000 or better and shall be reinforced by steel wire mesh. The steel wire mesh shall be 6 gage wire or larger and 6-inch by 6-inch mesh or smaller. An "Ordinary Surface Finish" is required per City of Seattle Standard Specification 6-02.3(14). When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete shall have a minimum 6-inch compacted aggregate base consisting of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch. Where visible, the concrete shall be inspected annually and all cracks shall be sealed.
- Portland cement liners are allowed irrespective of BMP size, and shotcrete may be used on slopes. However, specifications shall be designed by a licensed engineer who certifies the liner against cracking or losing water retention ability under expected conditions of operation, including BMP maintenance operations. Weight of maintenance equipment can be up to 80,000 pounds when fully loaded.
- Asphalt concrete may not be used for liners due to its permeability to many organic pollutants.
- If grass is to be grown over a concrete liner, slopes shall be no steeper than 5H:1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon recommended design by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.

Design Criteria for Impermeable Liners

Geomembrane Liners

- Geomembrane liners shall be ultraviolet (UV) light resistant and have a minimum thickness of 30 mils. A thickness of 40 mils shall be used in areas of maintenance access or where heavy machinery will be operated over the membrane.
- The geomembrane fabric shall be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top of and beneath the geomembrane. The geotextile fabric shall have a high survivability per the WSDOT Standard Specifications Section 9-33 Construction Geotextile. Equivalent methods for protecting the geomembrane liner may be permitted, subject to approval by Director. Equivalency will be based on the ability of the fabric to protect the geomembrane from puncture, tearing, and abrasion.
- Geomembranes shall be bedded according to the manufacturer's recommendations.
- Liners shall be covered with minimum of 12 inches of top dressing. Top dressing shall include 6 inches of crushed rock immediately over the liner to mark the location of the liner for future maintenance operations. As an alternative to crushed rock, orange plastic “safety fencing” or another highly-visible, continuous marker may be embedded 6 inches above the membrane to alert maintenance workers of the liner below.
- If possible, liners should be of a contrasting color so that maintenance workers are aware of any areas where a liner may have become exposed when maintaining the BMP.
- Non-textured geomembrane liners shall not be used on slopes steeper than 5H:1V to prevent the top dressing material from slipping. Textured liners may be used on slopes up to 3H:1V upon design by a geotechnical engineer that the top dressing will be stable for all site conditions, including maintenance.
- Geomembrane liners used to control seepage shall be joined using heat-fusion or equivalent, and include boots around all pipe and structure penetrations.
- Geomembrane liners shall extend vertically to the design water surface elevation plus 6 inches at a minimum. For bioretention, the design water surface elevation shall be the 25-year water surface elevation.

E-8. Geotextiles

The following recommended applications are provided courtesy of Tony Allen (Geotechnical Engineer-WSDOT) with references provided to the relevant tables in the City of Seattle Standard Specifications:

- For sand filter drain strip between the sand and the drain rock or gravel layers, use Geotextile Properties for Underground Drainage, moderate survivability, Class A, from Tables 1 and 2 in the City of Seattle Standard Specifications 9-37.
- For sand filter matting located immediately above the impermeable liner and below the drains, the function of the geotextile is to protect the impermeable liner by acting as a cushion. The specification provided in Table 4 in the City of Seattle Standard Specifications 9-37 shall be used to specify survivability properties for the liner protection application. Table 2 in the City of Seattle Standard Specifications 9-37, Class C shall be used for filtration properties. Only nonwoven geotextiles are appropriate for the liner protection application.
- For infiltration BMPs, use Geotextile for Underground Drainage, low survivability, Class C, from Tables 1 and 2 in the City of Seattle Standard Specifications 9-37.
- For a sand bed cover, a geotextile fabric is placed exposed on top of the sand layer to trap debris brought in by the stormwater and to protect the sand, facilitating easy cleaning of the surface of the sand layer. A polyethylene or polypropylene geonet shall be used in lieu of geotextile fabric. The geonet material shall have high UV resistance (90 percent or more strength retained after 500 hours in the weatherometer, ASTM D4355), and high permittivity (ASTM D4491, 0.8 sec^{-1} or more) and percent open area (CWO-22125, 10 percent or more). Tensile strength shall be on the order of 200 pounds grab (ASTM D4632) or more.
- For above and below a geomembrane liner, the geotextile fabric shall be Geotextile for Separation per the COS Standard Specifications Section 9-37 Construction Geotextile.

E-9. Plant Lists for Bioretention, Biofiltration Swales, Sand Filters, and Wet Ponds

The following plant lists were developed as a guide for bioretention (infiltrating and non-infiltrating), biofiltration swales, sand filters, and wet ponds. For information regarding planting for other BMPs, refer to *Volume 3*, *Chapter 5*. More stringent requirements have been developed for BMPs sited in the right-of-way and can be found in the Seattle Right-of-Way Improvements Manual.

The following design principles should be considered during plant selection:

- Select plants to minimize irrigation and maintenance needs. Coordinate planting design, whenever possible, with maintenance staff.
- Where appropriate, use regionally native species.
- Design a planting plan with a goal of achieving a minimum of 80 percent evergreen groundcover. Evergreen groundcover helps trap sediment and protects soil and infiltration rates during the wet season.
- Consider biodiversity of species, including a minimum of three to five species for planting plans for small BMPs, and increasing species diversity where possible. Species and genetic diversity increase resilience and the ability of a BMP to adapt during varying site conditions.
- Incorporate pollinator, bird, and wildlife species into planting plans where possible. Maximize various seasonal habitat function. For example, flowering plants should bloom three of the four seasons. Planting plans for BMPs adjacent to natural areas should include trees, shrubs, and groundcover that provide habitat value and support.

Bioretention

The Seattle Right-of-Way Improvements Manual establishes height limits for non-street tree plantings in rights-of-way. Maximum plant height within 30 feet of an intersection (as measured from the corner of the curb) is 24 inches. Elsewhere in the right-of-way, plantings are allowed to be 30 inches with the exception of accent shrubs as directed.

The following planting zone codes apply to Tables E.4 through E.19:

- Zone 1: designation for plants that are used for water quality in the bottoms of bioretention BMPs
- Zone 2: designation for plants that are used for water quality in the lower slopes/wetted/ponded area of bioretention BMPs
- Zone 3: species appropriate for planting at the tops and upper slopes of bioretention BMPs that are used as a border and as accents along the sidewalk, including vertical and accent plants and trees
- Zone 4: low, durable plants (under 24 inches) that are used in sight clearance areas or as accents at the edge of the BMP
- Zone 5: designation for steppable plants used in the crossing zones and access areas along the curb — these plants may need to tolerate foot traffic, depending on their location

The following operations and maintenance/special needs code (O&M code) apply to Tables E.4 through E.10:

- A = Cut back perennials to 3 inches above ground in fall (October/November).
- B = Leave foliage and seedheads for winter interest and cut back if foliage collapses. Cut back in spring (Mid-January to Mid-March) before new growth emerges.
- C = Hand-rake in spring (Mid-January to Mid-March) before new growth emerges. Cut back to ground or thin every 2 to 3 years as needed.
- DS = Deadhead perennials in spring/summer to encourage reblooming and for neater appearance. Deadheading not required for function.
- DF = Deadhead perennials in fall for neater appearance and to prevent resowing. Deadheading not required for function.
- E = Cut back or prune of over sidewalk or clear zones. Remove deadwood anytime fall to spring.
- F = May need replacing every 5+/- years. (Replacement not required if vegetation coverage meets requirements)
- G = May need dividing every few years. Reasons for division include dieback in center and to increase coverage.

Table E.4. Part Shade List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
SEMI			<24″	*Abelia x grandiflora* ‘Prostrata’	Prostrate white abelia	3, 4	1 Gal./30″ o.c.	UF	☼, Ø		E	
	DT		18″–30″	*Aster divaricatus*	White wood aster	3	1 Gal./24″ o.c.		Ø		B	
			<24″	*Carex elata* ‘Bowles Golden’	Bowles Golden sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
EG			<24″	*Carex laxiculmis* ‘Hobb’	Bunny Blue sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	Ø		C	
EG	DT	NWN	24″–48″+	*Carex obnupta*	Slough sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Do not intermix with other emergents. Do not plant near intersections. Drought tolerant wetland native.	C	Can be sheared more frequently if overcrowding other occurs. May require supplementary irrigation during prolonged dry periods.
		NWN	24″–36″	*Carex stipata*	Beaked sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Wetland native species. Limit to areas of approx. 36″x36″	B	May require supplementary irrigation during prolonged dry periods. Will die out if mowed or trimmed too regularly.
EG			24″–30″	*Carex testacea* or *dispacea*	Orange New Zealand or Autumn Sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	

Table E.4 (continued). Part Shade List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		24″–36″	*Cornus sericea* ‘Kelseyii’	Kelsey redstem dogwood	1, 2, 3	2 Gal./30″ o.c.	UF	☼, Ø		E	Stems fragile until established.
		NWN	24″–40″	*Deschampsia caespitosa*	Tufted Hair Grass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Native facultative species; does well in wet and dry conditions. Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
			<24″	*Deschampsia flexuosa* ‘Aurea’	Golden crinkled hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
			24″	*Fuchsia magellanica* ‘Aurea’	Dwarf Hardy Fuchsia	3, 4	2 Gal./30″ o.c.	UF	Ø		E	
			<24″	*Galanthus elwesii*	Giant Snowdrop	3, 4	Bulb	UF	☼, Ø	Prefers part shade. May be short-lived if too hot.	F	
EG	DT	NWN	24″–36″+	*Gaultheria shallon*	Salal	3	1 Gal./24″ o.c.	UF	☼, Ø		E	If height is a problem, Salal can be sheared with hedge trimmer.
EG			<24″	*Geum flore-plena* ‘Blazing Sunset’	Blazing Sunset Avens	3, 4	1 Gal./10″ o.c.	UF	☼, Ø		DS	
			24″–36″	*Iris pallida* ‘Variegata’	Variegated sweet iris	3	1 Gal./18″ o.c.	UF	☼, Ø		A	

Table E.4 (continued). Part Shade List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon holly-grape	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
EG	DR	NWN	24″–36″	*Polystichum munitum*	Western swordfern	3	2 Gal./24″ o.c.	UF	Ø	Limit to group of 3	B	Cut back before fronds appear.
EG	DT		24″–36″	*Prunus laurocerasus* ‘Mount Vernon’	Mount Vernon cherry laurel	3	2 Gal./24″ o.c.	UF	☼, Ø		E	
EG			36″	*Rhododendron* Yak Hybrids, such as ‘Ken Janeck’	Yak Hybrid	3	2 Gal./24″ o.c.	UF	☼, Ø	Several other Yak hybrids stay low and neat	E	LOS A: May produce more flowers if pruned and/or deadheaded after blooming.
EG	DT		<24″	*Sarcococca hookeriana humilis*	Himalayan Sweet Box	3	2 Gal./24″ o.c.	UF	Ø	Winter fragrance	E	
EG			30″	*Taxus* ‘Emerald Spreader’	Emerald Spreader Yew	3	2 Gal./24″ o.c.	UF	☼, Ø		E	
		NWN	<24″	*Tolmiea menziesii*	Youth on Age	1, 2, 3	1 Gal./10″ o.c.		Ø		G	
EG	DT		<24″	*Veronica liwanensis*	Speedwell	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø		E	LOS A: Cut back for neater appearance.

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant
DR = Drought Resistant
NWN = Northwest Natives or Cultivars

UF = Urban Frontage (Mixed Use/Commercial) appropriate plants
☼ = Full Sun
Ø = Part Sun/Part Shade
LOS = Level of Service

Table E.5. Sun List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
SEMI			<24″	*Abelia x grandiflora* ‘Prostrata’	Prostrate white abelia	3, 4	1 Gal./30″ o.c.	UF	☼, Ø		E	
	DT		<24″	*Aster novi-belgii* ‘Wood’s Blue’	Wood’s Blue New York Aster	3	1 Gal./18″ o.c.	UF	☼		B, G	
			24″–36″	*Carex muskingumen-sis*	Palm sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
			24″–36″	*Carex elata* ‘Bowles Golden’	Bowles Golden Sedge	1, 2, 3	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
			24″–36″+	*Carex grayi*	Gray’s sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	
		NWN	24″–36″	*Carex stipata*	Beaked sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Wetland native species Limit to areas of approx. 36″x36″	B	May require supplementary irrigation during prolonged dry periods. Will die out if mowed or trimmed too regularly.
EG			24″–30″	*Carex testacea or dispacea*	Orange New Zealand or Autumn Sedge	1, 2, 3	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	

Table E.5 (continued). Sun List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		24″–36″	*Caryopteris incana* ‘Sunshine Blue’	Sunshine Blue Bluebeard	3, 4	1 Gal./18″ o.c.	UF	☼		B OR DF	Cut back to about 18″ above the ground or by half in early spring after new leaves are visible
	DT	NWN	24″–30″	*Cornus sericea* ‘Kelseyii’	Kelsey redstem dogwood	1, 2, 3	2 Gal./30″ o.c.	UF	☼, Ø		E	Stems fragile until established.
		NWN	24″–40″	*Deschampsia caespitosa*	Tufted Hair Grass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Native facultative species; does well in wet and dry conditions. Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
			<24″	*Deschampsia flexuosa* ‘Aurea’	Golden crinkled hair grass	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
	DT		24″–36″	*Echinacea purpurea*	Coneflower	3	1 Gal./18″ o.c.	UF	☼		B	LOS A: For neater appearance, deadhead.
EG	DT	NWN	24″–36″+	*Gaultheria shallon*	Salal	3	1 Gal./24″ o.c.	UF	☼, Ø		E	If height is a problem, Salal can be sheared with hedge trimmer.

Table E.5 (continued). Sun List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT		24″–36″	*Hebe* 'Red Edge'	Red Edge Hebe	3, 4	1 Gal./24″ o.c.		☼		E	
	DT		<24″	*Hemerocallis* – Later Flowering Varieties	Later Flowering Daylily varieties	3, 4	1 Gal./15″ o.c.	UF	☼, Ø	Later flowering varieties are not as susceptible to Daylily gall midge.	A	LOS A: For neater appearance, deadhead.
EG	DT		<24″	*Geranium x cantabrigiense* 'Cambridge'	Perennial Geranium	3, 4	1 Gal./15″ o.c.	UF	☼, Ø		B	
SEMI	DT		<24″	*Helianthemum* 'Henfield Brilliant'	Sunrose	3, 4	1 Gal./10″ o.c.	UF	☼		B	
EG	DT		24″–36″	*Helictotrichon sempervirens*	Blue oat grass	3	1 Gal./18″ o.c.	UF	☼		C	
EG	DT		<24″	*Ilex x* 'Mondo'	Little Rascal Holly	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
EG	DT	NWN	<24″	*Iris douglasiana*	Pacific Coast Iris	3, 4	1 Gal./18″ o.c.	UF	☼	Many colors available.	G	LOS A: For neater appearance, cut back dead leaves and flower stalks.

Table E.5 (continued). Sun List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
SEMI	DT	NWN	<24″	*Iris missouriensis*	Rocky Mountain Iris	1, 2	1 Gal./12″ o.c.	UF	☼		G	May require supplementary irrigation during prolonged dry periods. LOS A: For neater appearance, cut back dead leaves and flower stalks.
			24″–36″	*Iris sibirica* cultivars such as 'Bennerup Blue'	Siberian Iris	1, 2, 3	1 Gal./18″ o.c.	UF			G	LOS A: For neater appearance, cut back dead leaves and flower stalks.
EG	DT	NWN	<24″	*Juncus balticus*	Baltic rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼	Wetland native species. Do not use in hot ROW locations.	C	May require supplementary irrigation during prolonged dry periods. Will die off if sheared too frequently. LOS A: Can be sheared more frequently if foliage collapses.

Table E.5 (continued). Sun List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG		NWN	24″–36″	*Juncus effusus* 'Quartz Creek'	Quartz Creek Soft Rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	LOS A: Can be sheared more frequently if foliage collapses.
EG	DT		<24″	*Juniperus conferta* 'Blue Pacific'	Blue Pacific Shore juniper	3, 4	1 Gal./3′ o.c.	UF	☼		E	
	DT	NWN	36″	*Leersia oryzoides*	Rice Cutgrass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼	Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon holly-grape	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
	DR		36″	*Miscanthus sinensis* 'Little Kitten'	Little Kitten Maiden Grass	3	1 Gal./15″ o.c.	UF	☼		B	
	DT		30″	*Nepetax* 'Walker's Low'	Catmint	3	1 Gal./18″ o.c.	UF	☼, Ø		B	
EG			36″	*Rhododendron* Yak Hybrids, such as 'Ken Janeck'	Yak Hybrid	3, 4	2 Gal./30″ o.c.	UF	☼, Ø	Several other Yak hybrids stay low and neat	E	LOS A: May produce more flowers if pruned and/or deadheaded after blooming
	DT		24″–36″	*Rudbeckia fulgida* 'Goldsturm'	Black-Eyed Susan	3, 4	1 Gal./18″ o.c.	UF	☼	Late season color accent.	A OR B	

Table E.5 (continued). Sun List.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		<24″	*Sedum* 'Autumn Joy' or 'Matrona'	Stonecrop	3, 4	1 Gal./12″ o.c.	UF	☼		G	LOS A: Can be cut back by half in June to prevent flopping.
	DT	NWN	<24″	*Solidago canadensis* 'Baby Gold' or *Solidago hybrida* 'Dansolitlem'	Baby Gold or Little Lemon Goldenrod	3, 4	1 Gal./18″ o.c.		☼	Late season color accent.	A	
		NWN	24″–48″	*Spiraea betulifolia* or *Spiraea betulifolia* 'Tor'	Birchleaf spirea	3	1 Gal./24″ o.c.	UF	☼		E	
EG	DT	NWN	<24″	*Sedum oreganum*	Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼	Tolerates hot dry sites.	E	
EG	DT		<24″	*Teucrium chamaedrys*	Wall germander	3, 4	1 Gal./18″ o.c.	UF	☼		E	LOS A: For neater appearance trim spent flowers in spring.
EG	DT		<24″	*Thymus serpyllum* 'Elfin'	Elfin creeping thyme	3, 4, 5	4″ Pot/12″ o.c.	UF	☼		F	

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant
DR = Drought Resistant
NWN = Northwest Natives or Cultivars

UF = Urban Frontage (Mixed Use/Commercial) appropriate plants
☼ = Full Sun
Ø = Part Sun/Part Shade
LOS = Level of Service

Table E.6. Native List (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DR	NWN	24″–36″	*Aquilegia formosa*	Western Columbine	3, 4	1 Gal./18″ o.c.		☼, Ø		DF	
EG	DT	NWN	<24″	*Arctostaphylos uva-ursi* 'Massachusetts' or 'Pt. Reyes'	Kinnikinnick	3, 4	1 Gal./12″ o.c.	UF	☼, Ø	Possible use at vertical wall or single use low accent. Requires approval by Project Manager and Maintenance prior to use.	E	
	DR	NWN	24″–36″	*Camus leichtlinii or Camus quamash*	Great Camus or Common Camus	3, 4	1 Gal./12″ o.c.		☼, Ø	Plant for in groups for effect. Can be planted as a bulb	DF	
	DR	NWN	24″–48″	*Carex deweyana*	Dewey's sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Grows best on side slopes. Limit to areas of approx. 36″x36″	B	Likely to need supplementary irrigation if planted in full sun.
EG	DT	NWN	24″–48″+	*Carex obnupta*	Slough sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Drought tolerant wetland native. Do not intermix with other emergents. Do not plant near intersections	C	May require supplementary irrigation during prolonged dry periods. Can be sheared more frequently if overcrowding other occurs.

Table E.6 (continued). Native List (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT	NWN	24″–36″	*Carex pachystachya*	Chamisso sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Grows best on side slopes. Limit to areas of approx. 36″x36″	B	
		NWN	24″–36″	*Carex stipata*	Beaked sedge	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	May require supplementary irrigation during prolonged dry periods. Will die out if mowed or trimmed too regularly.
	DT	NWN	24″–30″	*Cornus sericea* ‘Kelseyii’	Kelsey redstem dogwood	1, 2, 3	2 Gal./30″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	E	Stems fragile until established.
		NWN	24″–40″	*Deschampsia caespitosa*	Tufted Hair Grass	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Native facultative species; does well in wet and dry conditions. Limit to areas of approx. 36″x36″	B	LOS A: For neater appearance, trim seedheads.
	DT	NWN	<24″	*Erigeron peregrinus*	subalpine fleabane daisy	3, 4	1 Gal./12″ o.c.	UF	☼		DF	
	DT	NWN	36″	*Festuca idahoensis*	Idaho fescue	3, 4	1 Gal./18″ o.c.		☼		DF	
EG	DT	NWN	<24″	*Gaultheria ovatifolia*	Oregon wintergreen	3, 4	1 Gal./24″ o.c.	UF	☼, Ø	If Gaultheria shallon is substituted see additional O&M notes	E	If height is a problem, can be sheared with hedge trimmer.

Table E.6 (continued). Native List (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	<24″	*Iris douglasiana*	Pacific Coast Iris	3, 4	1 Gal./18″ o.c.	UF	☼	Many colors available.	G	LOS A: For neater appearance, cut back dead leaves and flower stalks.
SEMI	DT	NWN	<24″	*Iris missouriensis*	Rocky Mountain Iris	1, 2	1 Gal./12″ o.c.	UF	☼		G	LOS A: For neater appearance, cut back dead leaves and flower stalks.
EG	DT	NWN	<24″	*Juncus balticus*	Baltic rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼	Wetland native species. Do not use in hot ROW locations.	C	May require supplementary irrigation during prolonged dry periods. Will die off if sheared too frequently. LOS A: Can be sheared more frequently if foliage collapses.

Table E.6 (continued). Native List (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	24″–48″+	*Juncus effusus*	Common rush	1, 2	10 Cu. In. Plug/ 9″ o.c.		☼, Ø	Only *Juncus effusus* var. *pacificus* is native. Other varieties of *Juncus effusus*, even cultivars, are invasive and are not recommended for use in stormwater facilities. Do not intermix with other emergents. Do not plant near intersections	C	
EG		NWN	<24″	*Juncus ensifolius*	Dagger-leaf rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Limit to areas of approx. 36″x36″	B	Requires supplementary irrigation in summer to thrive.
EG	DT	NWN	<24″	*Juncus tenuis*	Path rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Native facultative species; does well in wet and dry conditions.	C	
EG	DT	NWN	<24″	*Juniperus communis* ‘Mondap’	Alpine carpet juniper	4	1 Gal./24″ o.c.	UF	☼		E	May require supplementary irrigation in summer. May require pruning

Table E.6 (continued). Native List (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG		NWN	36″	*Ledum glandulosum*	Pacific or trapper's tea	1, 2, 3	5 Gal./36″ o.c.	UF	☼, Ø	Plant near the bottom of swale	E	
EG	DT	NWN	<24″	*Lewisia cotyledon or cultivars*	Siskiyou lewisia	3, 4	1 Gal./12″ o.c.	UF	☼		E	
EG		NWN	36″	*Mahonia aquifolium* 'Orange Flame' or 'Compacta'	Compact tall Oregon grape	3	1 Gal./36″ o.c.	UF	☼, Ø		E	
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon grape	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
		NWN	24″–36″	*Mimulus guttatus*	Yellow monkey-flower	1, 2	1 Gal./18″ o.c.		☼, Ø	Provides temporary color and habitat value. Will die back in late summer or winter but will reseed. Should not be used in large areas and relied upon for water quality treatment.	DF	
EG	DT	NWN	36″	*Pachistima myrsinites*	Oregon Boxwood	3	1 Gal./36″ o.c.	UF	☼, Ø		E	
		NWN	<24″	*Potentilla fruticosa* 'Sunset'	Frosty potentilla	3, 4	2 Gal./30″ o.c.	UF	Ø		E	

Table E.6 (continued). Native List (Sun to Part Shade includes cultivars).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT	NWN	<24″	*Potentilla glandulosa* or *Potentilla gracilis*	Sticky cinquefoil or slender cinquefoil	3, 4	1 Gal./18″ o.c.		☼, Ø		DF	
EG		NWN	24″–36″	*Polystichum imbricans* or *Polystichum lonchitis*	Narrow-leaf sword fern or Northern holly fern	3, 4	2 Gal./30″ o.c.	UF	☼, Ø	If *Polystichum munitum* is substituted limit groups to 3 and prune yearly	B	Cut back before fronds appear.
	DT	NWN	<24″	*Solidago canadensis* ‘Baby Gold’ or *Solidago hybrida* ‘Dansolitlem’	Baby Gold or Little Lemon Goldenrod	3, 4	1 Gal./18″ o.c.		☼	Late season color accent.	A	
		NWN	24″–36″	*Spiraea betulifolia or Spiraea betulifolia* ‘Tor’	Birchleaf spirea	3	1 Gal./24″ o.c.	UF	☼		E	
EG	DT	NWN	<24″	*Sedum divergens*	Stonecrop	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	LOS A: For neater appearance deadhead.
EG	DT	NWN	<24″	*Sedum oreganum*	Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼	Tolerates hot dry sites.	E	
EG	DT	NWN	24″–36″	*Xerophyllum tenax*	Bear grass	3	1 Gal/18″ o.c.	UF	☼	Tolerates hot dry sites.	E	

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant
DR = Drought Resistant
NWN = Northwest Natives or Cultivars

UF = Urban Frontage (Mixed Use/Commercial) appropriate plants
☼ = Full Sun
Ø = Part Sun/Part Shade
LOS = Level of Service

Table E.7. Intersection and View Restriction Palette (under 24 inches in height).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
			<24″	*Chrysanthemum* ‘Peach Centerpiece’ or ‘Bienchen’	Peach Centerpiece or golden chrysanthemum	3, 4	1 Gal./15″ o.c.		☼	Late season color accent.	B & G	Pull if scraggly.
	DT		<24″	*Coreopsis lanceolata* ‘Sterntaler’	Tickseed	3, 4	1 Gal./15″ o.c.	UF	☼		B & G	
	DT		24″–30″	*Cornus sericea* ‘Kelseyii’	Kelsey redstem dogwood	1, 2, 3	1 Gal./30″ o.c.	UF	☼, Ø	Plant in bottom areas for sightlines.	E	Stems fragile until established.
EG	DT		<24″	*Epimedium rubrum or sulphurescens*	Barrenwort	3, 4	4″ Pot/12″ o.c.	UF	Ø	Part shade to shade only without irrigation.	B	Cut back before flower stalks appear.
EG	DT		<24″	*Euonymus fortunei* ‘Interbolwi’	Blondy winter-creeper	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
	DT		<24″	*Geranium* ‘Gerwat’ ‘Rozanne’	Rozanne geranium	3, 4	1 Gal./24″ o.c.		☼, Ø		A	LOS A: Can be sheared for neater appearance.
EG			<24″	*Geum flore pleno* ‘Blazing Sunset’	Blazing Sunset Avens	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		DS	
EG			<24″	*Hebe x* ‘Champion’	Champion Hebe	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
SEMI	DT		<24″	*Helianthemum nummularium* ‘Wisley Primrose’	Yellow Sunrose	3, 4	1 Gal./12″ o.c.	UF	Ø		B	

Table E.7 (continued). Intersection and View Restriction Palette (under 24 inches in height).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT		24″–36″	*Helictotrichon sempervirens*	Blue oat grass	3	1 Gal./18″ o.c.	UF	Ø	36″ height only when in flower. Airy flowers. Groups of 3 maximum.	C	
EG	DT		<24″	*Ilex x* ‘Mondo’	Little Rascal Holly	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	
EG		NWN	<24″	*Juncus effusus* ‘Carmen’s Japan’	Carmen’s Japanese Rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	
EG			<24″	*Juncus effusus* ‘Spiralis’	Corkscrew soft rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø		C	LOS A: Can be sheared more frequently if foliage collapses.
EG			24″–30″	*Juncus patens or Juncus patens* ‘Elk blue’	California gray rush	1, 2	10 Cu. In. Plug/ 9″ o.c.	UF	☼, Ø	Resilient wetland species; can survive summer drought and winter inundation. Plant in bottom areas for sightlines	C	LOS A: Can be sheared more frequently if foliage collapses.
EG			<24″	*Liriope muscari* and cultivars	Lily Turf	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø		C	OK to pull clumps for ease of weed control.
EG	DR	NWN	<24″	*Mahonia repens*	Creeping Oregon holly-grape	3	1 Gal./18″ o.c.	UF	☼, Ø		E	

Table E.7 (continued). Intersection and View Restriction Palette (under 24 inches in height).

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
	DT		<24″	*Narcissus* 'Dutch Master' *or* 'King Alfred'	Daffodil	3, 4	Bulb/As Shown	UF	Ø		DS	Cut back foliage in summer.
		NWN	<24″	*Potentilla fruticosa* 'Sunset'	Frosty potentilla	3, 4	2 Gal./30″ o.c.	UF	Ø		E	
EG	DT		<24″	*Veronica liwanensis*	Speedwell	3, 4, 5	4″ Pot/12″ o.c.	UF	Ø		E	LOS A: Cut back for neater appearance.

SEMI = Semi-evergreen

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☼ = Full Sun

Ø = Part Sun/Part Shade

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Table E.8. Vertical Shrubs and Accent Plants.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
		NWN	25′	*Amelanchier alnifolia*	Service Berry	1, 2, 3	Multi-stem, B&B, 5′–6′ ht.		Ø	Multi-stemmed native species. Can sucker and spread. Single stem species may be available if nursery prunes in advance.	E	May need windowing/ thinning.
			5′	*Cornus sanguinea* ‘Midwinter Fire’	Midwinter Fire Dogwood	1, 2, 3	5 gal		☼, Ø		E	Prune 2/3 of all (older) branches to 8″ above ground in March to keep in bounds and to maintain yellow twigs.
		NWN	6′ to 8′	*Cornus sericea* ‘Flaviramea’	Yellow-Twig Dogwood	1, 2, 3	5 gal		Ø		E	Prune 2/3 of all (older) branches to 8″ above ground in March to keep in bounds and to maintain red twigs.
			10′	*Hamamelis x intermedia* ‘Pallida’	Witch Hazel	3	10 gal		☼, Ø	Vase-shaped open growing form	E	
			5′	*Hydrangea quercifolia* ‘Pee Wee’	Oak-Leaf Hydrangea	3	5 gal		Ø	Late summer flowers. Fall color. Bold leaves in winter.	E	May need windowing/ thinning.

Table E.8 (continued). Vertical Shrubs and Accent Plants.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG			3′–4′	*Ilex glabra* ‘Shamrock’	Inkberry	1, 2	5 gal.		☼, Ø		E	Female plants need a male pollinator to produce berries.
			3′–12′	*Ilex verticillata* and cultivated varieties	Winterberry	1, 2	5 gal.		☼, Ø		E	Female plants need a male pollinator to produce berries.
EG			8′–12′	*Mahonia* ‘Arthur Menzies’	Ornamental Mahonia	3	5 gal		☼, Ø	Upright multi-stemmed.	E	
EG		NWN	6′–10′	*Mahonia aquifolium*	Oregon grape	3	5 gal		☼, Ø	Upright multi-stemmed.	E	
EG			5′	*Osmanthus* ‘Goshiki’	Variegated Osmanthus	3	5 gal		Ø	4′ wide. Considered dwarf. New foliage is colorful.	E	May need windowing/ thinning.
			6′	*Physocarpus opulifolius* 'Nanus'	Dwarf Ninebark	1, 2, 3	5 gal		☼, Ø	Even dwarf form may be tall and wide.	E	May need windowing/ thinning.
EG			4′	*Pieris japonica* 'Little Heath'	Little Heath Lily of the Valley	3	3 gal.		Ø	Variegated foliage that emerges pink in spring. Flowers in winter	E	May need windowing/ thinning.
		NWN	8′	*Ribes sanguineum* and cultivated varieties	Red Flowering Currant	3	5 gal		Ø	Attracts hummingbirds	E	May need windowing/ thinning.

Table E.8 (continued). Vertical Shrubs and Accent Plants.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
			15′–20′	*Salix integra* 'Hakuro Nishiki'	Dappled Willow	1, 2, 3	5 gal.		☼, Ø		E	Specify tree form; Prune to ground every other year to keep smaller
			8′–15′	*Sambucus nigra* 'Gerda'	Black Beauty Black Elder	1, 2, 3	5 gal.		☼, Ø		E	
		NWN	6′	*Symphoricar-pos albus*	Snowberry	1, 2, 3	5 gal		☼, Ø	Forms thickets.	E	May need windowing/ thinning.
			6′	*Taxodium distichum* 'Peve Minaret'	Dwarf bald cypress	1, 2, 3					E	
EG		NWN	6′	*Vaccinium ovatum*	Evergreen Huckleberry	1, 2, 3	5 gal		☼, Ø		E	
			6′	*Vaccinium* 'Sunshine Blue'	Blueberry	3	5 gal		☼, Ø	Self-pollinating edible fruits. Good fall color.	E	
EG			10′	*Viburnum cinnamomi-folium*	Cinnamon Viburnum	3	10 gal		☼, Ø		E	May need windowing/ thinning.
		NWN	7′–12′	*Viburnum edule*	Highbush cranberry	1, 2, 3	5 gal.		☼, Ø		E	

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Table E.9. Groundcovers if Low Profile is Required.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT		<24″	*Ajuga reptens*	Bugleweed	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø		E	Can be pulled if grows beyond desired boundaries.
EG	DT		<24″	*Epimedium rubrum* or *sulphurescens* or cultivars	Barrenwort	3, 4	4″ Pot/12″ o.c.	UF	Ø		B	Cut back foliage before flower stalks appear.
EG	DT		<24″	*Euonymus fortunei* 'Kewensis'	Winter-creeper euonymous	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		E	Can be mowed to keep low.
SEMI	DT		<24″	*Geranium macrorrhizum* 'Album' or other cultivars	Hardy Geranium	3, 4	1 Gal./18″ o.c.	UF	☼, Ø		B	
EG	DT		<24″	*Pachysandra terminalis*	Japanese Spurge	3, 4	4″ Pot/12″ o.c.	UF	Ø		C	
EG	DT		<24″	*Sibbaldiopsis tridentata (= Potentilla tridentata)*	Three-toothed Cinquefoil	3, 4	4″ Pot/12″ o.c.	UF	Ø		E	
EG	DT		<24″	*Rubus tricolor*	Creeping Chinese Bramble	3, 4	4″ Pot/12″ o.c.	UF	Ø	Tolerates deep shade. Not as aggressive or spiny as other Rubus groundcovers. Red fuzzy stems and shiny leaves.	E	

Table E.9 (continued). Groundcovers if Low Profile is Required.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG	DT	NWN	<24″	*Sedum divergens*	Stonecrop	3, 4	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	LOS A: For neater appearance deadhead.
EG	DT		<24″	*Sedum requieni*	Miniature Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	
	DT	NWN	<24″	*Vancouveria hexandra*	Inside Out Flower	3, 4	4″ Pot/12″ o.c.	UF	Ø		E	
SEMI			<24″	*Potentilla neumanniana* 'Nana'	Dwarf cinquefoil	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø		E	
EG			<24″	*Ophiopogon japonicus* 'Nanus'	Dwarf mondo grass	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Can space at 15″ o.c. for cost saving	E	

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Table E.10. Steppable Plants.

EG	DT	NWN	Height from Ground	Scientific Name	Common Name	Planting Zone	Suggested Size/ Spacing	Urban Frontage	Exposure	Design Comments	O&M Code	Additional O&M Comments
EG			<24″	*Ophiopogon japonicus* 'Nanus'	Dwarf mondo grass	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Can space at 15″ o.c. for cost saving	E	
SEMI			<24″	*Potentilla neumanniana* 'Nana'	Dwarf cinquefoil	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø		E	
EG	DT	NWN	<24″	*Sedum oreganum*	Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼	Tolerates hot dry sites.	E	
EG	DT		<24″	*Sedum requieni*	Miniature Stonecrop	3, 4, 5	4″ Pot/12″ o.c.	UF	☼, Ø	Tolerates hot dry sites.	E	
EG	DT		<24″	*Thymus serpyllum* 'Elfin'	Elfin creeping thyme	3, 4, 5	4″ Pot/12″ o.c.	UF	☼		F	
EG	DT		<24″	*Veronica liwanensis*	Speedwell	3, 4, 5	4″ Pot/12″ o.c.	UF	Ø		E	LOS A: Cut back for neater appearance.

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Table E.11. Conifers (deciduous and evergreen).

Scientific and Common Name	Mature Urban Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Calocedrus decurrens, Incense Cedar	75	15	No	8	3			
Metasequoia glyptostroboides, Dawn Redwood	50	25	No	6	1, 2, 3	Yes		Fast growing deciduous conifer.
Pinus contorta, Shore Pine	45	30	No	5	1, 2, 3			Facultative species that grows well in sandy soils. Found in wetland and upland habitats.
Taxodium distichum, Bald Cypress	55	35	No	8	1, 2, 3	Yes		A deciduous conifer, broadly spreading when mature – columnar when young.
Taxodium distichum 'Mickelson,' Shawnee Brave Bald Cypress	55	20	No	6	1, 2, 3	Yes	x	Deciduous conifer – tolerates city conditions.
Thuja plicata 'Excelsa' or 'Hogan,' Western Red Cedar	40	15–20	No	8	1, 2, 3			Narrow columnar form.

Table E.12. Medium/Large Broad-leaved Evergreen Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Lithocarpus densiflorus, Tanoak	50	20	No	6	3			
Quercus Ilex, Holly Oak	40	30	No	5	3	N/A	x	Underside of leaf is silvery-white. Often has a prominent umbrella form. Prune for form.
Umbellularia californica, Oregon Myrtlewood	60	30	No	5	1, 2, 3			Drought tolerant native in S. OR. Fruit looks like miniature limes.

Table E.13. Large Deciduous Columnar Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer nigrum 'Green Column,' Green Column Black Sugar Maple	50	10	No	6	3	Yes	x	
Ginko biloba 'Princeton Sentry,' Princeton Sentry Ginkgo	40	15	No	6	3	Yes	x	Prune for form
Quercus robur 'fastigiata,' Skyrocket Oak	40	15	No	6	3	N/A	x	

Table E.14. Large Deciduous Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer saccharum 'Commemoration' or 'Bonfire' Commemoration or Bonfire Sugar Maple	50	35	No	6	1, 2, 3	Yes	x	Resistant to leaf tatter.
Fagus sylvatica, Green Beech	50	40	No	6	3	Yes	x	Silvery-grey bark. Can't handle root disturbance.
Fagus sylvatica 'Asplenifolia,' Fernleaf Beech	60	50	No	6	3	Yes	x	Can't handle root disturbance.
Ginkgo biloba 'Magyar,' Magyar Ginkgo	50	25	No	6	3	Yes	x	More upright and narrow than 'Autumn Gold.' Needs training when young.
Liriodendron tulipifera, Tulip Tree	60+	30	No	8	1, 2, 3	Yes	x	Fast-growing tree.
Platins x acerifolia 'Bloodgood,' Bloodgood London Planetree	50+	40	No	8	1, 2, 3	N/A	x	More anthracnose resistant than other varieties – large tree that needs space.
Quercus bicolor, Swamp White Oak	60	45	No	8	1, 2, 3	N/A	x	Shaggy peeling bark. Wet-soil tolerant.
Quercus coccinea, Scarlet Oak	60	40	No	6	3	Yes	x	Good fall color.
Quercus imbricaria, Shingle Oak	60	50	No	6	3	N/A	x	Leaves can persist throughout the winter.
Quercus rubra, Red Oak	60	45	No	8	1, 2, 3	Yes	x	Fast growing oak – large tree that needs space. Heavy acorn producer.
Tilia tomentosa, Silver Linden	60	50	No	6	3	Yes		Larger leaves than Littleleaf Linden. Fragrant flowers.
Ulmus 'Frontier' or 'Morton Glossy,' Frontier or Triumph Elm	50	35	No	6	1, 2, 3	Yes	x	Resistant to Dutch elm disease.
Zelkova serrata 'Greenvase' or 'Village Green' Green Vase or Village Green Zelkova	45	40	No	6	3	Yes	x	Exfoliating bark. Dark green leaves turn orange-red and purple in fall.

Table E.15. Medium/Large Deciduous Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer campestre 'Evelyn,' Queen Elizabeth Hedge Maple	40	30	No	5	1, 2, 3	Yes	x	More upright branching than the species.
Acer freemanii 'Autumn Blaze,' Autumn Blaze Maple	50	40	No	6	1, 2, 3	Yes	x	Cross between red and silver maple – fast growing with good fall color.
Acer rubrum 'Scarsen,' Scarlet Sentinel Maple	40	25	No	6	1, 2, 3	Yes	x	Leaves are darker green and larger than those of other Red Maples and hold up well in summer heat. Upright branch habit.
Aesculus x carnea 'Briottii,' Red Horsechestnut	30	35	No	6	3	N/A	x	Do not use near greenways or bicycle routes due to litter. Resists heat and drought better than other horse chestnuts.
Betula nigra, River Birch	40	30	No	5	1, 2, 3	Yes		Excellent flaky bark. Resistant to Bronze Birch Borer.
Cercidiphyllum japonicum, Katsura tree	45	40	No	8	1, 2, 3	Yes		
Eucommia ulmoides, Hardy Rubber Tree	50	40	No	6	3	N/A	x	Dark green, very shiny leaves – insignificant fall color.
Fagus sylvatica 'Rohanii,' Purple Oak Leaf Beech	50	30	No	6	3	N/A	x	Purple leaves with wavy margins.
Ginko biloba 'Autumn Gold,' Autumn Gold Ginkgo	45	35	No	6	3	Yes	x	Narrow when young.
Nothofagus antarctica, Antarctic Beech	50	35	No	5	3	No	x	Rugged twisted branching and petite foliage.
Quercus frainetto, Italian Oak	50	30	No	6	3	N/A	x	Drought resistant – green, glossy leaves in summer.
Sophora japonica 'Regent,' Japanese Pagodatree	45	40	No	6	3	Yes	x	Has a rapid growth rate and tolerates city conditions, heat, and drought.
Tilia cordata 'Greenspire,' Greenspire Linden	40	30	No	6	3	Yes	x	Symmetrical, pyramidal form. Fragrant flowers.
Ulmus parvifolia 'Emer II,' Allee Elm	45	35	No	5	1, 2, 3	Yes	x	Exfoliating bark and good fall color – Resistant to Dutch Elm Disease.

Table E.16. Medium Columnar Deciduous Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer rubrum 'Bowhall,' Bowhall Maple	40	20	No	6	1, 2, 3	Yes	x	Upright, pyramidal form.
Carpinus betulus 'Fastigiata,' Pyramidal European Hornbeam	40	15	No	5	1, 2, 3	Yes	x	Broadens when older.
Fagus sylvatica 'Dawyck Purple,' Dawyck Purple Beech	40	12	No	6	3	Yes	x	Purple foliage.
Oxydendron arboreum, Sourwood	35	12	No	5	3	Yes	x	Consistent and brilliant fall color.
Nyssa sylvatica, Tupelo	40	20	No	6	1, 2, 3	Yes	x	Chunky bark. Takes standing water and drought.

Table E.17. Medium Deciduous Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer rubrum 'Karpick,' Karpick Maple	40	20	No	6	1, 2, 3	Yes	x	Finer texture than other narrow forms of columnar maple.
Acer truncatum x A. platanoides 'Keithsform' or 'Warrenred,' Norwegian or Pacific Sunset Maple	35	25	No	5	3	Yes	x	Reliable reddish orange fall color.
Cladrastis kentukea, Yellowwood	40	40	No	5	3	Yes	x	White flowers in spring, resembling wisteria flower – blooms profusely only every 2 to 4 years – yellow/gold fall color
Cornus controversa 'June Snow,' Giant Dogwood	40	30	No	5	3	Yes	x	Frothy, 6-inch clusters of white flowers in June.
Corylus colurna, Turkish Filbert	40	25	No	5	3	Yes	x	Tight, formal, dense crown – Nice central leader. Not for mixed use areas with high pedestrian traffic dues to significant debris from nuts. Drought tolerant. Plant smaller sizes in order to facilitate establishment.
Magnolia denudata, Yulan Magnolia	40	40	No	5	3	N/A	x	6-inch fragrant white flowers in spring.
Ostrya virginiana, Ironwood	40	25	No	5	3	Yes	x	Hop like fruit – slow growing
Pterostyrax hispida, Fragrant Epaulette Tree	40	30	No	5	3	Yes	x	Pendulous creamy white flowers – fragrant
Ulmus parvifolia 'Emer I,' Athena Classic Elm	30	35	No	5	1, 2, 3	Yes	x	High resistance to Dutch Elm Disease. Drought resistant. Cinnamon colored exfoliating bark.

Table E.18. Small Conifer/Broad-leaved Evergreen Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Chamaecyparis obtusa gracilis, Slender Hinoki False Cypress	15	6	Yes	5	3			Drought tolerant when established.
Embothrium coccineum, Chilean Flame Tree	30	15	No	5	3			Brilliant orange red flowers in late spring. Tree can sucker.
Eucryphia glutinosa, Brushbush	25	15	Yes	5	3			Semi-evergreen. Best in part shade.
Magnolia grandiflora 'Edith Bogue,' Edith Bogue Magnolia	18	12	Yes	5	1, 2, 3			Excellent BLE magnolia due to hardiness.
Magnolia grandiflora 'Victoria,' Victoria Evergreen Magnolia	25	20	Yes	5	1, 2, 3	N/A	x	
Magnolia maudiae *(= Michelia maudiae)*, NCN	25	20	Yes	5	3			
Magnolia virginiana	35	35		5	1, 2, 3		x	
Quercus hypoleucoides	30	15	No	5	3			
Quercus myrsinifolia, Chinese Evergreen Oak	30	15	No	5	3			

Table E.19. Small Deciduous Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Acer buegerianum, Trident Maple	30	30	Yes	5	3	Yes	x	Must train to a single stem – interesting bark.
Acer circinatum, Vine Maple	25	25	Yes	5	3	Yes	x	Avoid using on harsh sites – native tree.
Acer griseum, Paperbark Maple	30	20	Yes	5	3	Yes	x	Peeling cinnamon colored bark.
Acer tartaricum, Tartarian Maple	20	20	Yes	5	3	Yes		
Acer triflorum, Three-Flower Maple	25	20	Yes	5	3	Yes	x	Multi seasonal interest with tan, exfoliating bark and red, orange/red fall color.
Amelanchier laevis 'Snowcloud,' Snowcloud Serviceberry	25	15	Yes	4	3	Yes		
Asimina triloba, Paw	30	20	Yes	5	1, 2, 3	N/A	x	Burgundy flower in spring before leaves.
Betula nigra 'Little King,' Little King River Birch	10	12	Yes	5	1, 2, 3	Yes		Suitable for enclosed vertical walls.
Carpinus caroliniana, American Hornbeam	25	20	Yes	5	1, 2, 3	Yes	x	Good fall color (variable – yellow, orange, red).
Cornus kousa x nuttallii 'Starlight,' Starlight Dogwood	20	20	Yes	4	3	Yes		
Lagerstroemia 'tuscarora,' Tuscarora Hybrid Crape Myrtle	20	20	Yes	4	3	Yes	x	Light cinnamon brown bark lends year round interest – drought resistant – likes a warm site.
Maackia amurensis, Amur Maackia	30	20	Yes	5	3	N/A	x	Exfoliating bark – flowering in June or July – varies in intensity from year to year.
Magnolia 'Elizabeth,' Elizabeth Magnolia	30	20	Yes	5	3	N/A	x	Yellowish to cream colored flower in spring.

Table E.19 (continued). Small Deciduous Trees.

Scientific and Common Name	Mature Height	Spread	Under Wires?	Min Strip Width	Planting Zone	Fall Color	SDOT List	Design Comments
Magnolia 'Galaxy,' Galaxy Magnolia	25	25	Yes	5	1, 2, 3	Yes	x	Suitable for enclosed vertical walls. Showy pink flowers.
Magnolia kobus 'Wada's Memory,' Wada's Memory Magnolia'	30	20	Yes	5	3	Yes	x	Drought tolerant. Does not flower well when young.
Malus 'Lancelot' ('Lanzam'), Lancelot Crabapple	15	15	Yes	4	3	Yes	x	Red flower buds, blooming white – red persistent fruit.
Parrotia persica, Persian Parrotia	30	20	No	5	3	Yes		Blooms before it leafs out – drought tolerant – Varied fall color – reds, oranges and yellows.
Frangula purshiana, Cascara	30	20	Yes	5	1, 2, 3	Yes	x	Facultative native species. Found in wetland and upland habitats. Can tolerate bioretention street tree environments; however, does not grow as well in narrow, hot ROW locations. Suitable for enclosed vertical walls.
Salix matsudana 'Tortuosa,' Corkscrew willow	30	15	Yes	5	1, 2, 3	Yes		Do not use with underdrain.
Stewartia pseudocamellia, Japanese Stewartia	25	15	Yes	5	3	Yes		Camellia-like flowers in summer. Interesting bark. Slow grower.
Styrax japonica, Japanese Snowbell	25	25	Yes	5	3	Yes	x	Reliable and easy to grow, it has plentiful, green 1/2-inch seeds. Flowers similar to lily in the valley.
Tilia cordata 'Chancole' or 'De Groot,' Chancellor or De Groot Littleleaf Linden	30+	20	No	C = 6, D = 5	3	Yes	x	Pyramidal when young. Fragrant flowers that attract bees. One of the smaller stature littleleaf lindens.

Biofiltration Swales

Table E.20. Plants Tolerant of Frequent Saturated Soil Conditions or Standing Water.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments	
						Application	Mowable
	DT		A	*Agrostis* spp.	Bentgrass	S	M
SEMI	DT	NWN		*Agrostis exarata*	Spike bentgrass	S	M
	DT		A	*Agrostis alba* or *gigantea*	Redtop	S	M
EG	DT		A	*Agrostis tenuis* or *capillaris*	Colonial bentgrass	S	M
EG				*Alopecurus aequalis*	Shortawn foxtail	S	M
EG				*Alopecurus geniculatus*	Water foxtail	S	M
EG			A	*Alopecurus pratensis*	Meadow foxtail	S	M
EG	DT	NWN		*Bromus carinatus*	California brome	S	M
SEMI				*Carex densa*	Dense sedge		
EG		NWN		*Carex obnupta*	Slough sedge		
SEMI				*Carex stipata*	Sawbeak sedge		
SEMI				*Eleocharis palustris*	Spike rush		
EG	DT	NWN		*Elymus glaucus*	Blue wildrye	S	M
EG	DT	NWN		*Elymus mollis*	Dune wildrye	S	M
		NWN		*Glyceria borealis*	Northern mannagrass		
		NWN		*Glyceria elata*	Tall mannagrass		
				Glyceria grandis	American mannagrass		
EG	DT		A	*Juncus effusus*	Soft (common) rush		
SEMI	DT			*Juncus patens*	Spreading rush		
SEMI	DT			*Juncus tenuis*	Slender rush		
EG			A	*Poa trivialis*	Rough-stalked bluegrass	S	M
SEMI		NWN		*Scirpus acutus*	Hardstem bulrush		
SEMI	DT	NWN		*Scirpus microcarpus*	Small-fruited bulrush		

EG = Evergreen

SEMI = Semi-evergreen

DT = Drought Tolerant/Resistant

NWN = Northwest Natives or Cultivars

A = Aggressive

S = Allowable as seed

M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Table E.21. Plants Suitable for the Upper Side Slopes of a Biofiltration Swale.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments	
						Application	Mowable
Groundcovers							
EG	DT	NWN	A	*Achillea millefolium*	Common yarrow		
	DT	NWN		*Arctostaphylos uva-ursi*	Kinnikinnick		
	DT	NWN		*Allium Cernum*	Nodding onion		
SEMI	DT			*Epimedium grandiflorum*	Epimedium		
EG	DT			*Euonymus fortunei*	Wintercreeper		
EG	DT	NWN	A	*Fragaria chiloensis*	Beach strawberry		
		NWN		*Lupinus latifolius*	Broadleaf lupine		
	DT			*Omphalodes verna*	Creeping forget-me-not		
EG	DT		A	*Rubus calycinoides*	Creeping raspberry		
EG	DT	NWN		*Sedum oreganum*	Oregon stonecrop		
EG	DT	NWN		*Sedum divergens*	Cascade stonecrop		
EG	DT		A	*Trifolium repens*	White lawn clover	S	M
Grasses (drought-tolerant, minimum mowing)							
EG				*Buchloe dactyloides*	Buffalo grass	S	M
EG	DT			*Festuca* spp. (e.g., Many Mustang, Silverado)	Dwarf tall fescues	S	M
EG				*Festuca amethystine*	Tufted fescue	S	
EG	DT		A	*Festuca arundinacea*	tall fescue grass	S	M
EG	DT			*Festuca ovina duriuscula* (e.g., Reliant, Aurora)	Sheep fescue		
EG	DT	NWN		*Festuca idahoensis*	Idaho fescue		
EG	DT	NWN	A	*Festuca rubra*	Creeping red fescue	S	M
EG	DT		A	*Festuca rubra var. commutata*	Chewings fescue	S	M
EG	DT			*Helictotrichon sempervirens*	Blue oatgrass		

EG = Evergreen

SEMI = Semi-evergreen

DT = Drought Tolerant/Resistant

NWN = Northwest Natives or Cultivars

A = Aggressive

S = Allowable as seed

M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Table E.22. Recommended Plants for Wet Biofiltration Swales.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments	
						Application	Mowable
SEMI	DT	NWN		*Agrostis exarata*	Spike bentgrass	S	M
EG	DT		A	*Agrostis tenuis* or *capillaris*	Colonial bentgrass	S	M
				Alopecurus aequalis	Shortawn foxtail	S	M
				Alopecurus geniculatus	Water foxtail	S	M
				Eleocharis spp.	Spike rush		
SEMI				*Carex densa*	Dense sedge		
EG		NWN		*Carex obnupta*	Slough sedge		
SEMI		NWN		*Carex stipata*	Sawbeak sedge		
				Carex spp.	Sedge		
EG	DT		A	*Festuca arundinacea var.*	Tall fescue grass	S	M
EG	DT	NWN	A	*Festuca rubra*	Creeping red fescue	S	M
				Glyceria occidentalis	Western mannagrass		
EG	DT		A	*Juncus effusus*	Soft (common) rush		
SEMI	DT			*Juncus patens*	Spreading rush		
SEMI	DT	NWN		*Juncus tenuis*	Slender rush		
EG			A	*Lolium perenne* – Var. dwarf	Dwarf ryegrass	S	
SEMI		NWN		*Oenanthe sarmentosa*	Water parsley		
SEMI		NWN		*Scirpus acutus*	Hardstem bulrush		
SEMI	DT	NWN		*Scirpus microcarpus*	Small-fruited bulrush		

EG = Evergreen

SEMI = Semi-evergreen

DT = Drought Tolerant/Resistant

NWN = Northwest Natives or Cultivars

A = Aggressive

S = Allowable as seed

M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 12′ mature width with openings of minimum 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Sand Filters

Table E.23. Recommended Plants for Sand Filters.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments	
						Application	Mowable
Basin Sides							
	DT	NWN		*Achillea millefolium*	Yarrow	S	
EG	DT			*Agrostis alba*	Redtop	S	M
EG	DT	NWN		*Agrostis exerata*	Spike bentgrass	S	M
EG	DT			*Agrostis palustris*	Creeping bentgrass	S	M
	DT			*Alopecurus pratensis*	Meadow foxtail	S	M
EG	DT	NWN		*Bromus carinatus*	California Brome	S	M
	DT	NWN		*Calamagrostis nutkaensis*	Pacific reed grass		
EG	DT	NWN		*Elymus glaucus*	Blue wildrye	S	M
EG	DT	NWN		*Elymus mollis*	Dune wildrye	S	M
EG	DT	NWN	A	*Juncus effusus*	Soft rush	S	
	DT	NWN		*Lupinus albicaulus*	Sickle keeled lupine	S	
EG	DT	NWN		*Luzula multiflora*	Field woodrush	S	
	DT		A	*Poa palustris*	Fowl bluegrass	S	M
EG			A	*Poa pratensis*	Kentucky bluegrass	S	M
Pond Bottom (Sand Surface)							
EG	DT			*Agrostis tenuis*	Colonial bentgrass (Highland strain good)	S	M
	DT			*Buchloe dactyloides*	Buffalo grass	S	M
	DT	NWN		*Camassia leichlinii or quamash*	camas		
EG	DT	NWN		*Carex mertensii*	Merten’s sedge	S	
EG	DT	NWN		*Festuca elatior (arundinacea)*	Tall fescue	S	M
EG	DT	NWN		*Festuca elatior* "Many Mustang,” "Silverado"	Dwarf tall fescues	S	M
EG	DT	NWN		*Fescue roemeri (idahoensis)*	Roemer’s or Idaho fescue	S	
EG	DT	NWN		*Festuca rubra*	Red fescue	S	M
SEMI	DT	NWN		*Iris missouriensis*	Rocky Mountain iris		
EG	DT	NWN		*Juncus tenuis*	Slender rush	S	
EG	DT			*Lolium perenne*	Perennial ryegrass	S	M
EG	DT	NWN		*Luzula parviflora*	Small flowered woodrush	S	
EG	DT			*Trifolium repens*	White lawn clover	S	M
EG	DT			*Zoysia tenuifolia*	Korean grass	S	M

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
S = Allowable as seed
M = Mowable

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Wet Ponds

Table E.24. Plants for Wet Pond Peripheries.

EG	DT	NWN	Agg[a]	Scientific Name	Common Name	BMP Comments: Application[b]	BMP Comments: Mature Height
Trees to Provide Shading[c]							
	DT	NWN		*Acer circinatum*	Vine maple	W	25′
				Betula nigra	River birch	W	40′
EG		NWN		*Myrica californica*	Pacific wax myrtle		18′
				Nyssa Sylvatica	Tupelo	W	40′
		NWN		*Oemleria cerasiformis*	Indian plum		10′
		NWN		*Prunus emarginata*	Wild cherry		40′
				Taxus brevifolia	Pacific yew		40′
EG	DT	NWN		*Thuja plicata*	Western red cedar	W	40′
Small Trees/High Shrubs with Fibrous Roots for Berms							
		NWN		*Acer circinatum*	Vine maple	W	25′
		NWN		*Amelanchier alnifolia*	Serviceberry		25′
EG	DT			*Arbutus unedo*	Strawberry tree		25′
		NWN		*Comus Stolonifera*	Red twig dogwood	W	20′
		NWN		*Corylus comuta* var. *cornuta*	Filbert		20′
		NWN		*Physocarpus capitatus*	Pacific ninebark		12′
		NWN	A	*Rubus spectabillis*	Salmonberry	W	8′
		NWN		*Sambucus racemosa*	Red elderberry		10′
				Vaccinium opulus	Highbush cranberry		10′
				Vaccinium spp.	Blueberry		4′–12′
Low Shrubs and Grasses with Fibrous Roots for Berms							
EG		NWN		*Arctostaphylos uva-ursi*	Kinnikinnick		0.5′
				Cistus spp.	Rock rose		2′–4′
SEMI		NWN		*Deschampsia cespitosa*	Tufted hairgrass		3′
EG	DT			*Festuca arundinacea*	tall fescue grass		3′
EG	DT			*Festuca ovina duriuscula* (e.g., Reliant, Aurora)	Sheep fescue		1′
		NWN		*Festuca rubra*	red fescue	W	0.5′
EG		NWN		*Gaultheria shallon*	Salal		4′
				Helictotrichon sempervirens	blue oatgrass		3′
EG		NWN		*Ledum groenlandicum*	Labrador tea	W	5′
				Polystichum munitum	sword fern	W	4′
		NWN	A	*Symphoricarpus albus*	Snowberry		5′
			(A)	e.g., *Miscanthis, Pennisetum*	Ornamental grasses		varies

EG = Evergreen
SEMI = Semi-evergreen
DT = Drought Tolerant/Resistant
NWN = Northwest Natives or Cultivars
A = Aggressive
W = Wet Tolerant

[a] Aggressive category indicates plants to be used with caution or avoided in confined sites (e.g., right-of-way plantings), near greenbelts, etc., due to maintenance concerns.

[b] Tolerant of occasional saturated soils or minimal inundation (<6″ depth) for short periods (<72 hours).

[c] If BMP has a liner, designer should review plants accordingly; trees generally are not appropriate to liner conditions.

Note: Plants with mature height over 3′ should be grouped in masses no wider than 8′ mature size with openings of min. 10′ between tall plant masses.

Note: Designer needs to respond to the size and aspect of the individual BMP when selecting plants to be used.

Note: Many factors contribute to waterfowl use of ponds and adjacent areas. Designers should investigate site-specific conditions and best practice methods to discourage waterfowl use as necessary.

E-10. Drywell Sizing Tables

For small projects with no approved off-site point of discharge (refer to *Volume 3*, *Section 4.3.2*), Table E.25, Table E.26, and Table E.27 specify the required area for drywells of 4-foot and 6-foot depths to be used as overflow/point of discharge downstream of a bioretention cell or a permeable pavement facility sized for the water quality treatment standard, pre-developed pasture standard, and the on-site stormwater management standard, respectively.

The minimum measured infiltration rate from a Small or Large Pilot Infiltration Test (PIT) that is required to use these tables is 0.25 inch per hour (in/hr).

Table E.25. Drywell Sizing Downstream of Bioretention Sized for Water Quality Treatment Standard or Permeable Pavement Facility.[c]

Contributing Area (sf)	Drywell Area (sf)[a, b, c]	
	Drywell Depth = 4 ft	Drywell Depth = 6 ft
500	27	19
1,000	98	67
1,500	164	115
2,000	240	169
2,500	314	222
3,000	390	278
3,500	468	336
4,000	548	396
4,500	630	459
5,000	713	524

[a] Sizing was performed using a 5-minute computational time-step and the "Seattle 38″ 158-year synthetic precipitation series.

[b] Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

[c] Bioretention and permeable pavement facilities must be sized per the pre-sized requirements in *Volume 3* based on the amount of contributing area.

Table E.26. Drywell Sizing Downstream of Bioretention Sized for the Pre-Developed Pasture Standard.[c]

Contributing Area (sf)	Drywell Area (sf)[a, b, c]	
	Drywell Depth = 4 ft	Drywell Depth = 6 ft
500	14	9
1,000	71	49
1,500	130	90
2,000	200	137
2,500	260	184
3,000	326	234
3,500	393	286
4,000	462	341
4,500	532	399
5,000	605	458

[a] Sizing was performed using a 5-minute computational time-step and the “Seattle 38” 158-year synthetic precipitation series.

[b] Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

[c] Bioretention and permeable pavement facilities must be sized per the pre-sized requirements in *Volume 3* based on the amount of contributing.

Table E.27. Drywell Sizing Downstream of Bioretention Sized for the On-Site Stormwater Management Standard.

Contributing Area (sf)	Bioretention Bottom Area (sf)[a,b]	Drywell Area (sf)[b,c]	
		Drywell Depth = 4 ft	Drywell Depth = 6 ft
500	9	56	39
1,000	17	99	68
1,500	30	170	119
2,000	44	249	178
2,500	60	332	238
3,000	76	417	299
3,500	94	501	361
4,000	112	587	424
4,500	131	665	488
5,000	151	753	544

[a] Bioretention design/modeling representation included 6 inches of ponding, 0.25 in/hr measured soil infiltration rate, 3H:1V BMP side slopes, a square bottom area, 12-inch bioretention soil thickness, 40 percent porosity, 3 in/hr bioretention soil infiltration rate, and a 12-inch overflow structure diameter.

[b] Sizing was performed using a 5-minute computational time-step and the "Seattle 38" 158-year synthetic precipitation series.

[c] Drywell was sized to reduce the 25-year peak discharge rate to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a square bottom area.

Table E.28 specifies the required area for drywells of 4-foot and 6-foot depths that are not located downstream of a bioretention cell or permeable pavement facility.

Table E.28. Drywell Sizing Without Bioretention or Permeable Pavement Facility Upstream.

Contributing Area (sf)	Drywell Area (sf)[a, b]	
	Drywell Depth = 4 ft	Drywell Depth = 6 ft
500	125	88
1,000	249	175
1,500	347	263
2,000	498	350
2,500	623	438
3,000	747	526
3,500	872	613
4,000	996	701
4,500	1,121	788
5,000	1,245	876

a Sizing was performed using a 5-minute computational time-step and the “Seattle 38” 158-year synthetic precipitation series.

b Drywell was sized to minimize the 25-year peak flow target to no more than 0.0001 cfs. Drywell design/modeling representation included a 4-foot or 6-foot depth, 25 percent porosity, 0.25 in/hr measured soil infiltration rate, and a variable length and width.

Drywells that do not meet the above design criteria and assumptions shall be sized to meet the requirements for projects with no offsite point of discharge per *Volume 3*, *Section 4.3.2*.

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City of Seattle

Appendix F - Hydrologic Analysis and Design

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

Table of Contents

Attachments

Tables

Figures

F-1. Introduction

This appendix presents hydrologic modeling concepts to support the design of stormwater best management practices (BMPs) that meet minimum requirements in the Stormwater Code and in *Volume 1 — Project Minimum Requirements*. This appendix includes descriptions of acceptable methods for estimating the quantity and hydrologic characteristics of stormwater runoff, and the assumptions and data requirements of these methods. Specifically, hydrologic tools and methods are presented for the following tasks:

- Calculating runoff hydrographs and time series using single-event and continuous rainfall runoff models.
- Calculating peak flows for conveyance, peak flow detention and retention, and water quality rate treatment BMPs.
- Calculating volumes for detention and retention and water quality volume treatment BMPs.
- Calculating flow durations for flow duration detention and retention based requirements.

Flow control and water quality performance standards are presented in *Volume 1*. BMP design requirements and specific modeling methods are provided in *Volume 3, Chapters 4 and 5*. Any request for alternative calculation methods shall follow the principles laid out in this appendix and be approved by the Director.

F-2. Applicability of Hydrologic Analysis Methods

The choice of a hydrologic analysis method depends on the type of facility being designed (conveyance, detention, or water quality) and the required performance standard. The size of the tributary area and watershed characteristics, including backwater effects, should also be considered.

Hydrologic analysis methods may be grouped into three categories:

- **Continuous rainfall-runoff models** use multi-decade precipitation and evaporation time series as input to produce a corresponding multi-decade time series of runoff. Continuous models are used to size stormwater management facilities to meet peak or flow duration performance standards and water quality treatment requirements. Discharge rates computed with continuous models may also be used to size conveyance facilities.
- **Single-event rainfall-runoff models** simulate rainfall-runoff for a single storm, typically 2 hours to 72 hours in length, and usually of a specified exceedance probability (recurrence interval). Single-event methods are applicable for sizing conveyance facilities.
- The **rational method** is appropriate for designing conveyance systems that receive runoff from small, quickly responding areas (less than 10 acres) where short, intense storms generate the highest peak flow. This method only produces a flow peak discharge rate, and routing effects are not included. Advantages of this method are that it is easy to apply and generally produces conservative results. For larger, more complex basins, routing and timing of the flood peaks becomes more important and single-event or continuous rainfall-runoff modeling is required.

The applicability of each method is summarized in Table F.1.

Table F.1. Hydrologic Analysis Method Applicability.

Method	Applicable Models	Constraints	On-site BMP Sizing	FC BMP Sizing	WQ BMP Sizing	Conveyance Sizing	TESC Design Flow Sizing
Continuous Rainfall-runoff Modeling	• HSPF • MGSFlood[a] • WWHM • Other[b]	Refer to Table F.12 for time step requirements	✓	✓	✓	✓	✓
Single-event Rainfall-runoff Modeling	• NRCS TR-55 • SBUH • StormShed • Corps of Engineers HMS and HEC-1 • EPA SWMM, PCSWMM, and XP-SWMM • Other models approved by the Director	Refer to Table F.14	NA	NA	NA	✓	✓
Rational Method	NA	<10 acres (measured to individual conveyance elements) Upstream of storage routing and backwater effects	NA	NA	NA	✓	✓

[a] Refer to the *Approval Status of Continuous Simulation Models* section of the SWMMWW for a list of currently approved models.

[b] The following continuous hydrologic models may also be used for project-specific situations: EPA SWMM5, ModFlow, HMS, PCSWMM, and other models approved by the Director.

BMP – Best Management Practice
FC – Flow Control
HSPF – Hydrologic Simulation Program Fortran (US EPA)
NA – Not Applicable
NRCS – Natural Resources Conservation Service
On-site – On-site Stormwater Management
SBUH – Santa Barbara Urban Hydrograph
SWMM – Storm Water Management Model
TESC – Temporary Erosion and Sediment Control
WQ – Water Quality
WWHM – Western Washington Hydrology Model
✓ = acceptable

F-3. General Modeling Guidance

This section includes general modeling guidance that may apply to all hydrologic analysis methods, including both continuous modeling and single-event modeling using historical precipitation data, watershed characterization, hydrologic soil groups, infiltration equations, and outfalls.

Historical Precipitation Data

Data collected from the Seattle Public Utilities (SPU) rain gauge network may be used in rainfall runoff models to aid in the design process by replicating past floods, to investigate anecdotal flood information, or for use in model calibration. Use of the historical time series is recommended, but is not required for the design of stormwater BMPs.

Continuous historical precipitation data are available from 17 active and 2 closed rain gauges from January 1978 through the present at a time step of 1 minute. Active and closed gauge names and locations are summarized in Table F.2 and active locations are summarized on Figure F.1. Continuous Rainfall-Runoff Methods (*Section F-4*) and Single-event Rainfall-runoff Methods (*Section F-5*) provide additional detail regarding selection of precipitation data.

Table F.2. City of Seattle Rain Gauge Stations.

Station ID	Station Name	Period of Record	Status
45-S001	Haller Lake Shop	1978 – current	Active
45-S002	Magnusson Park	1978 – current	Active
45-S003	UW Hydraulics Lab	1978 – current	Active
45-S004	Maple Leaf Reservoir	1978 – current	Active
45-S005	Fauntleroy Ferry Dock	1978 – current	Active
45-S007	Whitman Middle School	1978 – current	Active
45-S008	Ballard Locks	1978 – current	Active
45-S009	Woodland Park Zoo	1978 – current	Active
45-S010	Rainier View Elementary	1978 – 2008	Closed
45-S011	Metro-KC Denny Regulating	1978 – current	Active
45-S012	Catherine Blaine Elementary School	1978 – current	Active
45-S014	Lafayette Elementary School	1978 – current	Active
45-S015	Puget Sound Clean Air Monitoring Station	1978 – current	Active
45-S016	Metro-KC E Marginal Way	1978 – current	Active
45-S017	West Seattle Reservoir Treatment Shop	1978 – current	Active
45-S018	Aki Kurose Middle School	1978 – current	Active
45-S020	TT Minor Elementary	1978 – 2010	Closed
RG25	Garfield Community Center	2010 – current	Active
RG30	SPL Rainier Beach Branch	2009 – current	Active

Watershed Characterization

Prior to conducting any detailed stormwater runoff calculations, the overall relationship between the proposed project site and upstream and downstream off-site areas must be considered. The general hydrologic characteristics of the project site dictate the amount of runoff that will occur and where stormwater facilities can be placed. It is important to identify the stormwater destination point, including potential backwater effects. Drainage patterns and contributing areas can be determined from preliminary surveys of the area, available topographic contour maps, and SPU drainage system maps. Note that the drainage systems often cross topographic divides within the City of Seattle. Maps can be obtained from the City's GIS web page (www.seattle.gov/utilities/services/gis).

Calculation of Total Impervious Area

Impervious coverage for proposed development must be estimated. Impervious coverage of streets, sidewalks, hard surface trails, etc., shall be taken from plans of the site. Refer to *Volume 1*, *Appendix A*, and the Stormwater Code for definitions and descriptions of all surfaces that must be considered. Impervious coverage for off-site areas contributing flow to the site can be estimated from orthophotos available through GIS.

Calculation of Effective Impervious Area

Effective impervious surface is the fraction of impervious surface connected to a drainage system and is used in hydrologic simulations to estimate runoff. The effective impervious area is the total impervious area multiplied by the effective impervious fraction. Non-effective impervious surface is assumed to have the same hydrologic response as the immediately surrounding pervious area. For the existing condition modeling, areas with unconnected rooftops may be estimated from visual survey as approved by the Director.

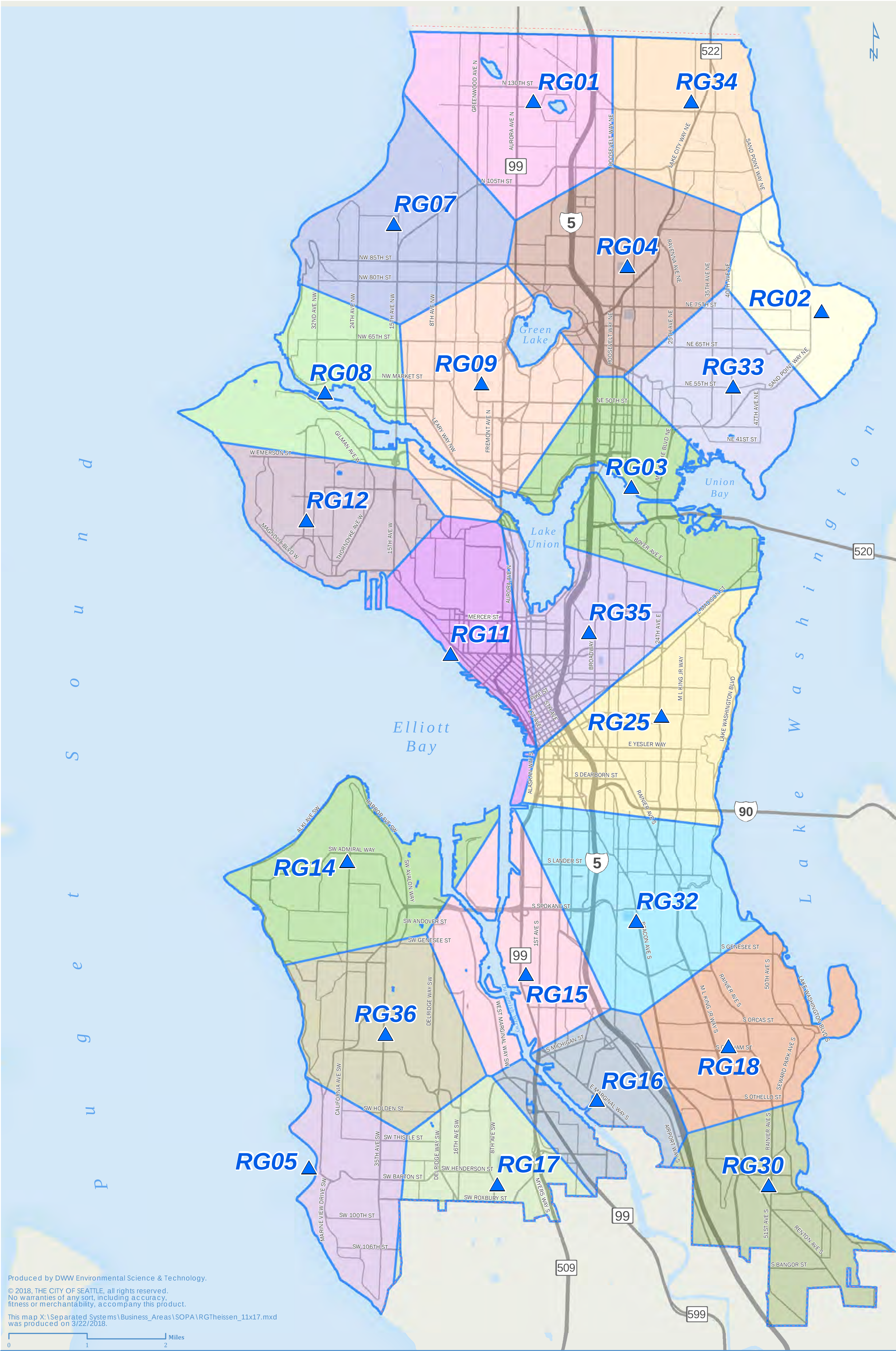


Figure F-1. Active City Rain Gauge Network Stations.

Soil and Infiltration Parameters

Hydrologic Soil Groups

Hydrologic soil groups for common soil types in the Seattle area are listed in Table F.3.

Infiltration Equations

When computing runoff in models other than those based on HSPF, an infiltration soil loss method should be used. Examples of infiltration methods include the Green-Ampt (Rawls et al. 1993), Philip (Rawls et al. 1993), and Holtan (Holtan 1961) methods. These methods are incorporated into several commonly available computer programs including StormShed, PCSWMM, HEC HMS, and HEC-1. The City recommends the use of Green-Ampt method; however, the other methods listed above can also be used based on project-specific situations.

Table F.3. Hydrologic Soil Group Definition for Common Soils in King County.

Soil Group	Hydrologic Group	Soil Group	Hydrologic Group
Alderwood	C	Orcas Peat	D
Arents, Alderwood Material	C	Oridia	D
Arents, Everett Material	B	Ovalt	C
Beausite	C	Pilchuck	C
Bellingham	D	Puget	D
Briscot	D	Puyallup	B
Buckley	D	Ragnar	B
Coastal Beaches	Variable	Renton	D
Earlmont Silt Loam	D	Riverwash	Variable
Edgewick	C	Salal	C
Everett	A	Sammamish	D
Indianola	A	Seattle	D
Kitsap	C	Shacar	D
Klaus	C	Si Silt	C
Mixed Alluvial Lan	Variable	Snohomish	D
Nellton	A	Sultan	C
Newberg	B	Tukwila	D
Nooksack	C	Urban	Variable
Normal Sandy Loam	D	Woodinville	D

Table F.3 (continued). Hydrologic Soil Group Definition for Common Soils in King County.

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

Source: TR-55 (NRCS 1986), Exhibit A-1. Revisions made from Soil Conservation Service (SCS), Soil Interpretation Record, Form #5, September 1988.

Green-Ampt Equation

The Green-Ampt model calculates cumulative infiltration by assuming water flow into a vertical soil profile like a piston flow.

$$f_t = K(\frac{\psi\Delta\theta}{F_t} + 1) \quad (1)$$

$$F_{t+\Delta t} = F_t + K\Delta t + \psi\Delta\theta \ln[\frac{F_{t+\Delta t} + \psi\Delta\theta}{F_t + \psi\Delta\theta}] \quad (2)$$

Where:

f_t = infiltration rate (mm/hr or in/hr)

ψ = initial matric potential of the soil (mm or inches)

$\Delta\theta$ = difference of soil water content after infiltration with initial water content

K = hydraulic conductivity (mm/hr or in/hr)

F_t = cumulative infiltration at time t (mm or inches)

$F_{t+\Delta t}$ = cumulative infiltration at time t+Δt (mm or inches)

Δt = time incremental (hours)

Equation (1) is used for determining ponding situation and (2) is used for calculating the cumulative infiltration after ponding. Trial and error method is the most popular method to solve equation (2) (Chow et al. 1988). Parameters ψ , $\Delta\theta$, and K were tabulated by Chow et al. (1988) for all soil classes. Chow et al. (1988) developed a procedure to solve infiltration with changing rainfall intensity by Green-Ampt method in a table. However, since it simplifies the water movement as a piston flow, the wetting front is distorted.

Typical values suggested by Rawls, Brakensiek, and Miller (as reflected in Chow et al. 1988) are shown in Table F.4 below.

Table F.4. Green-Ampt Infiltration Parameters.

USDA Soil Classification	Suction Head ψ		Hydraulic Conductivity *K*		Porosity	Effective Porosity θ_e
	(mm)	(in/hr)	(mm/hr)	(in/hr)		
Sand	49.5	1.95	117.8	4.64	0.437	0.417
Loamy Sand	61.3	2.42	29.9	1.18	0.437	0.401
Sandy Loam	110.1	4.34	10.9	0.43	0.453	0.412
Loam	88.9	3.50	3.4	0.13	0.463	0.434
Silt Loam	166.8	6.57	6.5	0.26	0.501	0.486
Sandy Clay Loam	218.5	8.61	1.5	0.06	0.398	0.330
Clay Loam	208.8	8.23	1.0	0.04	0.464	0.309
Silty Clay Loam	273.0	10.76	1.0	0.04	0.471	0.432
Sandy Clay	239.0	9.42	0.6	0.02	0.430	0.321
Silty Clay	292.2	11.51	0.5	0.02	0.479	0.423
Clay	316.3	12.46	0.3	0.01	0.475	0.385

in/hr – inches per hour
mm – millimeters
mm/hr – millimeters per hour
USDA – United States Department of Agriculture

Holtan's Equation

The empirical infiltration equation devised by Holtan (1961) is explicitly dependent on soil water conditions in the form of available pore space for moisture storage:

$$F = (GI)(AH)\ SMD^{IEXP} + FC \qquad (3)$$

Where:

F = surface infiltration rate at a given time (in/hr)

GI = Growth Index representing the relative maturity of the ground cover (0 for newly planted, 1 for mature cover)

AH = constant as specified below

SMD = soil moisture deficit at a given time (inches)

IEXP = infiltration exponent (default value is 1.4)

FC = minimum surface infiltration rate (in/hr) and occurs when SMD equals zero

Parameters GI, AH, FC, and the initial soil moisture deficit (SMD0) are the principal input parameters and can be determined as follows:

- GI is typically set to 1.0 to represent mature ground cover.
- AH can be determined from Table F.5.

- FC can be approximated from Table F.6 or by using the saturated hydraulic conductivity, which is available from soil survey reports.

Table F.5. Estimates of Holtan AH.

Land Use or Cover	Base Area Rating[a]	
	Poor Condition	Good Condition
Fallow[b]	0.10	0.30
Row crops	0.10	0.20
Small grains	0.20	0.30
Hay (legumes)	0.20	0.40
Hay (sod)	0.40	0.60
Pasture (bunchgrass)	0.20	0.40
Temporary pasture (sod)	0.40	0.60
Permanent pasture (sod)	0.80	1.00
Woods and forests	0.80	1.00

[a] Adjustments needed for "weeds" and "grazing."

[b] For fallow land only, "poor condition" means "after row crop," and "good condition" means "after sod."

Source: Holtan et al. (1975)

Table F.6. Estimates of Holtan FC Values.

NRCS Hydrologic Soil Group	Minimum Infiltration Rates FC (inches/hour)
A	0.30–0.45
B	0.15–0.30
C	0.05–0.15
D	< 0.05

Source: Musgrave (1955)

This equation has been found to be suitable for inclusion in catchment models because of soil water dependence, and satisfactory progress has been reported for runoff predictions (Dunin 1976).

Kostiakov's Equation

Kostiakov (1932) proposed the following equation for estimating infiltration:

$$i(t) = \alpha t^{-\beta} \tag{4}$$

Where:
t = time
i = infiltration rate
α= empirical constant ($\alpha > 0$)
β= empirical constant ($0 < \beta < 1$)

Upon integration from 0 to t, equation (4) yields equation (5), which is the expression for cumulative infiltration, I(t):

$$I(t) = \frac{\alpha}{1-\beta} t^{(1-\beta)} \tag{5}$$

Where: I(t) = cumulative infiltration

The constants α and β can be determined by curve-fitting equation (5) to experimental data for cumulative infiltration, I(t). Since infiltration rate (i) becomes zero as $t \to \infty$, rather than approach a constant non-zero value, Kostiakov proposed that equations (4) and (5) be used only for $t < t_{\max}$ where $t_{\max}$ is equal to $(\alpha / K_s)^{(1/\beta)}$, and K_s is the saturated hydraulic conductivity of the soil. Kostiakov's equation describes the infiltration quite well at smaller times, but becomes less accurate at larger times (Philip 1957a and 1957b; Parlange and Haverkamp 1989).

Horton's Equation

Horton (1940) proposed to estimate infiltration in the following manner,

$$i(t) = i_f + (i_0 - i_f)e^{-\gamma t} \tag{6}$$

and

$$I(t) = i_f t + \frac{1}{\gamma}(i_0 - i_f)(1 - e^{-\gamma t}) \tag{7}$$

Where:
i_0 = measured infiltration rate
i_f = final infiltration rate
γ = empirical constant

It is readily seen that i(t) is non-zero as t approaches infinity, unlike Kostiakov's equation. It does not, however, adequately represent the rapid decrease of i from very high values at small t (Philip 1957a and 1957b). It also requires an additional parameter over the Kostiakov equation. Parlange and Haverkamp (1989), in their comparison study of various empirical infiltration equations, found the performance of Horton's equation to be inferior to that of Kostiakov's equation.

Mezencev's Equation

In order to overcome the limitations of Kostiakov's equation for large times, Mezencev (Philip 1957a and 1957b) proposed the following as modifications to equations (4) and (5). Mezencev proposed infiltration estimated by:

$$i(t) = i_f + \alpha t^{-\beta} \tag{8}$$

and

$$I(t) = i_f t + \frac{\alpha}{1-\beta} t^{(1-\beta)} \tag{9}$$

Where: i_f = final infiltration rate at steady state

Outfalls

Outfalls to Lakes and the Ship Canal

Single-event hydraulic analysis of outfalls that discharge to lakes and the Ship Canal should be performed using high water surface elevation from the observed record. This assumption may lead to conservative results and it is recommended that the designer consider using continuous simulation with a varying receiving water level. Table F.7 shows the maximum observed water levels in Seattle lakes. Water levels may vary from year to year due to sedimentation and season.

For continuous simulations, the designer may choose to use the historical record or the highest observed elevations. Lake Washington and associated waters are controlled at the Hiram M. Chittenden Locks by the US Army Corps of Engineers (USACE). Refer to the USACE Reservoir Control Center website (www.nwd-wc.usace.army.mil/nws/hh/www/index.html) for Lake Washington Ship Canal data and note that elevations given are in USACE datum and should be converted to NAVD88 before use.

Table F.7. Physical Characteristics of Seattle Lakes.

	Bitter Lake	Haller Lake	Green Lake	Lake Union	Lake Washington
Water surface elevation (feet, NAVD88)[a]	434.4	376.9	164.3	16.8	18.6
Maximum depth (feet)[b]	31.0	36.0	30.0	50.0	214
Mean depth (feet)[b]	16.0	16.0	13.0	34.0	108
Area (acres)[b]	19.0	15.0	259	580	21,500

[a] SPU Engineering Support Division – Survey Field Books, measurements were all converted to NAVD88 from the old City of Seattle Vertical Datum based on a conversion factor of 9.7 feet.

[b] Sources: King County (2015) and King County (2016).

Note: Water levels may vary from year to year by as much as 3 feet.

Tidal Influence/Sea Level Rise

When utilizing single-event hydraulic analysis of the drainage system or combined sewer system with outfalls that discharge to the tidally influenced Duwamish River or Puget Sound, the highest observed tide from the observed record shall be used. Match the peak rainfall intensity to a tide cycle simulation with a peak of 12.14 feet (NAVD88). This assumption may lead to conservative results and it is recommended that the designer consider using continuous simulation with a varying receiving water level.

For continuous simulations, the designer should match, by time, the historical tidal record to the historical rainfall record. For rainfall simulations where there is no observed tidal elevation, use of a tide predictor is recommended. Tidal information is available from National Oceanic and Atmospheric Administration (NOAA) (http://tidesandcurrents.noaa.gov) and from the US Army Corps of Engineer's (www.nws.usace.army.mil/About/Offices/Engineering/HydraulicsandHydrology/HistoricalDatumRegions.aspx). The tidal boundary is simulated as a water surface elevation time series computed using astronomical tide theory (NOAA 1995).

Sea level is rising, and for both continuous and single-event modeling, the designer should evaluate the risks depending on the project design life and objectives. Since 1899, the observed trend was a rise of 2.06 mm per year, which is equivalent to 8 inches in 100 years. The effect of climate change on predicted sea level rise is expected to greatly exceed that rate, but there is uncertainty regarding timing and severity. The Washington Costal Resilience Project (Miller et al. 2018) represents the best available science on sea level rise. The report provides local projections at various likelihoods and time frames (see Figure F.2). For Seattle, the central estimate (i.e., 50 percent probability) is 1.9 to 2.3 feet of rise by 2100, and 3.0 to 3.9 feet by 2150. Upper-end estimates (1 percent probability) project 5.1 feet of rise by 2100, and 10.4 feet of rise by 2150.

For design of tidally impacted public drainage system and public combined sewer system, hydraulic analysis of sea level rise is required. For other projects, it is recommended that designers analyze risk by adjusting the tidal record upwards by 1 to 4 feet, depending on the design life and risk tolerance of the project. Likewise, designers should look to further mitigate risk by considering current design adjustments or identifying possible future modifications. For design of facilities where water level elevation at the outfall is critical, the City recommends that the designer consider storm surge due to low atmospheric pressure and/or wind and wave action.

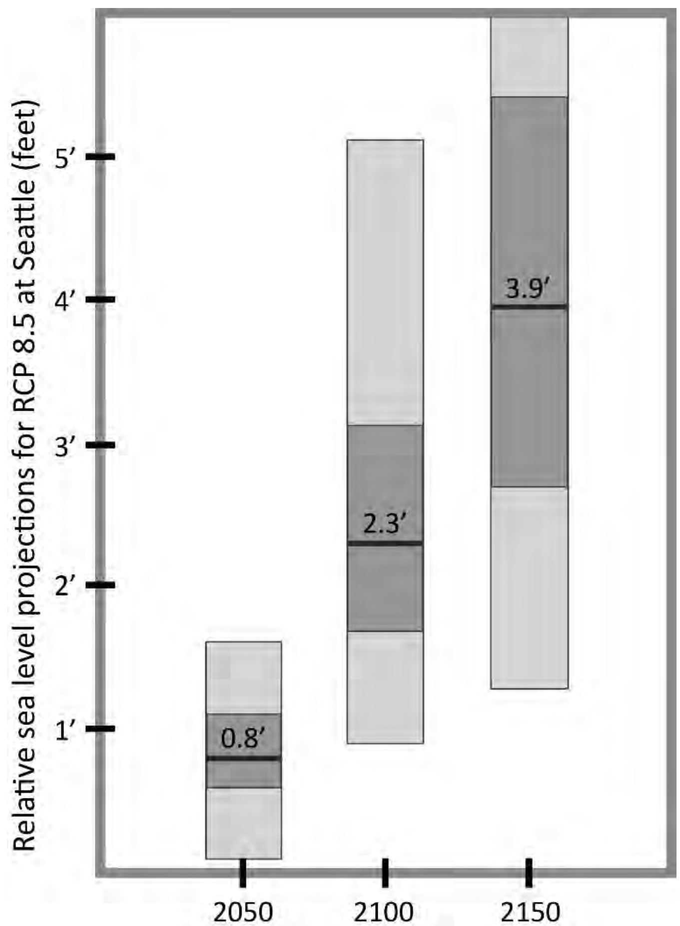


Figure F.2. Projected Sea Level Rise in Washington's Waters Relative to Year 2050.

F-4. Continuous Rainfall-Runoff Methods

This section includes specific modeling guidance that is applicable to continuous rainfall-runoff methods including precipitation input, land cover categorization, soil parameters, infiltration parameters, and modeling guidance.

Precipitation Input

Continuous rainfall-runoff models use multi-year inputs of precipitation and evaporation to compute a multi-year time series of runoff from the site. Using precipitation input that is representative of the site under consideration is critical for the accurate computation of runoff and the design of stormwater facilities.

Two types of precipitation and evaporation data are available for stormwater analysis. The first type is a design precipitation and evaporation time series. The design time series are appropriate for design and analysis of stormwater facilities and were developed by combining and scaling records from distant precipitation stations. The second type of time series is historical precipitation and evaporation time series (described in *Section F-3 — General*

Modeling Guidance). Because the record length of the historical precipitation and evaporation is relatively short, this data should be used for model calibration and not for design.

The City of Seattle Design Time Series consists of a precipitation and evaporation time series that are representative of the climatic conditions in the City of Seattle. The design precipitation time series was developed by combining and scaling precipitation records from widely separated stations to produce an “extended precipitation time series” with a 158-year record length (Schaefer and Barker 2002; Schaefer and Barker 2007). The precipitation scaling was performed such that the scaled precipitation record would possess the regional statistics at durations of 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, 45 minutes, 60 minutes, 2 hours, 6 hours, 24 hours, 3 days, 10 days, 30 days, 90 days, 6 months, and 12 months (Refer to www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code for modeling resources). The precipitation time series was developed at a 5-minute time step. For modeling of the combined sewer system, a shorter precipitation record length may be approved by the Director.

The evaporation time series was developed using a stochastic evaporation generating approach whereby daily evaporation was generated in a manner to preserve the daily and seasonal variability and accounting for differences observed on days with and without rainfall. The evaporation time series was developed from data collected at the Puyallup 2 West Experimental Station (station number 45-6803). Refer to www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/stormwater-code for modeling resources. The evaporation time series has a 1-hour time step.

Land Cover Categorization

Continuous hydrologic models based on HSPF (e.g., WWHM and MGSFlood) include five land cover types: forest, pasture, lawn (or grass), wetland, and impervious. These cover types shall be applied as specified in Table F.8.

Soil and Infiltration Parameters

Soil Mapping

Mapping of soil types by the Natural Resources Conservation Service (NRCS), or the Washington Department of Natural Resources Geologic Information Portal (www.dnr.wa.gov/geologyportal) may be used as a source of soil/geologic information for use in continuous hydrologic modeling. If using NRCS maps, each soil type defined by the NRCS has been classified into one of four hydrologic soil groups; A, B, C, and D. Table F.3 shows hydrologic soil groups for common soil types in King County. As is common practice in hydrologic modeling in western Washington, the soil groups used in the model generally correspond to the hydrologic soil groups as shown in Table F.9.

Table F.8. Continuous Model Land Cover and Areas of Application.

Continuous Model Land Cover	Application	
	Pre-Developed	**Post-Developed**
Forest	All forest/shrub cover, irrespective of age	All permanent (e.g., protected by covenant) onsite forest/shrub cover, irrespective of age planted at densities sufficient to ensure 80%± canopy cover within 5 years.
Pasture	All grassland, pasture land, lawns, and cultivated or cleared area except for lawns in redevelopment areas with pre-development densities greater than 4 DU/GA	● All areas that are amended using implementation options 2, 3, or 4 from *Volume 3, Section 5.1.5.2* may be modeled as pasture rather than lawn (WWHM) or grass (MGSFlood). ● Unprotected forest in rural residential development shall be considered half pasture, half grass.
Lawn (or Grass)	Lawns in redevelopment areas with pre-development densities greater than 4 DU/GA	● All post-development grassland and landscaping that is not amended using implementation options 2, 3, or 4 from *Volume 3, Section 5.1.5.2.* ● All onsite forested land not protected by covenant.
Wetland	All delineated wetland areas	All delineated wetland areas
Impervious	● All impervious surfaces, including heavily compacted gravel and dirt roads, parking areas, etc. ● Open receiving waters (ponds and lakes)	● All impervious surfaces (with and without underdrains), including heavily compacted gravel and dirt roads, parking areas, etc. ● Pervious surfaces with underdrains ● Open receiving waters (ponds, lakes, and onsite detention ponds, and wet ponds)

BMP – Best Management Practice

DU/GA – Dwelling Unit per Gross Acre

Table F.9. Relationship Between Hydrologic Soil Group and Continuous Model Soil Group.

Hydrologic Soil Group	Continuous Model Soil Group
A	Outwash
B	Till or Outwash
C	Till
D	Wetland

Type B soils can be classified as either glacial till or outwash depending on the type of soil under consideration. Type B soils underlain by glacial till or bedrock, or with a seasonally high water table would be classified as till. Conversely, well-drained B type soils would be classified as outwash.

The NRCS maps may not be used for determining infiltration capacity or a design infiltration rate.

Infiltration Parameters

The following discussion on HSPF model parameters applies to the use of continuous modeling (e.g., WWHM, MGSFlood). Default model parameters that define interception, infiltration, and movement of moisture through the soil, are based on work by the United States Geological Survey (USGS) (Dinicola 1990, 2001) and King County (2009). Pervious areas have been grouped into three land cover categories (forest, pasture, and lawn) and three soil/geologic categories (till, outwash, and saturated/wetland soil) for a total of seven cover/soil type combinations as shown in Table F.10. The combinations of soil type and land cover are called pervious land segments or PERLNDs. Default runoff parameters for each PERLND are summarized in Table F.11. These parameter values are used automatically by WWHM and MGSFlood programs for each land use type. A complete description of the PERLND parameters can be found in the HSPF User Manual (US EPA 2001). For a general discussion of infiltration equations refer to *Section F-3 — General Modeling Guidance*.

Table F.10. Pervious Land Soil Type/Cover Combinations used with HSPF Model Parameters.

Pervious Land Soil Type/Cover Combinations
1. Till/Forest
2. Till/Pasture
3. Till/Lawn
4. Outwash/Forest
5. Outwash/Pasture
6. Outwash/Lawn
7. Saturated Soil/All Cover Groups

Modeling Guidance

Computational Time Step Selection

An appropriate computational time step for continuous hydrologic models depends on the type of facility under consideration and the characteristics of the tributary watershed. In general, the design of facilities dependent on peak discharge require a shorter time step than facilities dependent on runoff volume. A longer time step is generally desirable to reduce the overall simulation time provided that computational accuracy is not sacrificed. Table F.12 summarizes the allowable computational time steps for various hydrologic design applications.

HSPF Parameter Modification

In HSPF (and MGSFlood and WWHM) pervious land categories are represented by PERLNDs and impervious land categories are represented by IMPLNDs. The only PERLND and IMPLND parameter values that should be adjusted by the user are LSUR (length of surface overland flow plane in feet), SLSUR (slope of surface overland flow plane in feet/feet), and NSUR (roughness of surface overland flow plane). The default HSPF parameter values in MGSFlood and WWHM are appropriate for large sites that are not typical for City of Seattle projects. Users are required to change the values for LSUR, SLSUR, and NSUR per guidance in

Table F.11 or adjust values for LSUR, SLSUR, and NSUR based on site-specific observations. Any changes made to parameter values noted in in Table F.11 shall be recorded in the model output report and included with a project submittal.

Table F.11. Required Runoff Parameter Values for Each Pervious Land Segment (PERLND) and Impervious Land Segment (IMPLND).

	Pervious Land Segment (PERLND)							
	Till Soil			Outwash Soil			Saturated Soil	
Parameter	Forest	Pasture	Lawn	Forest	Pasture	Lawn	Forest, Pasture, or Lawn	Impervious Land Segment (IMPLND)
LZSN	4.5	4.5	4.5	5.0	5.0	5.0	4.0	NA
INFILT	0.08	0.06	0.03	2.0	1.6	0.8	2.0	NA
LSUR[a]	$2 * \sqrt{Contributing\ Area\ (square\ feet)}$							
SLSUR[a]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
KVARY	0.5	0.5	0.5	0.3	0.3	0.3	0.5	NA
AGWRC	0.996	0.996	0.996	0.996	0.996	0.996	0.996	NA
INFEXP	2.0	2.0	2.0	2.0	2.0	2.0	10.0	NA
INFILD	2.0	2.0	2.0	2.0	2.0	2.0	2.0	NA
BASETP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA
AGWETP	0.0	0.0	0.0	0.0	0.0	0.0	0.7	NA
CEPSC	0.2	0.15	0.1	0.2	0.15	0.1	0.1	NA
UZSN	0.5	0.4	0.25	0.5	0.5	0.5	3.0	NA
NSUR[a]	0.35	0.3	0.25	0.35	0.3	0.25	0.5	0.02
INTFW	6.0	6.0	6.0	0.0	0.0	0.0	1.0	NA
IRC	0.5	0.5	0.5	0.7	0.7	0.7	0.7	NA
LZETP	0.7	0.4	0.25	0.7	0.4	0.25	0.8	NA
RETSC	NA	NA	NA	NA	NA	NA	NA	0.1

[a] LSUR, SLSUR, and NSUR parameter values shall be adjusted based on site-specific observations.

LZSN = lower zone storage nominal (inches)
INFILT = infiltration capacity (in/hr)
LSUR = length of surface overland flow plane (feet)
SLSUR = slope of surface overland flow plane (feet/feet)
KVARY = groundwater exponent variable (inch -1)
AGWRC = active groundwater recession constant (day -1)
INFEXP = infiltration exponent
INFILD = ratio of maximum to mean infiltration
BASETP = base flow evapotranspiration (fraction)
AGWETP = active groundwater evapotranspiration (fraction)
CEPSC = Interception storage (inches)
UZSN = upper zone storage nominal (inches)
NSUR = roughness of surface overland flow plane (Manning's n)
INTFW = interflow index
IRC = interflow recession constant (day $^{-1}$)
LZETP = lower zone evapotranspiration (fraction)
RETSC = retention storage capacity (in)
NA = not applicable

Table F.12. Required Continuous Simulation Model Computational Time Step for Various Stormwater Facilities.

Type of Analysis	Maximum Time Step
Conveyance Sizing (Off-site)	5 minutes[a]
Conveyance Sizing Upstream of Stormwater Detention Facility (Onsite), TESC Design Flows	5 minutes[a]
Conveyance Sizing Downstream of Stormwater Detention Facility (Onsite), TESC Design Flows	15 minutes
Downstream Analysis, Off-site	5 minutes[a]
Flow Control (Detention and/or Infiltration) Facility and On-site BMP Sizing	5 minutes[a]
Water Quality Design Flow Rate	15 minutes
Water Quality Design Flow Volumes/Pollutant Loading	1 hour

[a] A 15-minute time step may be used if the time of concentration computed is 30 minutes or more (refer to *Time of Concentration Estimation* in *Section F-5*).

Steps for Hydrologic Design Using Continuous Rainfall-Runoff Models

This section presents the general process involved in conducting hydrologic analyses using continuous models. The actual design process will vary considerably depending on the project scenario, the applicable requirements, the facility being designed, and the environmental conditions.

Step #	Procedure
C-1	Review all minimum requirements that apply to the proposed project (*Volume 1*)
C-2	Review applicable site assessment requirements (*Volume 1, Chapter 7*)
C-3	Identify and delineate the overall drainage basin for each discharge point from the development site under existing conditions: • Identify existing land use • Identify existing soil types using onsite evaluation, NRCS soil survey, or mapping performed by the University of Washington (http://geomapnw.ess.washington.edu) • Convert hydrologic soil types to HSPF soil classifications (till, outwash, or wetland) • Identify existing drainage features such as streams, conveyance systems, detention facilities, ponding areas, depressions, etc.
C-4	Select and delineate pertinent subbasins based on existing conditions: • Select homogeneous subbasin areas • Select separate subbasin areas for onsite and off-site drainage • Select separate subbasin areas for major drainage features
C-5	Determine hydrologic parameters for each subbasin under existing conditions, if required: • Determine appropriate rainfall time series. For most design applications, the City of Seattle Design Time Series will be required. • Categorize soil types and land cover • Determine total and effective impervious areas within each subbasin • Determine areas for each soil/cover type in each subbasin • Select the required computational time step according to Table F.12
C-6	Compute runoff for the pre-developed condition. The continuous hydrologic model will utilize the selected precipitation time series, compute runoff from each subbasin, and route the runoff through the defined network. Flood-frequency and flow duration statistics will subsequently be computed at points of interest in the study area by the model.

Step #	Procedure
C-7	Determine hydrologic parameters for each subbasin under developed conditions: • Utilize rainfall time series selected for existing conditions • Categorize soil types and land cover • Determine total and effective impervious areas within each subbasin • Determine areas for each soil/cover type in each subbasin • Utilize computational time step selected for existing conditions
C-8	Compute runoff for the developed condition. The continuous hydrologic model will utilize the selected precipitation time series, compute runoff from each subbasin, and route the runoff through the defined network. Flood-frequency and flow duration statistics will subsequently be computed at points of interest in the study area by the model.

Additional design steps specific to flow control and water quality treatment facility design are described below.

Flow Control Facility Design

Peak Standard

Peak flow control-based standards require that the stormwater facilities be designed such that the post-development runoff peak discharge rate is controlled to one or more discharge rates, usually at specified recurrence intervals. An example of this type of standard is the Peak Flow Control Standard.

Flood-frequency analysis seeks to determine the flood flow or water surface elevation with a probability (p) of being equaled or exceeded in any given year. Return period (T_r) or recurrence interval is often used in lieu of probability to describe the frequency of exceedance of a flood of a given magnitude. Return period and annual exceedance probability are reciprocals (equation 10). Flood-frequency analysis is most commonly conducted for flood peak discharge and peak water surface elevation but can also be computed for maximum or minimum values for various durations. Flood-frequency analysis as used here refers to analysis of flood peak discharge or peak water surface elevation.

$$\mathrm{Tr} = \frac{1}{\mathrm{p}} \qquad (10)$$

Where: T_r = average recurrence interval in years

p = the annual exceedance probability

The annual exceedance probability of flow (or water surface elevation) may be estimated using the Gringorten (1963) plotting position formula (equation 11), which is a non-parametric approach.

$$Tr = \frac{N + 0.12}{i - 0.44} \qquad (11)$$

Where: T_r = recurrence interval of the peak flow or peak elevation in years
i = rank of the annual maxima peak flow from highest to lowest
N = total number of years simulated

A probability distribution, such as the Generalized Extreme Value or Log-Pearson III (Interagency Advisory Committee on Water Data 1981), is not recommended for estimating the frequency characteristics.

Flood frequency analyses are used in continuous flow simulations to determine the effect of land use change and assess the effectiveness of flow control facilities. Flow control facilities are designed such that the post-developed peak discharge rate is at or below a target pre-developed peak discharge rate at one or more recurrence intervals. For example, Figure F.3 shows pre-developed and post-developed flood frequency curves for a stormwater pond designed to control peak discharges at the 2-year and 10-year recurrence intervals. Continuous simulation hydrologic models perform the frequency calculations and present the results in graphical and tabular form.

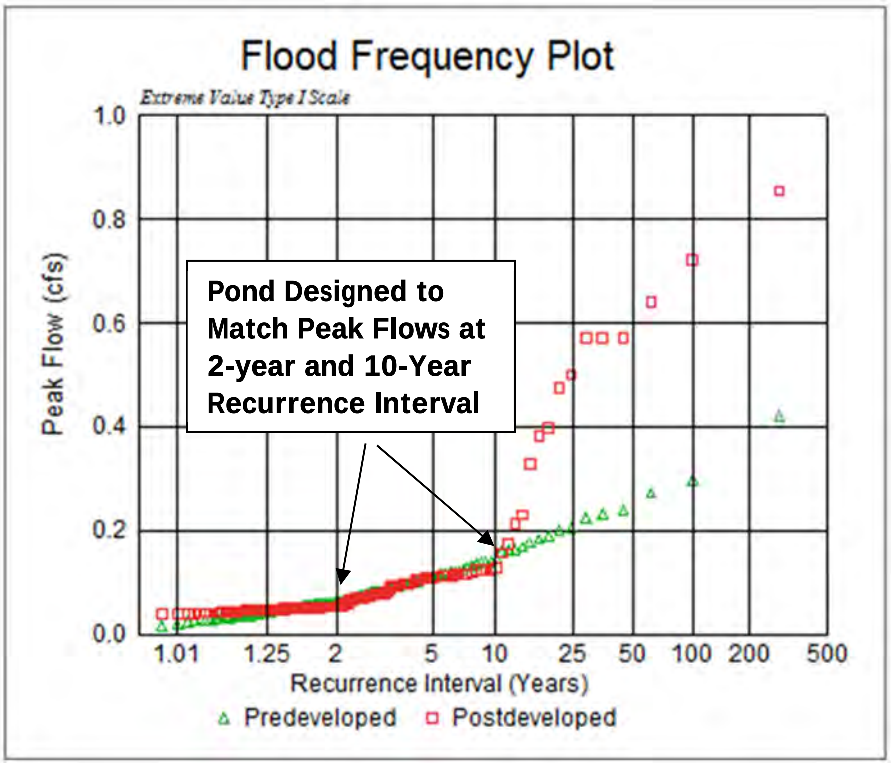


Figure F.3. Example Flood-Frequency Curves for a Stormwater Pond Designed to Control Post-Developed Peak Discharge Rates to Pre-Developed Levels at the 2-Year and 10-Year Recurrence Interval.

Flow Duration Standard

Flow duration statistics provide a convenient tool for characterizing stormwater runoff computed with a continuous hydrologic model. Examples of this type of standard are the Pre-developed Forest Standard and the Pre-developed Pasture Standard. Evaluation of a flow duration design standard requires continuous simulation to compute the pre-development and post-development runoff record. Duration statistics are computed by tracking the fraction of total simulation time that a specified flow rate is equaled or exceeded. Continuous rainfall-runoff models do this by dividing the range of flows simulated into discrete increments, and then tracking the fraction of time that each flow is equaled or exceeded. For example, Figure F.4 shows a 1-year flow time series computed at hourly time steps from a 10-acre forested site and Figure F.5 shows the flow duration curve computed from this time series.

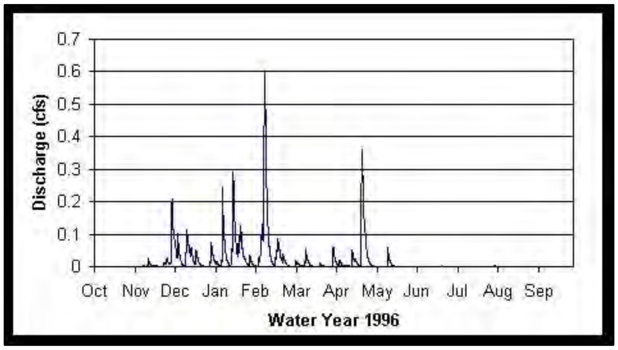


Figure F.4. Runoff from 10-Acre Forested Site.

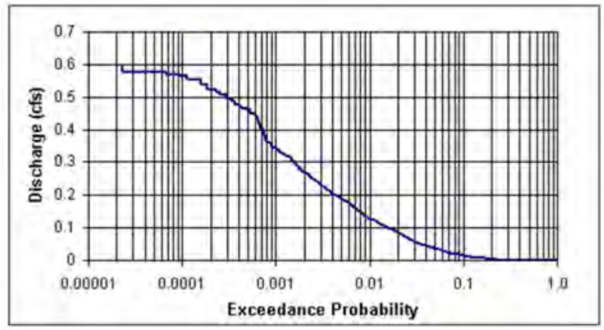


Figure F.5. Flow Duration Curve Computed Using Time Series in Figure F.4.

The fraction of time is termed "exceedance probability" because it represents the probability that a particular flow rate will be equaled or exceeded. It should be noted that exceedance probability for duration statistics is different from the "annual exceedance probability" associated with flood frequency statistics and there is no practical way of converting/relating annual exceedance probability statistics to flow duration statistics.

The flow duration standard can be viewed graphically as shown in Figure F.6. The flow duration curve for the site under pre-developed conditions is computed and is the target to which the post-developed flow duration curve is compared. The flow duration curve for the pond discharge must match the applicable pre-developed curve between 50 percent of the pre-developed 2-year (0.5 Q_2) and an upper limit, either the 2-year (Q_2) or the 50-year (Q_{50}) depending on the flow duration design standard for the facility.

Specified flow levels for the Pre-developed Forest Standard are typically 50 percent of the pre-developed 2-year peak flow (0.5 Q_2), the pre-developed 2-year peak flow (Q_2), and the pre-developed 50-year peak flow (Q_{50}) plus 97 other incremental flow values between 0.5 Q_2 and Q_{50}. Specified flow levels for the Pre-developed Pasture Standard are typically 50 percent of the pre-developed 2-year peak flow (0.5 Q_2) and the pre-developed 2-year peak flow (Q_2) plus 98 other incremental flow values between 0.5 Q_2 and Q_2.

Depending on the flow duration design standard applicable to the stormwater facility, three criteria are evaluated to determine if the standard has been met.

1. Post-development flow duration values may not exceed the pre-development flow duration values between 50 percent of the pre-developed 2-year peak flow (0.5 Q_2) and the pre-developed 2-year peak flow (Q_2).
2. Post-development flow duration values may not exceed pre-development flow duration values between the pre-developed 2-year peak flow (Q_2) and the pre-developed 50-year peak flow (Q_{50}) by more than 10 percent, i.e., a post-development flow duration value may be up to 110 percent of the corresponding pre-development flow duration value.

3. Post-development flow duration values may not exceed pre-development flow duration values for more than 50 percent of flow duration levels, i.e., not more than half of the post-development flow duration values may exceed 100 percent of the corresponding pre-development flow duration value.

General guidance for adjusting the geometry and outlets of stormwater ponds to meet the duration standard were developed by King County (1999) and are summarized in Figure F.7 and described below. Refinements should be made in small increments with one refinement at a time. In general, the recommended approach is to analyze the duration curve from bottom to top, and adjust orifices from bottom to top. Inflection points in the outflow duration curve occur when additional structures (e.g., orifices, notches, overflows) become active. Refer to *Volume 3, Chapter 5* for complete facility design and sizing requirements.

Step #	Parameter	Procedure
P-1	Bottom Orifice Size	Adjust the bottom orifice to control the bottom arc of the post-developed flow duration curve. Reducing the bottom orifice discharge lowers and shortens the bottom arc while increasing the bottom orifice raises and lengthens the bottom arc.
P-2	Height of Second Orifice	The invert elevation of the second orifice affects the point on the flow duration curve where the transition (break in slope) occurs from the curve produced by the low-level orifice. Lower the invert elevation of the second orifice to move the transition point to the right on the lower arc. Raise the height of the second orifice to move the transition point to the left on the lower arc.
P-3	Second Orifice Size	The upper arc represents the combined discharge of both orifices. Adjust the second orifice size to control the arc of the curve for post-developed conditions. Increasing the second orifice raises the upper arc while decreasing the second orifice lowers the arc.
P-4	Pond Volume	Adjust the pond volume to control the upper end of the duration curve. Increase the pond volume to move the entire curve down and to the left to control riser overflow conditions. Decrease the pond volume to move the entire curve up and to the right to ensure that the outflow duration curve extends up to the riser overflow.

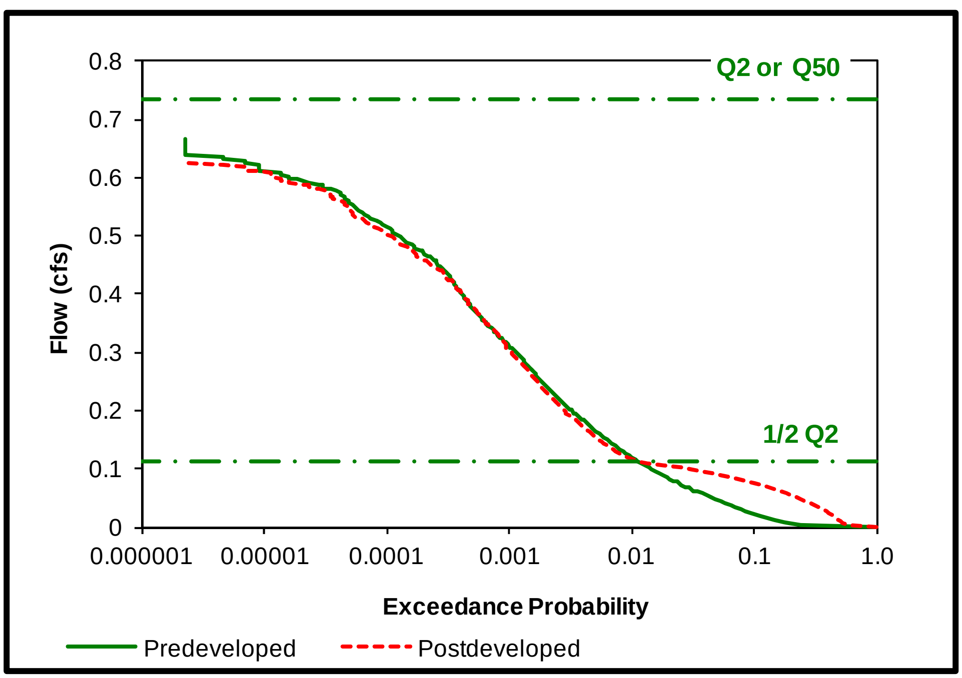


Figure F.6. Comparison of Pre-Developed and Post-Developed Flow Duration Curves.

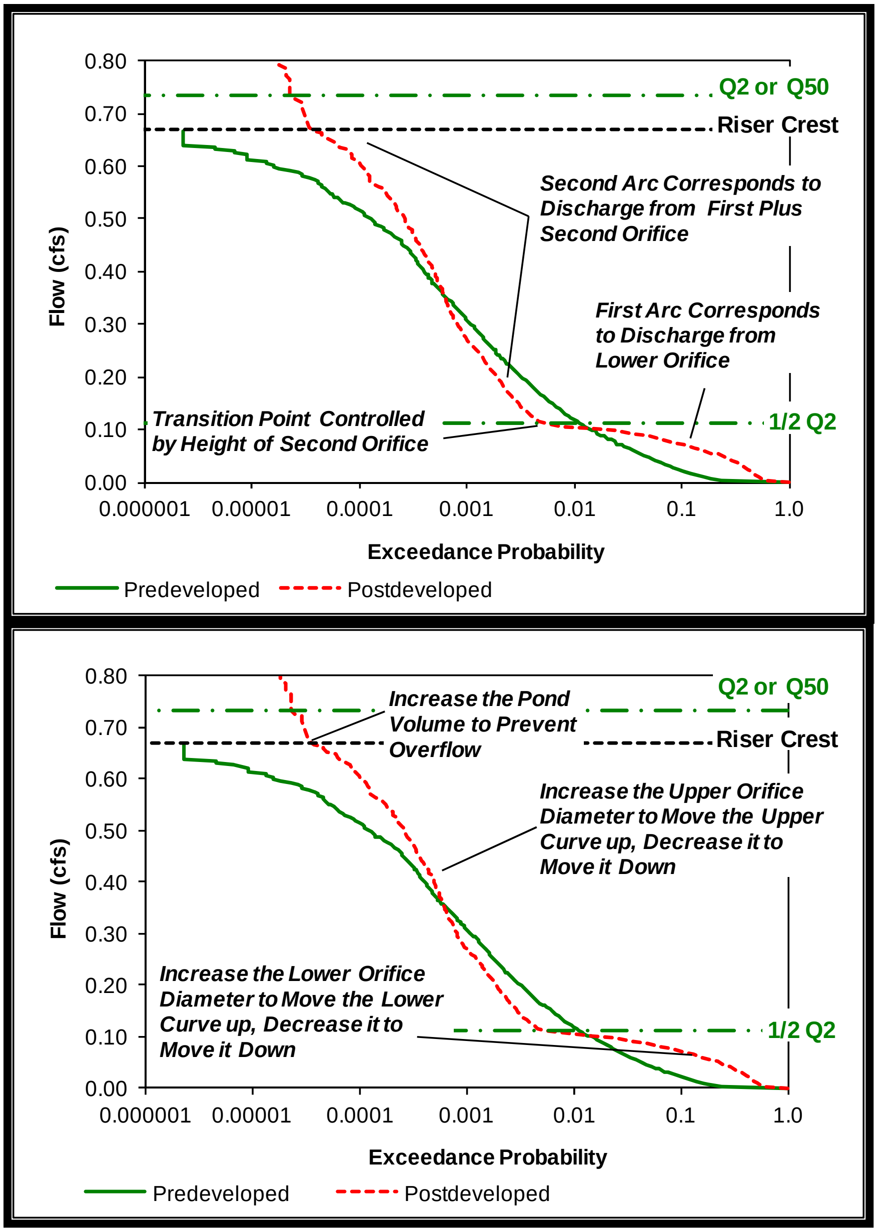


Figure F.7. General Guidance for Adjusting Pond Performance.

On-site Performance Standard BMP Design

This section provides guidance for sizing BMPs to meet the On-site Performance Standard. If the applicant chooses to use the On-site List Approach, modeling is typically not required (refer to sizing requirements in Chapter 5 of Volume 3). If the applicant chooses to use the On-site Performance Standard, the modeling procedures will depend upon the applicable target (i.e., forest or pasture). See Volume 3, Section 5.2.1 to determine the target based on the percent of existing hard surface and the type of drainage basin.

If the project discharge durations must match pre-developed forest flow durations for from 8 percent to 50 percent of the 2-year pre-developed flow, the procedures outlined above in the *Flow Duration Standard* subsection are generally applicable (with duration bounds revised to 8 percent to 50 percent of the 2-year flow). Both WWHM and MGSFlood have the capability to evaluate (and report "pass" and "fail") for this standard.

If the project discharge durations must match pre-developed pasture flow durations for the range of pre-developed discharge rates between the 1 percent and 10 percent exceedance values, the procedures outlined in this section are applicable.

The "frequency of exceedance" or "percent exceedance" (as referenced in the Stormwater Code), is the percent of time, over the simulation period (e.g., 158 years), that a given flow is equaled or exceeded. MGSFlood and WWHM both report "exceedance probability"– the decimal equivalent of "percent exceedance." For example, the 1 to 10 percent exceedance range corresponds to the 0.01 and 0.1 exceedance probabilities displayed on the flow duration curves (see Figure F.7a). The standard is achieved if the post-developed flows are less than the pre-developed flows for the 1 to 10 percent exceedance range (red line is beneath the green line for the shaded range of exceedance values).

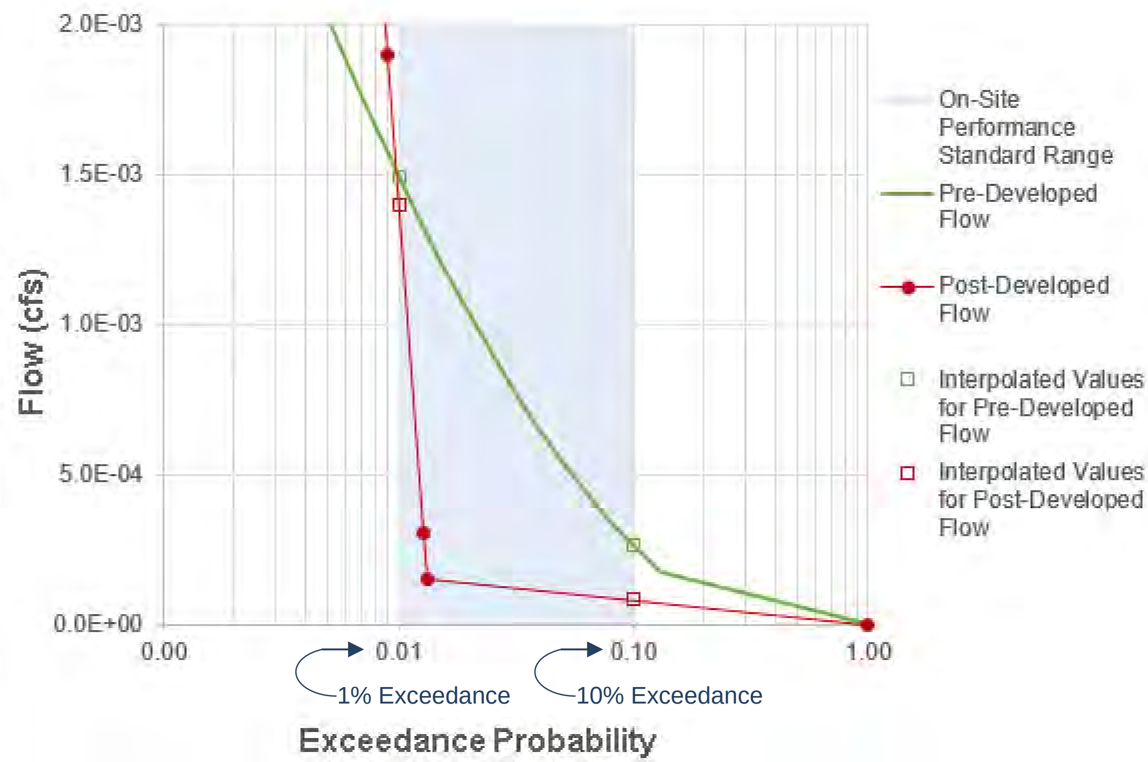


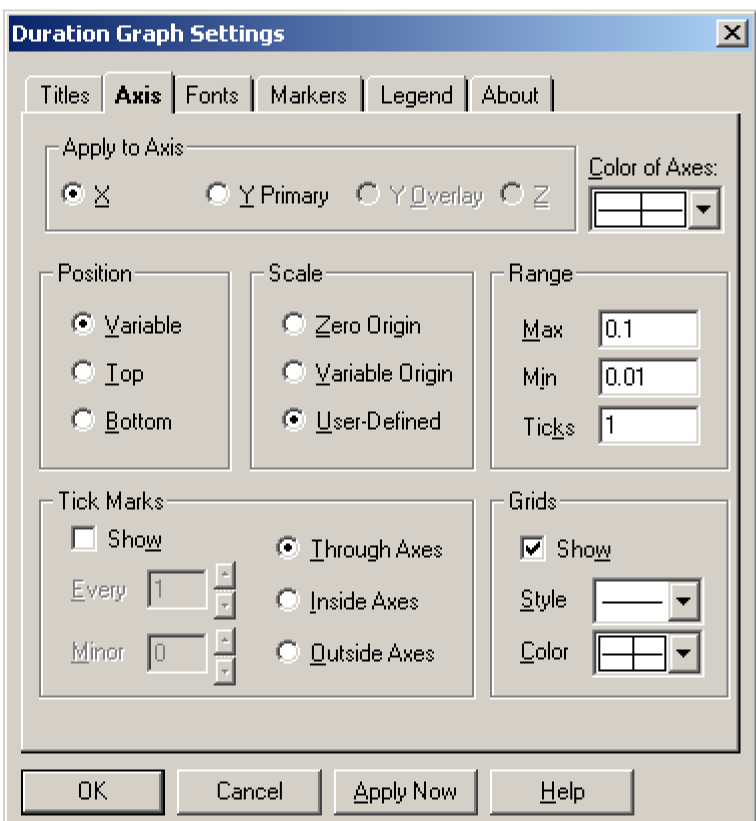
Figure F.7a. On-site Performance Standard Duration Curve.

The latest versions of MGSFlood (as of April 2021) include the option to conduct a flow duration analysis based on the 1 to 10 percent exceedance standard. An MGSFlood user can select the option on the LID Duration tab in the Options menu. MGSFlood will then report "pass" or "fail" for the 1 to 10 percent exceedance standard. WWHM does not currently (as of April 2021) explicitly report "pass" or "fail" for the 1 to 10 percent exceedance standard. However, WWHM allows the user to define the bounds of duration analysis in term of flow rate (cubic feet per second). A user can calculate the pre-developed pasture 1 and 10 percent exceedance flow rates using the software and manually enter them as the bounds for the flow duration analysis on the Duration Criteria tab in the Options menu. WWHM will then report "pass" or "fail" for the 1 to 10 percent exceedance standard. For users with different or older software, the following procedures may be used to determine compliance with Seattle Stormwater Code. Details are provided for determining compliance with both MGSFlood and WWHM but similar procedures may be applicable to other software programs.

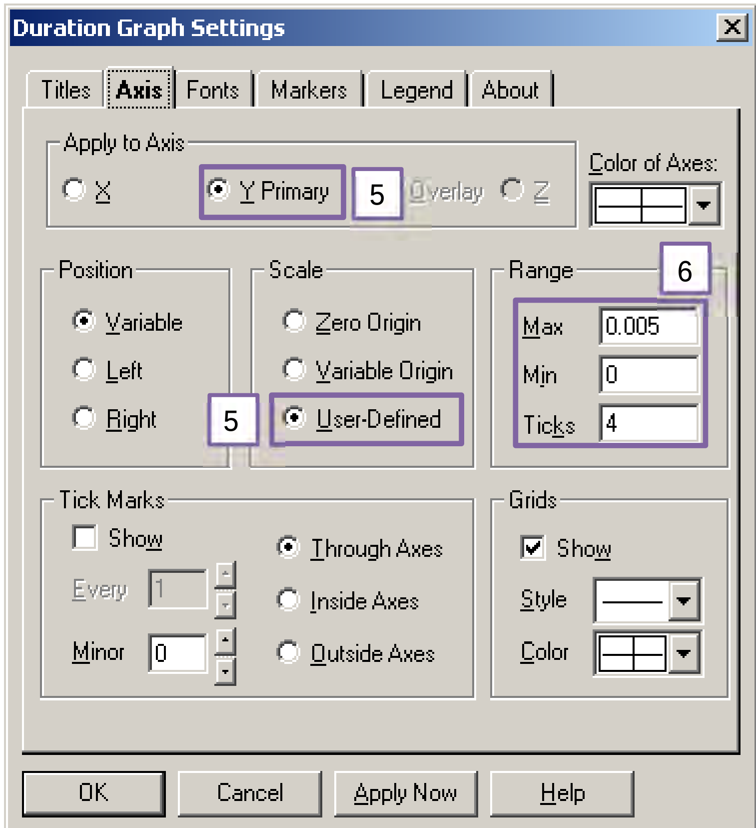
Visual Evaluation of On-site Performance Standard in MGSFlood

Compliance with the 1 to 10 percent exceedance standard may be confirmed by visually observing the MGSFlood Flow Duration Plot. The axes on the plot may be adjusted to clearly display the duration curve from 1 to 10 percent exceedance. Step-by-step instructions are provided below.

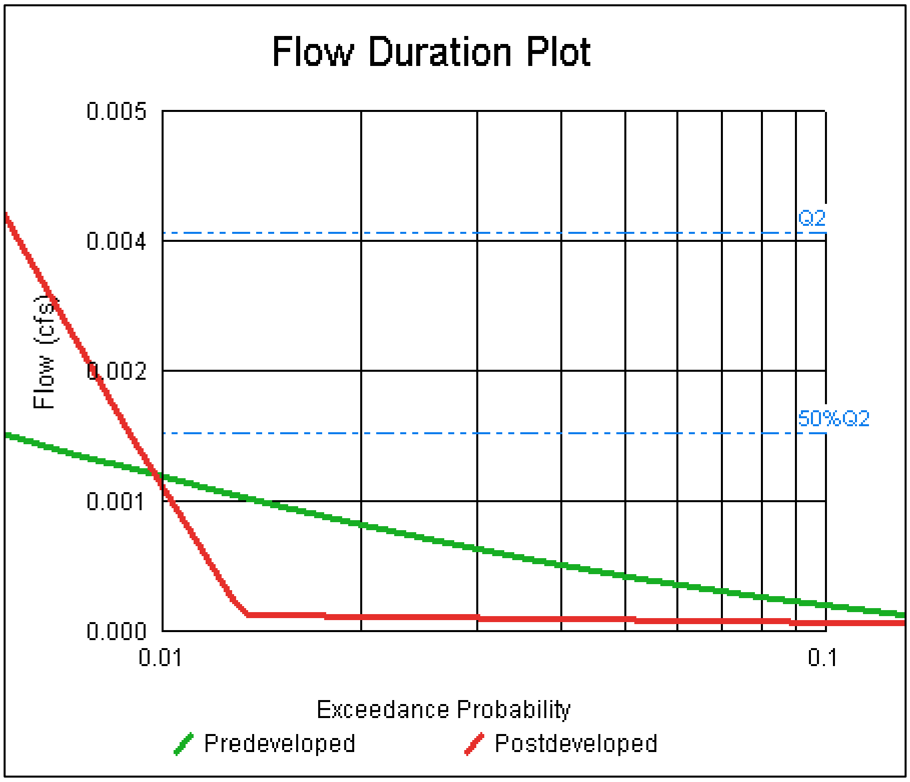
1. Right click on the Flow Duration Plot to open Duration Graph Settings
2. Select "Axis" tab
3. Edit x-axis scale (select "X", "User Defined")
4. Update x-axis range of values as follows:
   a. Max = 0.1
   b. Min = 0.01
   c. Ticks = 1



5. Edit y-axis scale (select "Y Primary," "User Defined")
6. Update y-axis range of values. Values will vary depending on size of contributing area.



7. Visually inspect to confirm that the post-developed flows are less than the pre-developed flows for the 1 to 10 percent exceedance range (red line is beneath the green line for the range plotted).



Quantitative Evaluation of the On-site Performance Standard in MGSFlood

If the user wishes to fully optimize BMP sizes for the 1 to 10 percent exceedance standard, values must be calculated and evaluated outside of the model. Step-by-step procedures are provided below with an example:

1. Build and run the model
2. View report file (File>View Report)
3. Select "Full Output" to get full detailed report and click "Refresh"
4. Navigate to "Point of Compliance Flow Duration Data"
5. Determine pre-developed flows associated with 1 percent and 10 percent exceedance probability using the steps below. Note that a higher probability of exceedance corresponds to lower, more frequent, flows.
   a. Identify the exceedance probability values immediately higher and immediately lower than the 1 percent exceedance. Record the exceedance probabilities and the associated flows as shown in the example below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Higher than 1%	1.37E-03	1.19%
Lower than 1%	1.54E-03	0.94%

6. Identify the exceedance probability values immediately higher and immediately lower than the 10 percent exceedance. Record the exceedance probabilities and the associated flows as shown in the example below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Higher than 10%	1.71E-04	13.15%
Lower than 10%	3.42E-04	7.97%

7. Logarithmically interpolate flows associated with the 1 and 10 percent exceedance probabilities using Equation 1 and Equation 2, respectively.

$$Flow_{1\%} = Flow_{lower} + \frac{Flow_{lower} - Flow_{higher}}{\log(Exceedance_{lower}) - log(Exceedance_{higher})} \times [log(1\%) - log(Exceedance_{lower})] \qquad \text{Eq 1.}$$

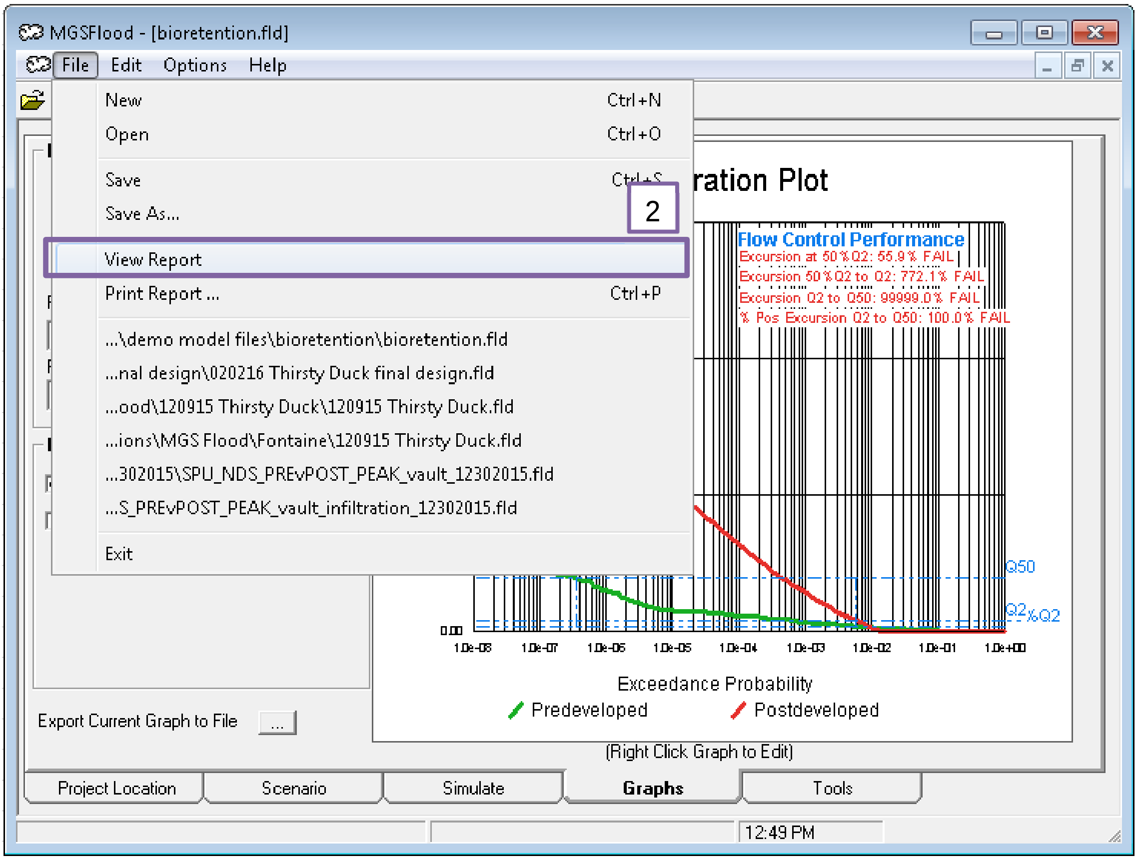
$$Flow_{10\%} = Flow_{lower} + \frac{Flow_{lower} - Flow_{higher}}{\log(Exceedance_{lower}) - log(Exceedance_{higher})} \times [log(10\%) - log(Exceedance_{lower})] \qquad \text{Eq 2.}$$

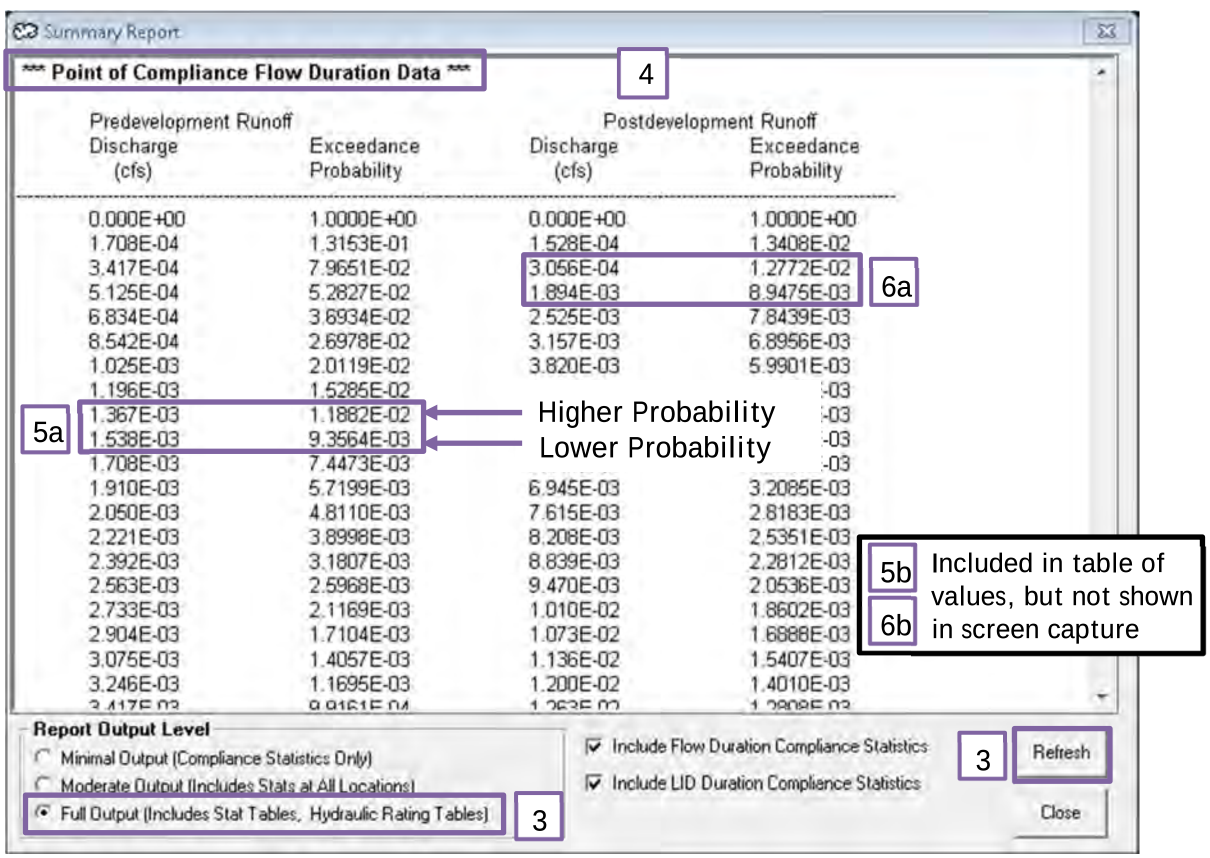
Results for this example are shown below:

	Pre-development Runoff Discharge (cfs)	Exceedance Probability
Interpolated flows at 1%	1.49E-03	1.00%
Interpolated flows at 10%	2.64E-04	10.00%

8. Determine post-developed flows associated with 1 percent and 10 percent exceedance probability. Repeat Steps 5a, 5b, and 5c using post-developed flows.

	Post-development Runoff Discharge (cfs)	Exceedance Probability
Interpolated flows at 1%	1.40E-03	1.00%
Interpolated flows at 10%	8.16E-05	10.00%


MGSFlood - [bioretention.fld]
File Edit Options Help
New Ctrl+N
Open Ctrl+O
Save Ctrl+S
Save As...
2
View Report
Print Report ... Ctrl+P
...\demo model files\bioretention\bioretention.fld
...nal design\020216 Thirsty Duck final design.fld
...ood\120915 Thirsty Duck\120915 Thirsty Duck.fld
...ions\MGS Flood\Fontaine\120915 Thirsty Duck.fld
...302015\SPU_NDS_PREvPOST_PEAK_vault_12302015.fld
...S_PREvPOST_PEAK_vault_infiltration_12302015.fld
Exit
ration Plot
Flow Control Performance
Excursion at 50%Q2: 55.9% FAIL
Excursion 50%Q2 to Q2: 772.1% FAIL
Excursion Q2 to Q50: 99999.0% FAIL
% Pos Excursion Q2 to Q50: 100.0% FAIL
Q50
Q2
%Q2
Exceedance Probability
Predeveloped
Postdeveloped
Export Current Graph to File
(Right Click Graph to Edit)
Project Location
Scenario
Simulate
Graphs
Tools
12:49 PM


Summary Report
*** Point of Compliance Flow Duration Data ***
4
Predevelopment Runoff
Postdevelopment Runoff
Discharge (cfs) Exceedance Probability Discharge (cfs) Exceedance Probability
0.000E+00 1.0000E+00 0.000E+00 1.0000E+00
1.708E-04 1.3153E-01 1.528E-04 1.3408E-02
3.417E-04 7.9651E-02 3.056E-04 1.2772E-02
5.125E-04 5.2827E-02 1.894E-03 8.9475E-03
6.834E-04 3.6934E-02 2.525E-03 7.8439E-03
8.542E-04 2.6978E-02 3.157E-03 6.8956E-03
1.025E-03 2.0119E-02 3.820E-03 5.9901E-03
1.196E-03 1.5285E-02
1.367E-03 1.1882E-02
1.538E-03 9.3564E-03
1.708E-03 7.4473E-03
1.910E-03 5.7199E-03 6.945E-03 3.2085E-03
2.050E-03 4.8110E-03 7.615E-03 2.8183E-03
2.221E-03 3.8998E-03 8.208E-03 2.5351E-03
2.392E-03 3.1807E-03 8.839E-03 2.2812E-03
2.563E-03 2.5968E-03 9.470E-03 2.0536E-03
2.733E-03 2.1169E-03 1.010E-02 1.8602E-03
2.904E-03 1.7104E-03 1.073E-02 1.6888E-03
3.075E-03 1.4057E-03 1.136E-02 1.5407E-03
3.246E-03 1.1695E-03 1.200E-02 1.4010E-03
6a
5a
Higher Probability
Lower Probability
5b
6b
Included in table of values, but not shown in screen capture
Report Output Level
Minimal Output (Compliance Statistics Only)
Moderate Output (Includes Stats at All Locations)
Full Output (Includes Stat Tables, Hydraulic Rating Tables)
3
Include Flow Duration Compliance Statistics
Include LID Duration Compliance Statistics
3
Refresh
Close

9. Compare pre-developed flows and post-developed flows at 1 and 10 percent exceedance probabilities and visually confirm, from the flow duration curves in the model, that the post-developed flows are smaller than the pre-developed flows. If post-developed flows at the 1 or 10 percent exceedance probability are higher than the pre-developed flows, or if the post developed flows appear to exceed the pre-developed flows for the 1 to 10 percent exceedance range of the duration curve (refer to procedures for visual observation, above), increase the BMP size(s), run the model, and repeat Steps 2 through 9.

See Figure F.7a for a comparison of pre-and post-developed flow duration curves for the target exceedance probability range. Figure F.7a also includes the interpolated data points described above, shown as hollow squares on the graph. If post-developed flows (shown in red) are smaller than pre-developed flows (shown in green) for the target exceedance probability range (grey hatch), the project satisfies the On-site Performance Standard.

Visual Evaluation of On-site Performance Standard in WWHM

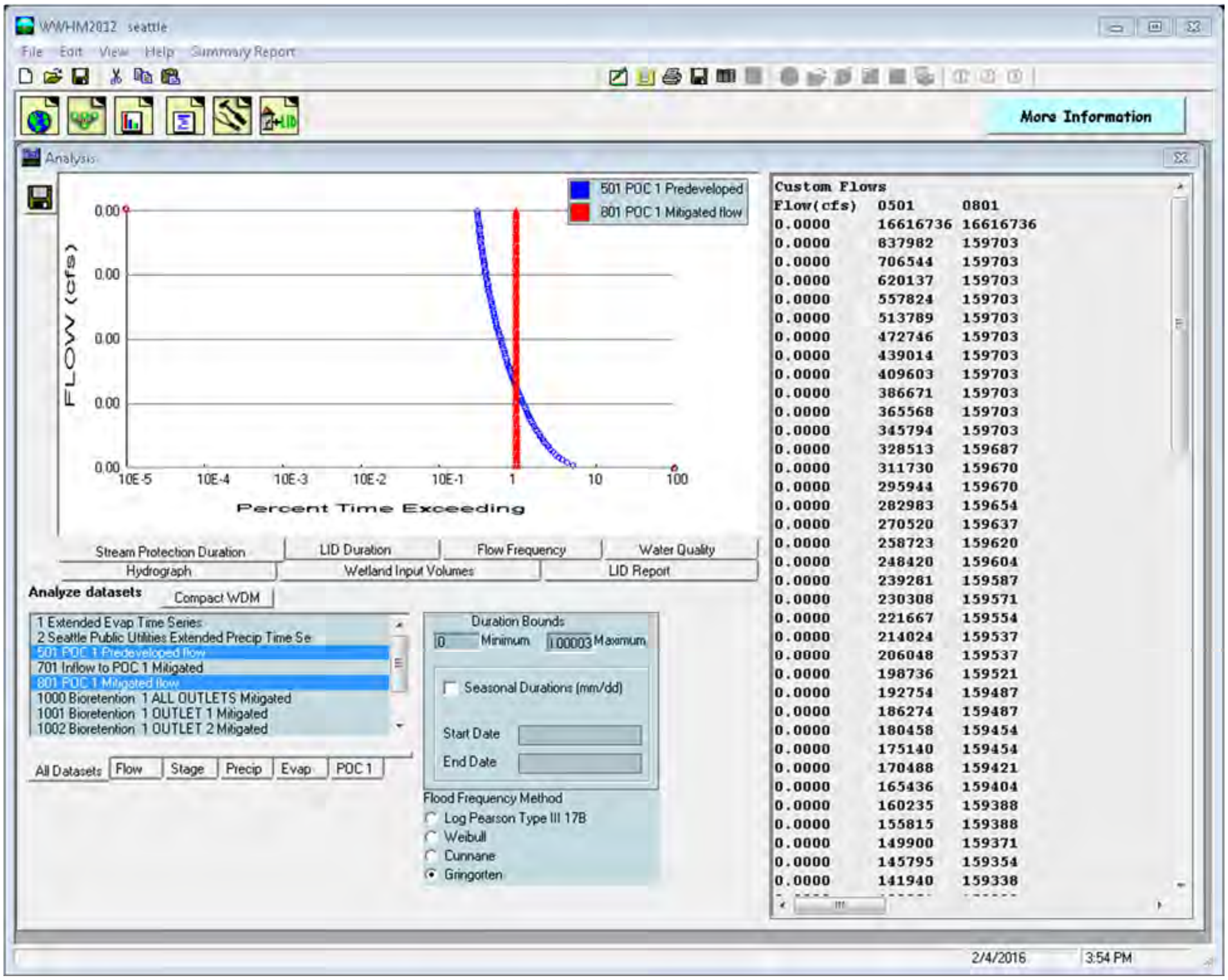
Compliance with the 1 to 10 percent exceedance standard may be estimated by visually observing the WWHM Stream Protection Duration Plot. The axes on the plot must be adjusted and manually evaluated to more clearly display the duration curve from 1 to 10 percent exceedance. Because the graphs are difficult to accurately read, the facility may need to be somewhat oversized to visually confirm compliance. Step-by-step instructions are provided below:

1. Build and run the model
2. View the “Stream Protection Duration” results in the Analysis tab window
3. Select the appropriate points of compliance for the pre-developed scenario and the mitigated (i.e., post-developed) scenario under “All Datasets” (hold CTRL to select more than one)

    501 POC 1 Predeveloped flow
    801 POC 1 Mitigated flow

4. Modify the “Duration Bounds” to include the 1 and 10 percent exceedance values
    a. Minimum = 0 cfs
    b. Maximum = established by trial and error until the pre-developed flows corresponding to the 1 percent exceedance are visible on the graph. To optimize the facility size(s), set the maximum value slightly above the predeveloped flow that is exceeded 1 percent of the time. This value can be approximated as the contributing area in acres times 0.00025 cfs per acre.
5. Select the “Stream Protection Duration” tab to re-calculate the results with the new duration bounds

6. Visually inspect the duration plot to confirm that the mitigated flows are smaller than the pre-developed flows for the 1 to 10 percent exceedance range. Because the plots are difficult to accurately read, the following steps are required to confirm compliance with the 1 to 10 percent exceedance standard:
    a. Take a screenshot of the flow duration curve
    b. Paste the screenshot into a word processing software, e.g., Microsoft Word
    c. Overlay two vertical lines at the 1% and 10% tick marks
    d. Confirm the mitigated flows (red line) are below the pre-developed flows (blue line) within the range of the two horizontal lines. Note: to visually ensure compliance, the facility may need to be somewhat oversized (the screenshot shown below is 10 percent larger than required when quantitative evaluated using the procedure provided below).


WWHM2012 seattle
File Edit View Help Summary Report
More Information
Analysis
501 POC 1 Predeveloped
801 POC 1 Mitigated flow
FLOW (cfs)
0.00
10E-5 10E-4 10E-3 10E-2 10E-1 1 10 100
Percent Time Exceeding
Stream Protection Duration
LID Duration
Flow Frequency
Water Quality
Hydrograph
Wetland Input Volumes
LID Report
Analyze datasets
Compact WDM
1 Extended Evap Time Series
2 Seattle Public Utilities Extended Precip Time Se
501 POC 1 Predeveloped flow
701 Inflow to POC 1 Mitigated
801 POC 1 Mitigated flow
1000 Bioretention 1 ALL OUTLETS Mitigated
1001 Bioretention 1 OUTLET 1 Mitigated
1002 Bioretention 1 OUTLET 2 Mitigated
All Datasets Flow Stage Precip Evap POC 1
Duration Bounds
0 Minimum 1.00003 Maximum
Seasonal Durations (mm/dd)
Start Date
End Date
Flood Frequency Method
Log Pearson Type III 17B
Weibull
Cunnane
Gringorten
Custom Flows
Flow(cfs) 0501 0801
0.0000 16616736 16616736
0.0000 837982 159703
0.0000 706544 159703
0.0000 620137 159703
0.0000 557824 159703
0.0000 513789 159703
0.0000 472746 159703
0.0000 439014 159703
0.0000 409603 159703
0.0000 386671 159703
0.0000 365568 159703
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0.0000 328513 159687
0.0000 311730 159670
0.0000 295944 159670
0.0000 282983 159654
0.0000 270520 159637
0.0000 258723 159620
0.0000 248420 159604
0.0000 239281 159587
0.0000 230308 159571
0.0000 221667 159554
0.0000 214024 159537
0.0000 206048 159537
0.0000 198736 159521
0.0000 192754 159487
0.0000 186274 159487
0.0000 180458 159454
0.0000 175140 159454
0.0000 170488 159421
0.0000 165436 159404
0.0000 160235 159388
0.0000 155815 159388
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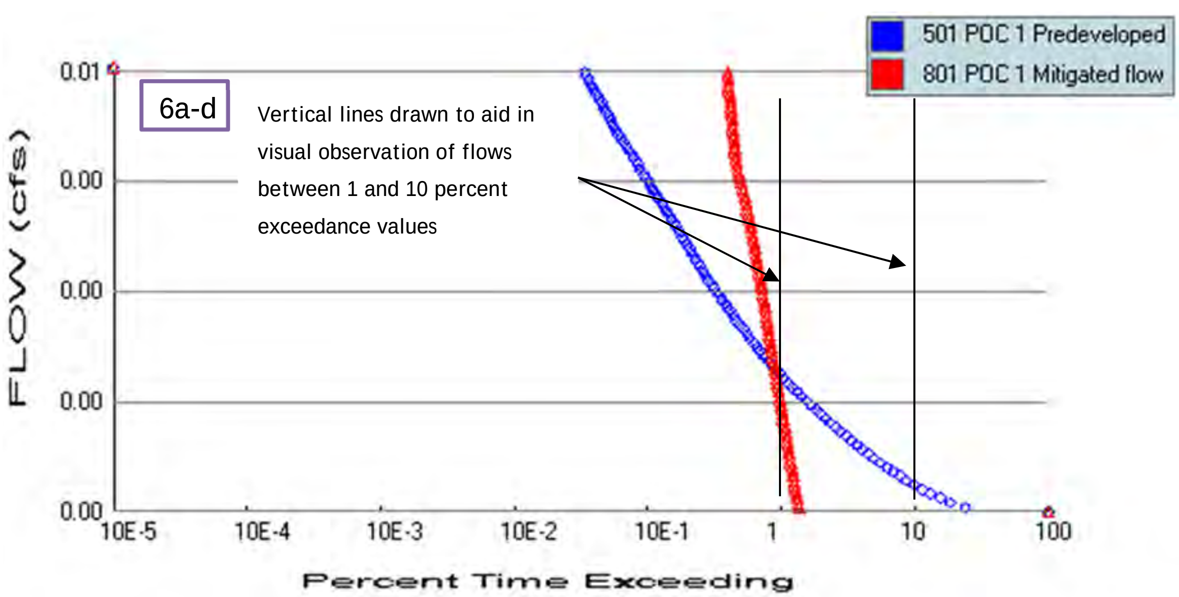
0.0000 145795 159354
0.0000 141940 159338
2/4/2016 3:54 PM


501 POC 1 Predeveloped
801 POC 1 Mitigated flow
6a-d
Vertical lines drawn to aid in visual observation of flows between 1 and 10 percent exceedance values
FLOW (cfs)
0.01
0.00
0.00
0.00
0.00
10E-5 10E-4 10E-3 10E-2 10E-1 1 10 100
Percent Time Exceeding

Evaluation of the On-site Performance Standard in WWHM

To quantitatively evaluate and fully optimize BMP sizes for the 1 to 10 percent exceedance standard, values must be calculated and evaluated outside of the model. Step-by-step procedures are provided below with an example:

1. Build and run the model
2. View the "Stream Protection Duration" results in the Analysis tab window
3. Select the appropriate points of compliance for the pre-developed scenario and the mitigated (i.e., post-developed) scenario under "All Datasets" (hold CTRL to select more than one)

   501 POC 1 Predeveloped flow
   801 POC 1 Mitigated flow

4. Modify the "Duration Bounds" to include the 1 and 10 percent exceedance values
   a. Minimum = 0 cfs
   b. Maximum = established by trial and error until the pre-developed flows corresponding to the 1 percent exceedance are visible on the graph. To optimize the facility size(s), set the maximum value slightly above the predeveloped flow that is exceeded 1 percent of the time. This value can be approximated as the contributing area in acres times 0.00025 cfs per acre.

   0.12 acres x 0.00025 cfs/acre = 0.00003

5. Select the "Stream Protection Duration" tab to re-calculate the results with the new duration bounds
6. Determine the total number of timesteps calculated by the model. Refer to the first line in the "Custom Flows" table (i.e., number of timesteps associated with a flow of zero cfs [flow at every timestep is greater than or equal to zero cfs]).

   Custom Flows

Flow(cfs)	0501	0801
0.0000	16616736	16616736

7. Calculate the number of timesteps that correspond to the 1 percent and 10 percent exceedance values using Equations 3 and 4

$$\text{1 Percent of Timesteps} = \text{Total number of Timesteps} \times 0.01 \quad \text{Eq 3.}$$

$$\text{10 Percent of Timesteps} = \text{Total number of Timesteps} \times 0.1 \quad \text{Eq 4.}$$

1 Percent of Timesteps = 16,616,736 x 0.01 = 166,167
10 Percent of Timesteps = 16,616,736 x 0.1 = 1,661,674

8. Compare pre-developed flows and post-developed (i.e., mitigated) flows at the 1 percent exceedance probability. While the flow values themselves are often too small to display in the "Custom Flows" table in WWHM, the number of timesteps a given flow is exceeded can be used to evaluate facility performance relative to the pre-developed condition. For the On-site Performance standard, all flows with a probability of exceedance from 1 to 10 percent should be exceeded at the same

frequency, or less frequently than the predeveloped condition. In other words, for a given flow in the target range, the number of timesteps that flow is exceeded should be fewer in the mitigated scenario than the pre-developed scenario. To compare the pre-developed and mitigated flows:

a. Identify the flow values immediately higher and immediately lower than the target 1 percent of timesteps (as determined in Step 7) for the pre-developed scenario

b. Compare the number of timesteps these flow values are exceeded in the mitigated scenario to the pre-developed scenario.

c. If the pre-developed scenario is exceeded less frequently than the mitigated scenario, increase facility size and repeat Step 8.

d. Proceed to Step 9.

Custom Flows

Flow(cfs)	0501	0801
0.0000	170488	159421
0.0000	165436	159404

The first flow is exceeded for 170,488 timesteps (170,488/16,616,736 = 1.03%) in the pre-developed condition. The second flow is exceeded for 165,436 timesteps (165,436/16,616,736 = 0.996%) in the pre-developed condition. For these flows, the mitigated scenario is exceeded for a fewer number of timesteps than the pre-developed scenario, therefore the mitigated condition meets the On-site Performance Standard at the 1 percent exceedance value.

9. Compare pre-developed flows and post-developed (i.e., mitigated) flows at the 10 percent exceedance probability:

a. Identify the flow values immediately higher and immediately lower than the target 10 percent of timesteps (as determined in Step 7) for the pre-developed scenario.

b. Compare the number of timesteps these flow values are exceeded in the mitigated scenario to the pre-developed scenario.

c. If the pre-developed scenario is exceeded less frequently than the mitigated scenario, increase facility size and repeat Step 9.

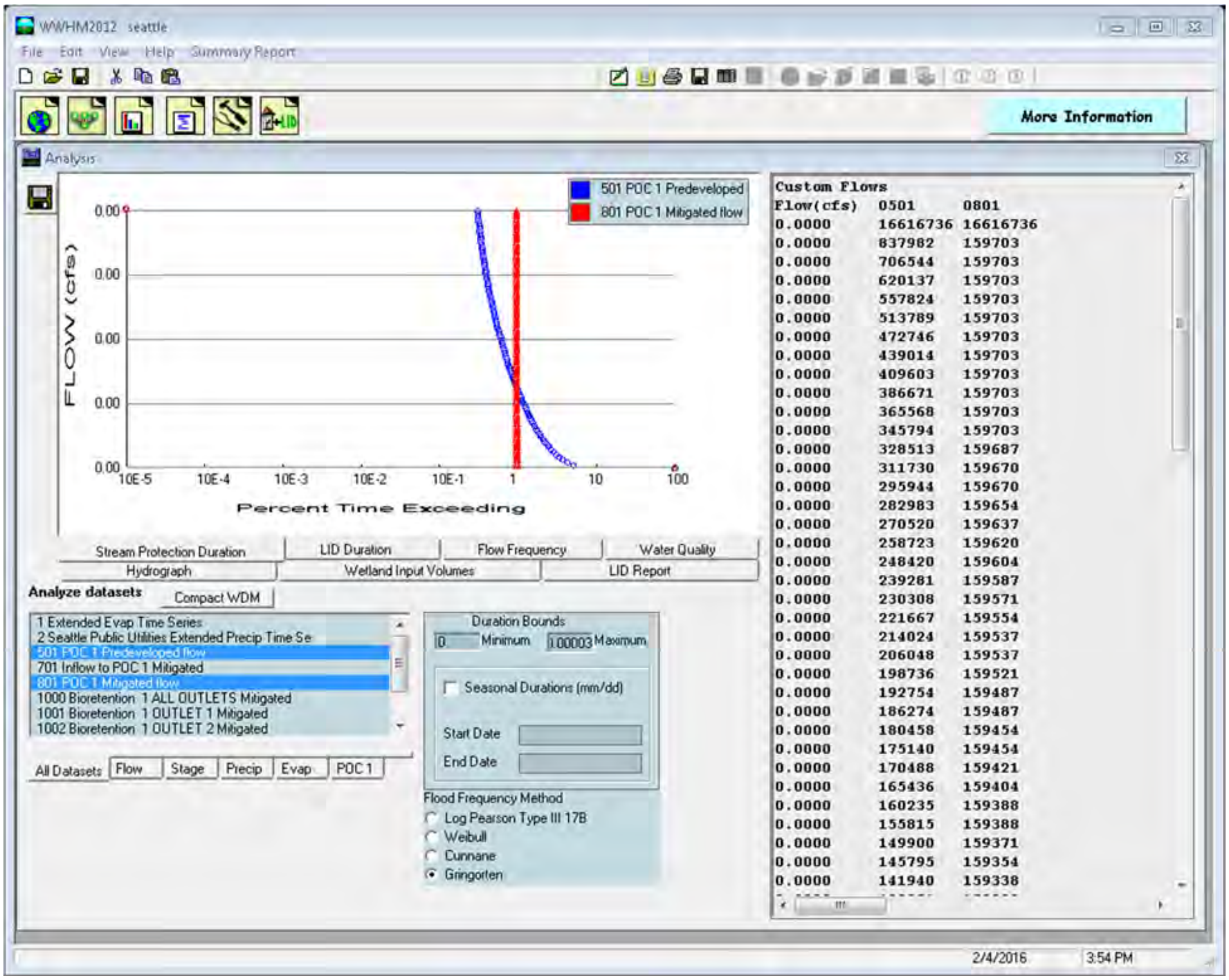
d. Proceed to Step 10.

Custom Flows

Flow(cfs)	0501	0801
0.0000	16616736	16616736
0.0000	837982	159703

The first flow is exceeded for 16,616,736 timesteps (16,616,736/16,616,736 = 100%) for both the pre-developed scenario and the mitigated scenario. The second flow is exceeded for 837,982 timesteps (837,982/16,616,736 = 5.04%) in the pre-developed condition and is exceeded for 21,134 timesteps in the mitigated condition. Therefore the mitigated condition meets the on-site standard at the 10 percent exceedance value.

10. Visually confirm, from the flow duration curves in the model, that the mitigated flows are smaller than the pre-developed flows for the 1 to 10 percent exceedance range. If the post developed flows appear to exceed the pre-developed flows for the 1 to 10 percent exceedance range of the duration curve, increase the BMP size(s) and repeat Steps 8 through 10.



Water Quality Treatment BMP Design

Water Quality Design Volume

The water quality design volume for sizing wet ponds is computed as the daily runoff volume that is greater than or equal to 91 percent of all daily values in the simulation period. The continuous model develops a daily runoff time series from the pond inflow time series and scans the computed daily time series to determine the 24-hour volume that is greater than or equal to 91 percent of all daily values in the time series. This value is then used as the volume for a “Basic Wet Pond” and 1.5 times this value is used for sizing a “Large Wet Pond."

The water quality design volume is defined as the daily runoff volume at which 91 percent of the total runoff volume is produced by smaller daily volumes. The procedure can be visualized using Figure F.8 below. The bars on the graph represent daily inflow volume for the entire simulation. The time span along the x-axis in Figure F.8 is for 105 days, but in practice, this would include the entire simulated inflow time series (e.g., 158 years).

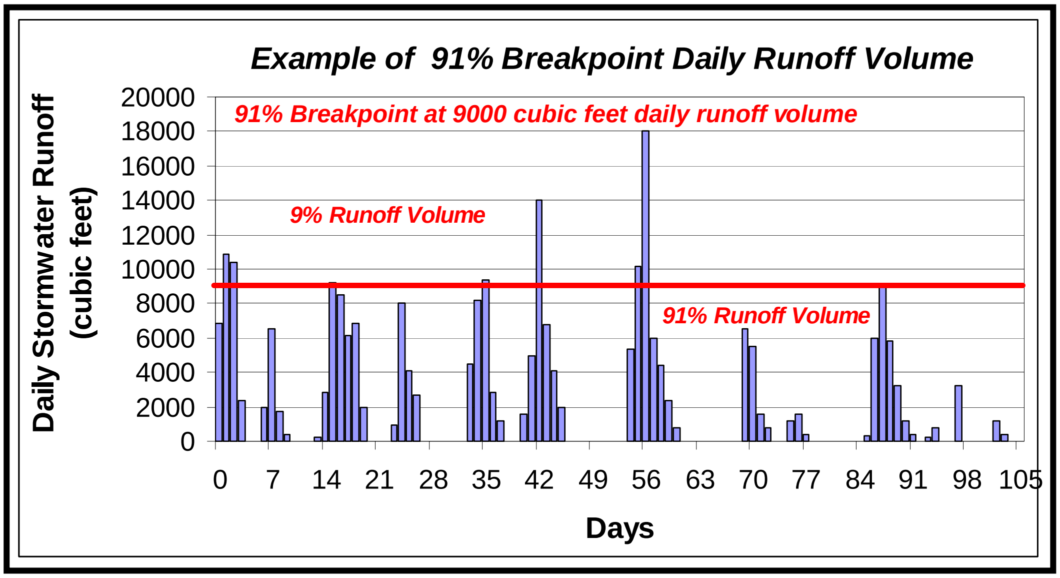


Figure F.8. Example of Portion of Time-Series of Daily Runoff Volume and Depiction of Water Quality Design Volume.

The horizontal line represents the water quality design volume. Its value is calculated such that 91 percent of the total daily runoff volume for the entire simulation resides below this line and 9 percent of the total daily runoff volume for the entire simulation exceeds the water quality design volume. Stated another way, if you total the daily runoff volumes that exceed the 9,000 cubic foot water quality design volume, they represent 9 percent of the total runoff volume.

The process for computing this water quality design volume may vary among continuous simulation models. An example of a typical approach used to compute the water quality design volume (WQDV) is summarized below.

Step #	Procedure
WQDV-1	Compute daily volume to the pond using the inflow time (convert the inflow rate to inflow volume on a midnight to midnight basis using a 1-hour or less time step).
WQDV-2	Compute the total inflow volume by summing all of the daily inflow volume values for the entire simulation.
WQDV-3	Compute a breakpoint value by multiplying the total runoff volume computed in Step WQDV-2 by 9 percent.
WQDV-4	Sort the daily runoff values from Step WQDV-1 in descending order (highest to lowest).
WQDV-5	Sum the sorted daily volume values until the total equals the 9 percent breakpoint. That is, the largest volume is added to the second largest, which is added to the third largest, etc., until the total equals the 9 percent breakpoint.
WQDV-6	The last daily value added to match the 9 percent breakpoint is defined as the water quality design volume.

Water Quality Treatment Design Flow Rate

The flow rate used to design flow rate dependent treatment facilities depends on whether or not the treatment is located upstream of a stormwater detention facility and whether it is an on-line or offline facility (Figure F.9).

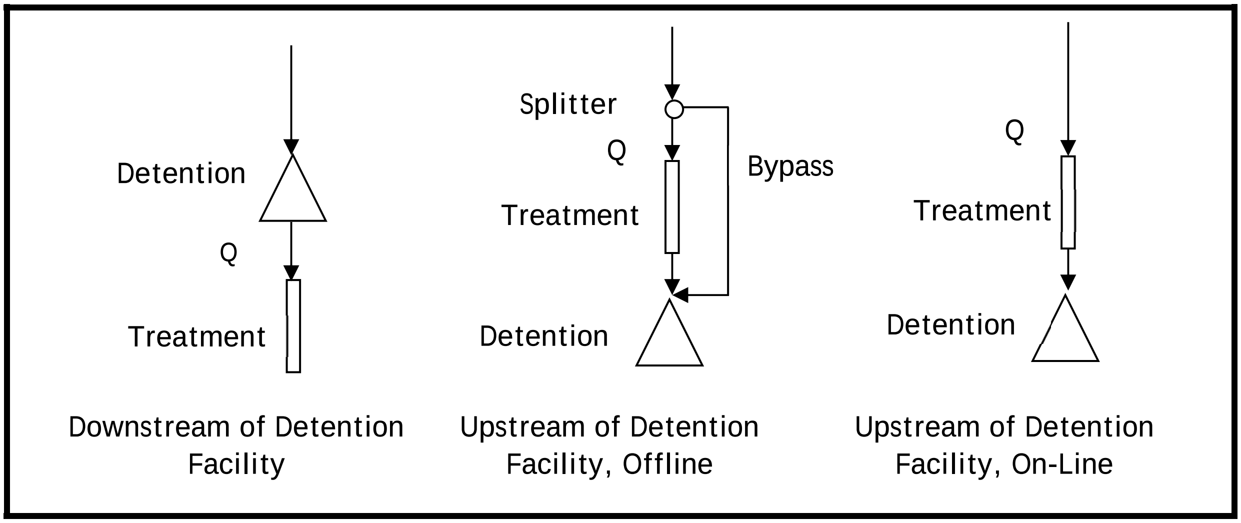


Figure F.9. Water Quality Treatment and Detention Definition.

Downstream of Detention Facilities: If the treatment facility is located downstream of a stormwater detention facility, then the water quality design flow rate is the release rate from the detention facility that has a 50 percent annual probability of occurring in any given year (2-year recurrence interval).

Upstream of Detention Facilities, Offline: Offline water quality treatment located upstream of the detention facility includes a high-flow bypass that routes the incremental flow in excess of the water quality design rate around the treatment facility. It is assumed that flows from the bypass enter the system downstream of the treatment facility but upstream of the detention facility. The continuous model determines the water quality treatment design flow rate as the rate corresponding to the runoff volume that is greater than or equal to 91 percent of the 15-minute runoff volume entering the treatment facility (Figure F.10). If runoff is computed using the City of Seattle Design Time Series with a time step of 15 minutes or less, then no time step adjustment factors are need for the water quality design discharge.

Upstream of Detention Facilities, On-line: On-line water quality treatment does not include a high-flow bypass for flows in excess of the water quality design flow rate and all runoff is routed through the facility. The continuous model determines the water quality treatment design flow rate as the rate corresponding to the runoff volume that is greater than or equal to 91 percent of the 15-minute runoff volume entering the treatment facility. However, those flows that exceed the water quality design flow are not counted as treated in the calculation (Figure F.11). Therefore, the design flow rate for on-line facilities is higher than for offline facilities. If runoff is computed using the City of Seattle Design Time Series with a time step of 15 minutes or less, then no time step adjustment factors are need for the water quality design discharge.

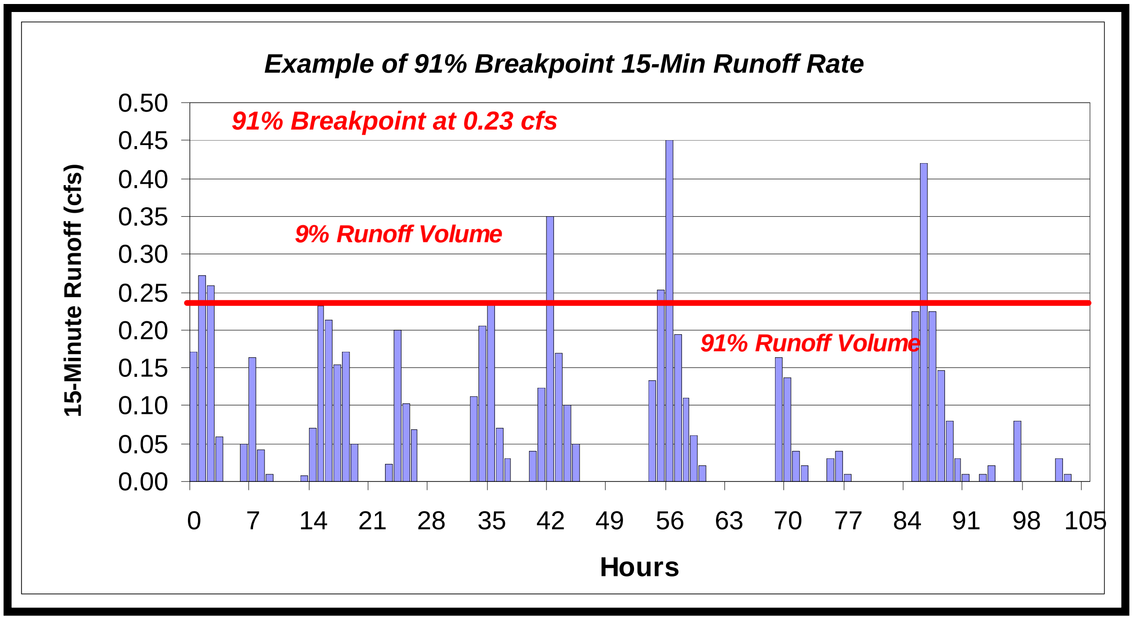


Figure F.10. Offline Water Quality Treatment Discharge Example.

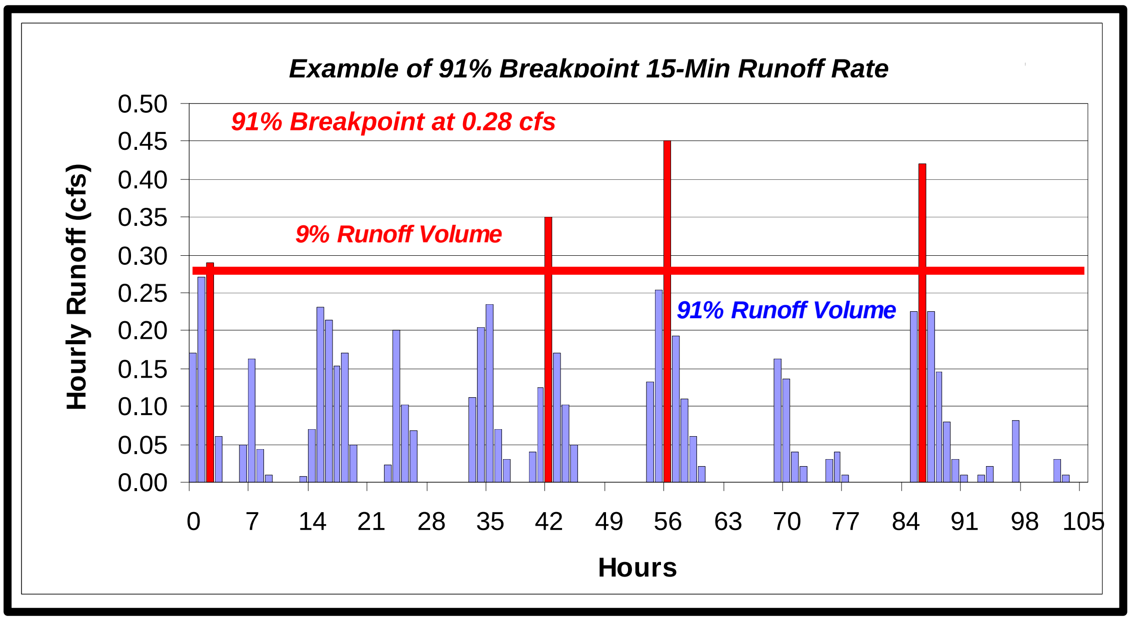


Figure F.11. On-Line Water Quality Treatment Discharge Example.

Infiltration Facilities Providing Water Quality Treatment: Infiltration facilities designed for water quality treatment must infiltrate 91 percent of the total runoff volume through soil meeting the treatment soils requirements outlined in *Volume 3, Section 4.5.2*. The procedure is the same as for designing infiltration for flow control, except that the target is to infiltrate 91 percent of the runoff file without overflow (refer to *Volume 3, Section 4.5.1*). In addition, to prevent the onset of anaerobic conditions, an infiltration facility designed for water quality treatment purposes must be designed to drain the water quality design volume within 48 hours. Drain time can be calculated by using a horizontal projection of the infiltration basin mid-depth dimensions and the design infiltration rate.

Stormwater Conveyance

Storms that produce the highest rates of runoff from developed areas are typically shorter in duration and are characterized by brief periods of high intensity rainfall. A 5-minute time step (refer to Table F.12) is required to adequately simulate the runoff peak discharge and hydrograph shape resulting from these high-intensity storms. A 15-minute time step may be used if the time of concentration computed is 30 minutes or more. Follow the modeling steps outlined in *Steps for Hydrologic Design Using Continuous Models*, and for conveyance-specific designs also perform the following:

Step #	Procedure
SC-1	Identify downstream hydraulic controls, such as outfalls (refer to Outfalls in *Section F-3*), known flooding locations, receiving pipe hydraulic grade line (HGL), pump station, regulator station, weirs, or orifices. Determine if backwater calculations or a dynamic hydraulic routing model are required.
SC-2	Analyze flood frequencies and select the flows representing the level of conveyance service and/or flood protection required.
SC-3	Utilize the peak flows to size or assess the capacity of pipe systems, culverts, channels, spillways and overflow structures.
SC-4	Perform a capacity analysis to verify that there is sufficient capacity in the public drainage system or the public combined sewer system. Refer to *Volume 3, Section 4.3* and SMC, Section 22.805.020.J for specific requirements.
SC-5	Size the pipe to convey the selected peak flows.

Using Continuous Simulation Hydrographs with Dynamic Routing Models

Continuous hydrologic models based on the HSPF program utilize hydrologic (also known as lumped) routing routines to determine the time and magnitude of flow of a watercourse. Because of this, these models cannot simulate complex hydraulics such as where the flow reverses direction or where a downstream channel or pipe influences another upstream in a time dependent way.

For simulation of complex hydraulics in pipe systems or tidally influenced boundaries, a dynamic routing hydraulic program, such as the SWMM Extran routine, may be necessary to accurately determine the discharge rate and the water surface elevation or hydraulic grade line (HGL). Flows simulated using the continuous hydrologic model may be exported and used as input to the dynamic routing hydraulic model.

Dynamic routing models solve the full unsteady flow equations using numeric approximation methods. These methods typically require computational time steps that are relatively short to maintain numerical stability, and it may not be practical to attempt routing of multi-year sequences of runoff produced by the continuous hydrologic model. To reduce the simulation time, flow hydrographs from specific storms of interest computed using the continuous flow model may be used rather than the entire simulated flow time series.

To utilize a dynamic routing model to route hydrographs computed with the continuous hydrologic model, the procedure described in the *Steps for Hydrologic Design Using Continuous Models* should be followed to create the runoff time series. The following additional steps should be followed to identify storms of a particular recurrence interval, export them from the continuous model, and import them into SWMM (or other dynamic routing model):

Step #	Procedure
DR-1	Delineate the watershed with subbasin outlets (runoff collection points) corresponding to the main inflows to the pipe system.
DR-2	Run the continuous hydrologic model for the full period of record. For most design applications, the City of Seattle Design Time Series should be used. The routing effects of the pipe or other conveyance system to be analyzed should not be included in the continuous hydrologic model.
DR-3	Use flood peak discharge statistics computed by the continuous model to identify when floods of various recurrence intervals occur in the simulated time series. Export hydrographs with peak discharge rates corresponding to desired recurrence intervals in a format that can be read by the hydraulic model.

For example, Table F.13 shows flood peak discharge-frequency results for a subbasin. If hydrographs corresponding to the 100-year, 25-year, and 10-year recurrence intervals were needed for conveyance design purposes, then simulated hydrographs with recurrence intervals closest to those required would be exported from the continuous hydrologic model as indicated in the right column of the table. The hydrograph duration would include a period antecedent to the flood peak (typically several days to a week) and several days following the flood peak.

F-5. Single-Event Rainfall–Runoff Methods

Single-event models simulate rainfall-runoff processes for a single-storm, typically 2 hours to 72 hours in length and usually of a specified exceedance probability. Because the primary interest is the flood hydrograph, calculation of evapotranspiration, soil moisture changes between storms, and base flow processes are typically not needed. This is in contrast to continuous rainfall-runoff models (*Section F-4*) where multi-decade precipitation and evaporation time series are used as input to produce a corresponding multi-decade time series of runoff.

Precipitation input to single-event models can include either historical data recorded from a rain gauge or a synthetic design storm hyetograph. This section describes the use of both types of precipitation input.

Design Storm Hyetographs

Design storm hyetographs were developed using noteworthy storms that were recorded by the City of Seattle gauging network. NOAA Atlas 2 precipitation-frequency (isopluvial) maps published in the early 1970s have historically been used in hydrologic analysis and design. These maps are replaced in this manual by precipitation magnitude-frequency estimates more specific to the City of Seattle. These estimates are based on a regional analysis using data from the SPU Rain Gauge Network and gauges from the NOAA national cooperative gaging network in western Washington. The most recent analysis included data from 1940 to 2003. Attachment 2 provides the precipitation data based on the SPU Rain Gauge Network.

Table F.13. Example Simulated Peak Discharge Frequency Table and Hydrographs Exported to SWMM or Other Hydraulic Model for Desired Recurrence Intervals.

Flood Peak Recurrence Interval (years)	Date of Peak[a]	Peak Discharge Rate (cfs)	Desired Recurrence Interval for Analysis
282	06/10/2010	7.62	
101	**11/04/1998**	**6.11**	**100-year**
62	06/29/1952	6.06	
44	02/03/2062	5.38	
35	07/18/2043	4.71	
28	10/06/1981	4.64	
24	**03/03/1950**	**4.54**	**25-year**
21	01/09/1990	4.40	
18	09/30/2011	4.40	
17	11/24/1990	4.27	
15	08/24/2077	4.25	
14	05/03/2002	4.25	
13	10/27/2054	4.15	
12	10/26/1986	4.03	
11	09/01/2061	3.93	
10	**01/20/2013**	**3.92**	**10-year**
9.6	08/23/1968	3.92	
9.0	01/14/2040	3.76	

[a] Simulation was performed using SPU Design Time Series, which is 158 years in length, and has dates spanning 10/1/1939 through 9/30/2097. (Note: This table may be revised in a future version of the 2021 Seattle Stormwater Manual.)

Statistical analyses were conducted for the storm characteristics and dimensionless design storms were developed for short, intermediate, and long duration storm events (Schaefer 2004). The short, intermediate, and long duration design storms can be scaled to any site-specific recurrence interval using precipitation magnitudes at the 2-hour, 6-hour, and 24-hour duration.

Table F.14 summarizes the applicability of the four City design storms. If multiple storm types are listed for a particular application, then all applicable storm types should be considered candidates and used in the hydrologic model. The candidate storm that produces the most severe hydrologic loading and most conservative design is then adopted as the design storm. Note that this table does not override the modeling requirements for specific facilities outlined in *Volume 3*, *Chapters 4* and *5*, or Table F.1. Table F.14 is for general guidance and applicability only.

Table F.14. Applicability of Storm Types for Hydrologic Design Applications.

Storm Type	Description	Applicability	Total Storm Duration	Precipitation from SPU Rain Gauges
Short-duration	• Typically occurs in late spring through early fall • High intensity • Limited volume	• Conveyance (storm drains, ditches, culverts, and other hydraulic structures) • Flow Control	3 hours	2 hours
Intermediate Duration	• Typically occurs in fall through early winter • Low intensity • High volume	• Conveyance (storm drains, ditches, culverts, and other hydraulic structures) • Flow Control	18 hours	6 hours
Seattle 24-hour	NA	Volume Based BMPs	24 hours	24 hours
Long-duration – Front and Back Loaded	• Typically occurs in late fall through early spring • Low intensity • High volume	Flow Control	64 hours	24 hours

NA – not applicable

Short-Duration Storm (3-hour)

Short-duration design storms are used for design situations where peak discharge is of primary interest. The storm temporal pattern is shown in Figure F.12 as a dimensionless unit hyetograph. Tabular values for this hyetograph are listed in Attachment 1. The total storm precipitation is 1.06 times the 2-hour precipitation amount.

Use the following steps to utilize the short-duration storm in hydrologic analyses.

Step #	Procedure
SD-1	Obtain the 2-hour precipitation amount for the recurrence interval of interest (refer to Table 2 in Attachment 2). Note that the 2-hour precipitation values for short-duration storms do not vary across the City.
SD-2	Multiply the 5-minute incremental ordinates of the dimensionless short-duration design storm (Attachment 1, Table 1) by the 2-hour value from Step SD-1. Note that the resulting storm has a duration of 3 hours and the total storm amount will be 1.06 times the volume of the 2-hour precipitation (refer to the SDCI SPU Stormwater webpage for modeling resources).
SD-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 12.

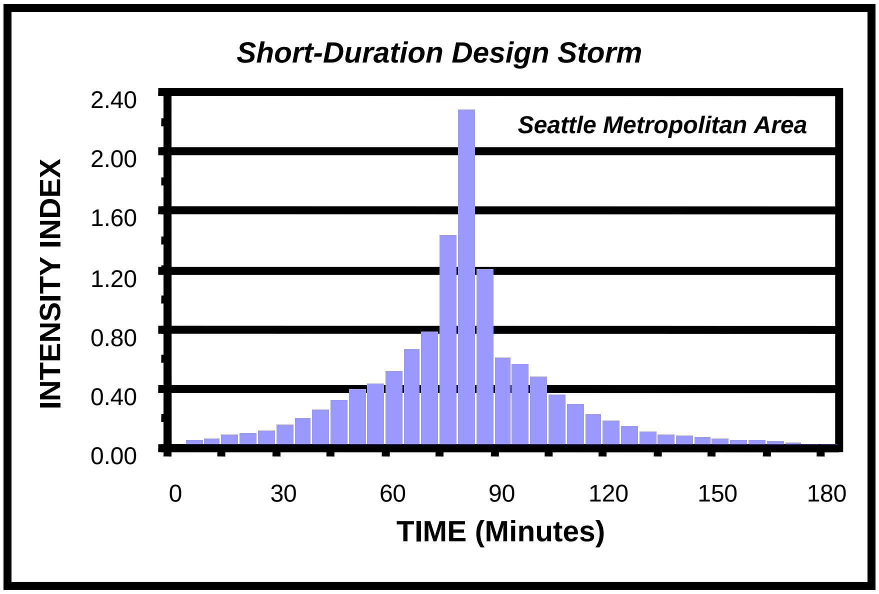


Figure F.12. Dimensionless Short-Duration (3-hour) Design Storm, Seattle Metropolitan Area.

Intermediate-Duration Storm (18 hour)

Intermediate-duration design storms are used in design applications where both peak discharge and runoff volume are important considerations and there is a need for a runoff hydrograph. The storm temporal pattern is shown in Figure F.13 as a dimensionless unit hyetograph. Tabular values for this hyetograph are listed in Attachment 1. The total storm precipitation is 1.51 times the 6-hour precipitation amount.

The following steps describe how to utilize the intermediate-duration storm in hydrologic analyses.

Step #	Procedure
ID-1	Obtain the 6-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Attachment 2 for data from the SPU Gauge(s) of interest).
ID-2	Multiply the 10-minute incremental ordinates of the dimensionless intermediate-duration and long-duration design storms (Attachment 1, Tables 2 and 4) by the 6-hour value from Step ID-1. Note that the resulting storm has a duration of 18 hours and the total storm amount will be 1.51 times the volume of the 6-hour precipitation (refer to the SDCI SPU Stormwater webpage for modeling resources).
ID-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 6.

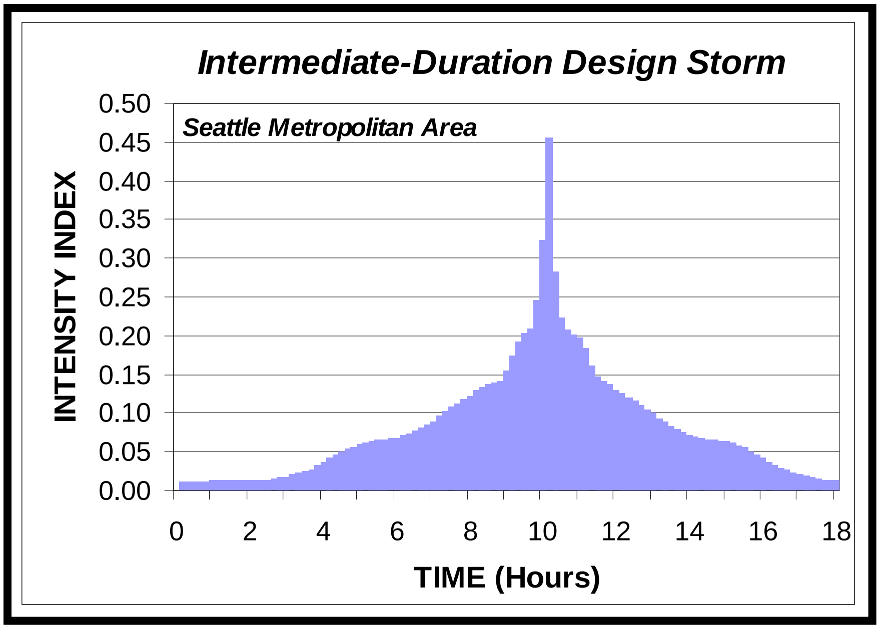


Figure F.13. Dimensionless Intermediate-Duration (18-hour) Design Storm, Seattle Metropolitan Area.

24-Hour Dimensionless Design Storm

Some specific volume-based stormwater facilities require or allow the use of a 24-hour design storm. To meet this need, the 24-hour dimensionless design storm was developed based on the maximum 24-hour period of precipitation within the long-duration design storm. It should be noted that the 24-hour dimensionless design storm has the same temporal shape and ordinates as the period of maximum 24-hour precipitation within the front-loaded and back-loaded long-duration dimensionless design storms. The City of Seattle 24-hour design storm is shown in Figure F.14.

Use the following steps to utilize the 24-hour design storm in hydrologic analyses:

Step #	Procedure
DD-1	Obtain the 24-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Attachment 2 for data from the SPU Gauge(s) of interest).
DD-2	Multiply the 10-minute incremental ordinates of the dimensionless 24-hour duration design storm (Attachment 1, Table 5) by the 24-hour value from Step DD-1 (refer to the SDCI SPU Stormwater webpage for modeling resources).
DD-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 6.

Long-Duration Storm (64 hour)

Long-duration design storms are primarily used in design of stormwater detention facilities and other projects where runoff volume is a primary consideration. Long-duration storms occur primarily in the late fall into early spring.

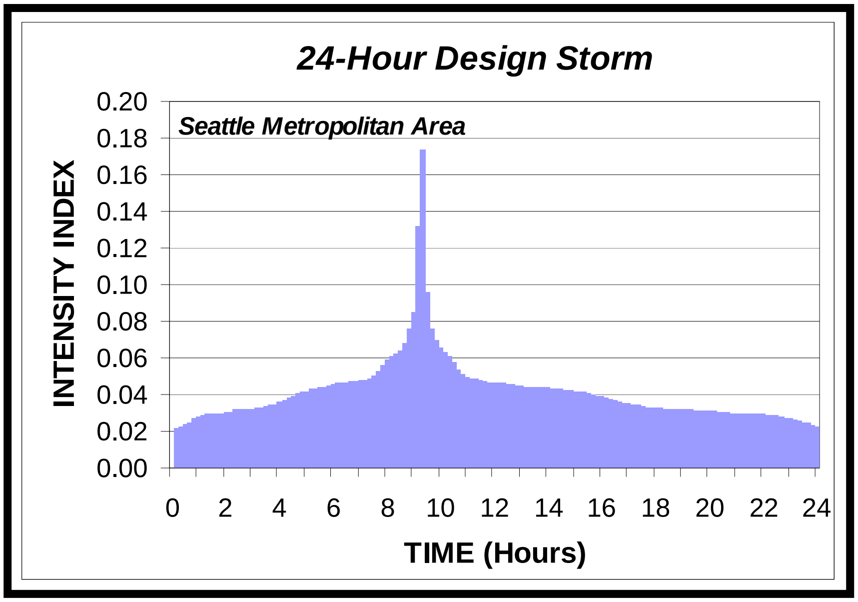


Figure F.14. Dimensionless 24-Hour Design Storm for Seattle Metropolitan Area.

Two long-duration dimensionless design storms are provided: a front-loaded design storm with the highest intensities at the beginning of the storm; and a back-loaded storm with the higher intensities nearer the end of the storm period. Characteristics of the front-loaded design storm have been observed more frequently, and this storm would be expected to produce more "typical" runoff conditions. The back-loaded storm occurs less often and is typically a more conservative event for drainage control facility design.

The long-duration storm hyetographs are 64 hours in duration. The storm temporal patterns for the front loaded and back loaded storms are shown in Figures F.15 and F.16 respectively. Tabular values for these storms are listed in Attachment 1. The total storm precipitation is 1.29 times the 24-hour precipitation amount for both the front and back loaded long-duration storm.

Use the following steps to utilize the long-duration storm in hydrologic analyses.

Step #	Procedure
LD-1	Obtain the 24-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Attachment 2 for data from the SPU Gauge(s) of interest).
LD-2	Multiply the 10-minute incremental ordinates of the dimensionless long-duration design storm (Attachment 1, Table 3 or 4) by the 24-hour value from Step LD-1. Note that the resulting storm has a duration of 64 hours and the total storm amount will be 1.29 times the volume of the 6-hour precipitation (refer to the SDCI SPU Stormwater webpage for modeling resources).
LD-3	Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (in/hr), multiply the precipitation increments by 6.

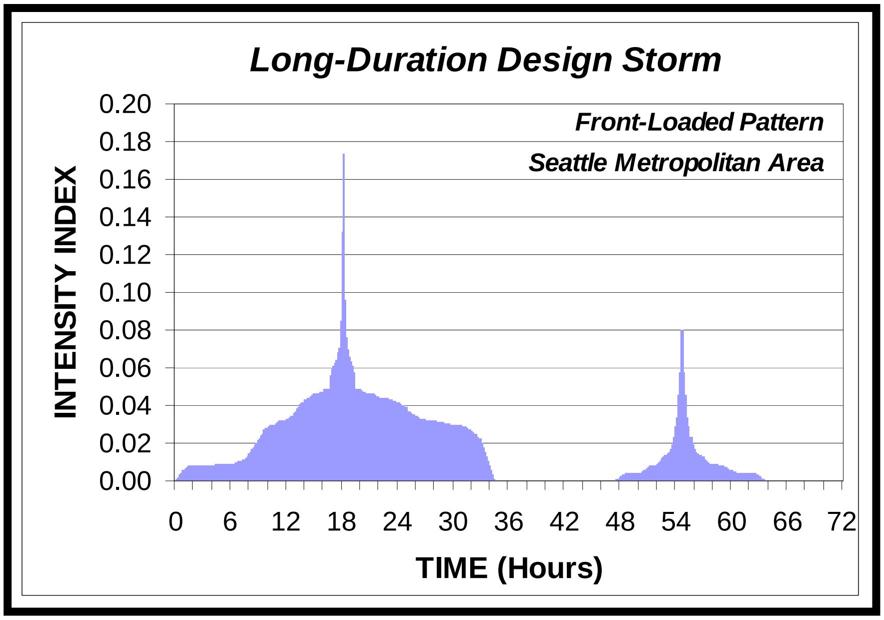


Figure F.15. Dimensionless Front-Loaded Long-Duration (64-hour) Design Storm for the Seattle Metropolitan Area.

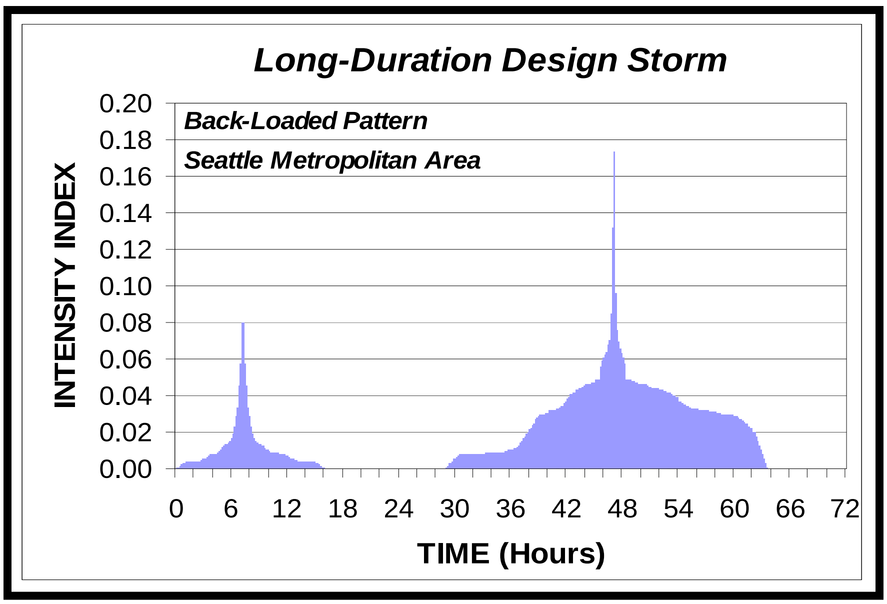


Figure F.16. Dimensionless Back-Loaded Long-Duration (64-hour) Design Storm for the Seattle Metropolitan Area.

Curve Number Equation and Infiltration Parameters

The Curve Number method may be used when computing runoff using the Long-duration storms (24 hours or 66 hours in length). The NRCS 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 — Part 630: Hydrology (NRCS 1997) contains a detailed description of the development and use of the curve number method.

The CN is related to the runoff potential of a watershed according to equations (12) and (13).

$$Q_d = \frac{(P - 0.2\,SMD_{MAX})^2}{(P + 0.8\,SMD_{MAX})} \qquad (12)$$

$$SMD_{MAX} = \frac{1000}{CN} - 10 \qquad (13)$$

Where: Q_d = runoff depth (inches)
P = precipitation depth (inches)
SMD_{MAX} = maximum soil moisture deficit (inches)
CN = Curve Number for the soil (Table F.15)

The CN is a combination of a hydrologic soil group and land cover with higher CNs resulting in higher runoff. CN values for combinations of land cover and hydrologic soil group are listed in Table F.15. Refer to Table F.3 in General Modeling Guidance (*Section F-3*) for information on soil groups in King County.

Table F.15. Post-Development Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas.

Land Use Description	Curve Numbers by Hydrologic Soil Group			
Land Cover Type and Hydrologic Condition	**A**	**B**	**C**	**D**
Pasture, grassland, or range-continuous forage for grazing				
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
Woods				
Fair Condition (woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good Condition (woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Open space (Lawns, parks, golf courses, cemeteries, landscaping, etc.)				
Fair Condition (grass cover on 50 to 75% of the area)	77	85	90	92
Good Condition (grass cover on greater than 75% of the area)	68	80	86	90

Table F.15 (continued). Post-Development Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas.

Land Use Description	Curve Numbers by Hydrologic Soil Group			
Land Cover Type and Hydrologic Condition	**A**	**B**	**C**	**D**
Impervious areas				
Open receiving waters (lakes, wetlands, ponds, etc.)	100	100	100	100
Paved surfaces (roads, roofs, driveways, etc.)	98	98	98	98
Gravel roads and parking lots	76	85	89	91
Dirt roads and parking lots	72	82	87	89
Permeable pavement				
Porous asphalt, porous concrete, or grid/lattice systems (without underlying perforated drain pipes to collect stormwater)	77	85	90	92
Paving blocks (without underlying perforated drain pipes to collect stormwater)	87	91	94	96
All permeable pavement types (with underlying perforated drain pipes to collect stormwater)	98	98	98	98

Time of Concentration Estimation

The time of concentration for the various surfaces and conveyances should be computed using the following methods, which are based on Chapter 3 of TR-55 (NRCS 1986).

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

Water is assumed to move 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. The time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments.

$$T_c = T_1 + T_2 + T_3 + \ldots T_n \qquad (14)$$

Where: T_c = time of concentration (minutes)
$T_{1,2,3,n}$ = time for consecutive flow path segments with different land cover categories or flow path slope

Travel time for each segment is computed using the following equation:

$$T_t = \frac{L}{60V} \qquad (15)$$

Where: T_t = travel time (minutes)
L = length of flow across a given segment (feet)
V = average velocity across the land segment (ft/sec)

Sheet Flow: Sheet flow is flow over plane surfaces. Sheet flow travel time is computed using equation (16). This equation is applicable for relatively impervious areas with shallow flow depths up to about 0.1 foot and for travel lengths up to 300 feet. Modified Manning's effective roughness coefficients (n_s) are summarized in Table F.16. These n_s values are applicable for shallow flow depths up to about 0.1 foot and for travel lengths up to 300 feet.

$$T_t = 0.42 * (n_s * L)^{0.8} \; / \; ((P_{24})^{0.5} * (S_o)^{0.4}) \qquad (16)$$

Where:
- T_t = travel time (minutes)
- n_s = sheet flow Manning's effective roughness coefficient from Table F.16
- L = overland flow length (feet)
- P_{24} = 2-year, 24-hour rainfall (inches)
- S_o = slope of hydraulic grade line or land slope (feet/feet)

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 F.16 in which average velocity is a function of watercourse slope and type of channel. After computing the average velocity using the velocity equation (17), the travel time (T_t) for the shallow concentrated flow segment can be computed using the travel time equation (15).

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

$$V = k_s \sqrt{S_o} \qquad (17)$$

Where:
- k_s = velocity factor (Table F.16)
- S_0 = slope of flow path (feet/feet)

"k" values in Table F.16 have been computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = (1.49 (R) 0.667)/n \qquad (18)$$

Where:
- R = assumed hydraulic radius
- n = Manning's roughness coefficient for open channel flow, from Tables F.16 or F.17

Open Channel Flow: Open channels are assumed to begin where flow enters ditches or pipes, where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on USGS quadrangle sheets. The k_c values from Table F.16 used in velocity equation (17) or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full conditions. The travel time (T_t) for the channel segment can be computed using travel time equation (15).

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 the *Level-Pool Routing Method* section.

Limitations: The following limitations apply in estimating travel time (T_t):

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet.
- In watersheds with drainage systems, carefully identify the appropriate hydraulic flow path to estimate T_c. Drainage systems generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and other surfaces, to the outlet. Consult a standard hydraulics textbook (e.g., Gray 1961; Linsley et al. 1975; Pilgrim and Cordery 1993; Viessman et al. 1977) to determine average velocity in pipes for either pressure or non-pressure 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.

Table F.16. Values of "n" and "k" for use in Computing Time of Concentration.

FOR SHEET FLOW	n_s
Smoot 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 = 0.04)	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

Source: USDA (1986).

Table F.17. Other Values of the Roughness Coefficient "n" for Channel Flow.

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

Single-Event Routing Methods Overview

In the United States, the majority of single-event models for computation of runoff hydrographs are based on unit hydrographs. Most commercial software packages utilize unit hydrographs for making the transformation from computation of runoff volume to generation of the runoff hydrograph. This may require direct input of the ordinates of the unit hydrograph or the unit hydrograph may be computed internally based on watershed characteristics provided by the user. Notable exceptions include event-based models that utilize linear reservoir concepts, such as the Santa Barbara Urban Hydrograph model (SBUH), event-based models that utilize kinematic wave approaches, and continuous flow simulation models such as HSPF.

The *Unit Hydrograph Routing Methods* section describes rainfall-runoff modeling based on unit hydrograph concepts. The reader is referred to any standard hydrology textbook (e.g., Gray 1961; Linsley et al. 1975; Pilgrim and Cordery 1993; Viessman et al. 1977) for a detailed discussion of unit hydrograph theory. The *SBUH Routing Method* section includes a discussion of runoff hydrographs developed using the SBUH model. The *Level-Pool Routing Method* section provides a discussion on the level-pool method, which is appropriate for routing hydrographs through lakes, wetlands, and other areas of standing water.

Unit Hydrograph Routing Methods

The unit hydrograph is defined as the time-distribution of runoff (Figure F.17) measured at the watershed outlet as produced by 1 inch of runoff uniformly generated over the watershed during a specified period of time. Thus, a 10-minute unit hydrograph would be the runoff hydrograph (cfs) observed at the watershed outlet as generated by 1 inch of runoff uniformly produced over the watershed in a 10-minute period.

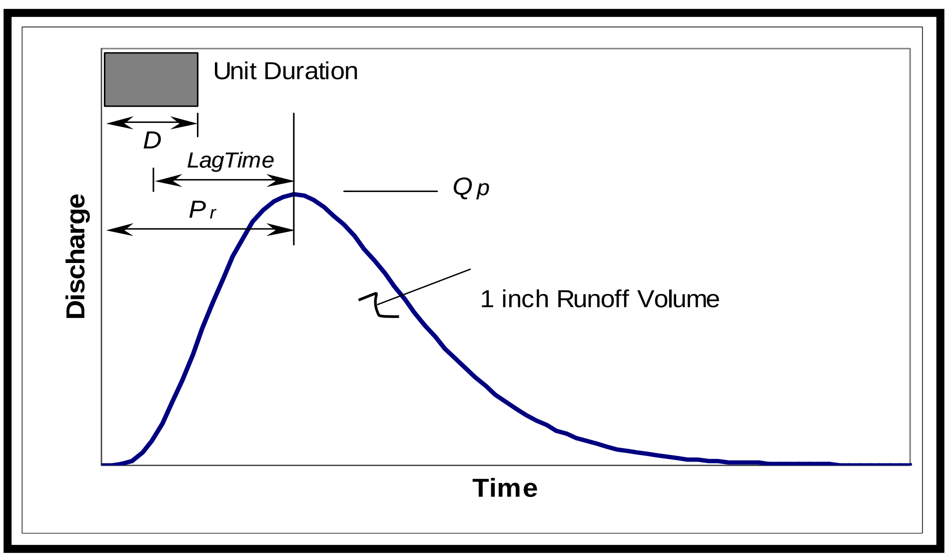


Figure F.17. Characteristics of Unit Hydrographs.

In computation of the runoff hydrograph, the unit hydrograph is scaled by the runoff in each D-minute period, and the resultant hydrographs for each D-minute period are added by superposition to yield the runoff hydrograph from the watershed.

Relationship of Computational Time Step to Time Lag (Lag Time). As indicated above, the ordinates of the unit hydrograph are specified on intervals equal to the computational time step. Recognizing that the time step and unit duration are equal ($\Delta t = D$), the unit duration must be chosen small enough to allow reasonable definition of the rising limb of the unit hydrograph. This is required to provide for adequate definition of the resultant runoff hydrograph in the vicinity of the runoff peak discharge. In addition, the value of D should be an integer multiple of the period of rise P_r so that the computational time step (Δt) falls on the peak discharge of the unit hydrograph.

Selection of Time Step (Δt) Based on Time of Concentration (T_c). The time-of concentration of the watershed (T_c) is often taken to be the elapsed time from the end of the unit duration (D) to the inflection point on the recession limb of the unit hydrograph (NRCS 1997). When the runoff hydrograph is computed based on unit hydrograph concepts utilizing time of concentration, the computational time step should be:

$$\Delta t < T_c/5 \tag{19}$$

To enhance compatibility with the City of Seattle design storms, the computational time step for runoff computations should be a multiple of the time step used to describe the design storm. The short-duration design storm is described in 5-minute intervals and the intermediate and long-duration design storms are described in 10-minute intervals. Therefore, the following additional criteria are required for selection of the time step for use with the short-duration design storm:

$$\Delta t = 5/n \tag{20}$$

And, for use with the intermediate and long-duration design storms:

$$\Delta t = 10/n \tag{21}$$

Where: n = integer greater than or equal to one

The above information should be particularly helpful for use with computer software that allows output of the runoff hydrograph on a time interval other than that used for internal computation of the runoff hydrograph. For those cases, the user may be unaware of the unit duration (D) and internal time step (Δt) being used by the computer program.

SBUH Routing Method

The SBUH method is an adaptation of standard hydrologic routing methods that employ the principle of conservation of mass. The routing equation for the SBUH method may be derived from linear reservoir concepts (Linsley et al. 1975; Fread 1993) where storage is taken to be a linear function of discharge.

The SBUH method uses two steps to synthesize the runoff hydrograph:

Step 1 — Compute the instantaneous hydrograph
Step 2 — Compute the runoff hydrograph

The instantaneous hydrograph is computed as follows:

$$I(t) = 60.5\ R(t)\ A/\Delta t \qquad (22)$$

Where: $I(t)$ = instantaneous hydrograph at each time step (Δt) (cfs)
$R(t)$ = total runoff depth (both impervious and pervious) at time increment Δt (inches)
A = area (acres)
Δt = computational time step (minutes)

The runoff hydrograph is then obtained by routing the instantaneous hydrograph through an imaginary reservoir with a time delay equal to the time of concentration of the drainage basin. The following equation estimates the routed flow:

$$Q(t+1) = Q(t) + w[I(t) + I(t+1) - 2Q(t)] \qquad (23)$$

$$w = \Delta t\ /(2T_c + \Delta t) \qquad (24)$$

Where: $Q(t)$ = runoff hydrograph or routed flow (cfs)
T_c = time of concentration (minutes)
Δt = computational time step (minutes)

Selection of Time Step (Δt) Based on Time of Concentration (T_c). Equation (23) requires that the computational time step be sufficiently short that the change in inflow, outflow, and storage during the time step can be treated as linear. For the case of very small urban watersheds, the low to moderate intensities in the long-duration design storm would typically generate runoff over a longer period than the time of concentration of the watershed. As a result, the elapsed time of the rising limb of the runoff hydrograph (T_r) would likewise be much longer than the time of concentration of the watershed. In addition, the computational time step for routing should be a multiple of the time step used to describe the design storm. Therefore, for intermediate and long-duration storms, the computational time step should satisfy equations (25) and (26):

$$\Delta t < T_c \qquad (25)$$

$$\Delta t = 10/n \qquad (26)$$

Where: Δt = computational time step (minutes)
T_c = time of concentration (minutes)
n = an integer greater than or equal to one

For short duration design storms, the flood peak of the runoff hydrograph may be quite flashy and produced by high-intensity precipitation during a limited portion of the storm. For this case, the elapsed time for the rising limb of the runoff hydrograph may be similar in magnitude to that of the time-of-concentration of the watershed. In this situation, the time step should be smaller than the time of concentration. In addition, the computational time step for routing should be a multiple of the time step used to describe the design storm. Therefore, for the short-duration storm, the computational time step should satisfy equations (27) and (28):

$$\Delta t < T_c/5 \qquad (27)$$

$$\Delta t = 5/n \qquad (28)$$

Where:
- Δt = computational time step (minutes)
- T_c = time of concentration (minutes)
- n = an integer greater than or equal to one

Level-Pool Routing Method

This section presents a general description of the methodology for routing a hydrograph through a retention/detention facility, closed depression, or wetland. Note that the City does not allow the use of single-event models for retention/detention facility design. The information presented in this section is for informational purposes only. The level pool routing technique (Fread 1993) is based on the continuity equation:

Inflow-outflow=change in storage

$$\left[\frac{I_1+I_2}{2}-\frac{O_1+O_2}{2}\right]=\frac{\Delta S}{\Delta t}=S_2-S_1 \qquad (29)$$

rearranging:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2 \qquad (30)$$

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 = computational time step (minutes)

The time step (Δt) must be consistent with the time interval used in developing the inflow hydrograph.

The following summarizes the steps required in performing level-pool hydrograph routing:

- Develop stage-storage-discharge relationship, which is a function of pond/wetland geometry and outflow
- Route the inflow hydrograph through the structure by applying equation (30) at each time step, where the inflow hydrograph supplies values of I, the stage-storage relationship supplies values of S, and the stage discharge relationship provides values of O.

Commercially available hydrologic computer models perform these calculations automatically.

Modeling Guidance

The following sections present the general process involved in conducting a hydrologic analysis using single-event hydrograph methods to evaluate or design stormwater conveyance systems. Applicability of single-event methods and design standard requirements are discussed in *Section F-2*.

Steps for Hydrologic Design Using Single-Event Methods

The following summarizes the process for conducting hydrologic analyses using single-event models.

Step #	Procedure
SE-1	Review all minimum requirements that apply to the proposed project (*Volume 1*)
SE-2	Review applicable site definition and mapping requirements (*Volume 1*)
SE-3	Identify and delineate the overall drainage basin for each discharge point from the development site under existing conditions: ● Identify existing land use ● Identify existing soil types using on-site evaluation, NRCS soil survey, or mapping performed by the University of Washington (http://geomapnw.ess.washington.edu) ● Identify existing drainage features such as streams, conveyance systems, detention facilities, ponding areas, depressions, etc.
SE-4	Select and delineate pertinent subbasins based on existing conditions: ● Select homogeneous subbasin areas ● Select separate subbasin areas for on-site and off-site drainage ● Select separate subbasin areas for major drainage features.

Stormwater Conveyance

Existing and proposed stormwater conveyance facilities may be analyzed and designed using peak flows from hydrographs derived from single-event approaches described in this appendix. In addition to the steps listed in the *Steps for Hydrologic Design Using Single-event Methods* section, the following steps should be followed for designing/analyzing conveyance facilities:

Step #	Procedure
SC-1	Determine runoff parameters for each subbasin
SC-2	Identify pervious and impervious areas ● The short- or intermediate-duration design storm generally governs the design of conveyance facilities. Both storm durations should be treated as candidate design storms and the one that produces the more conservative design (higher peak discharge rates) used as the design storm (refer to Design Storm Hyetograph section). ● Select runoff parameters per the Infiltration Equation section. ● Compute time of concentration per the Time of Concentration Estimation section.
SC-3	Identify downstream hydraulic controls, such as outfalls (refer to Outfalls in *Section F-3*), known flooding locations, receiving pipe HGL, pump station, regulator station, weirs or orifice. Determine if backwater calculations or a dynamic hydraulic routing model are required.

Step #	Procedure
SC-4	Compute runoff for the drainage system and determine peak discharge at the outlet of each subbasin for the design storm of interest
SC-5	Perform a capacity analysis to verify that there is sufficient capacity in the public drainage system or the public combined sewer system. Refer to *Volume 3, Section 4.3* and SMC, Section 22.805.020.J for specific requirements.
SC-6	Size the pipe based on the designated level of service.

F-6. Rational Method

The rational method is based on the assumption that rainfall intensity for any given duration is uniform over the entire tributary watershed. The rational formula relates peak discharge from the site of interest to rainfall intensity times a coefficient:

$$Q = CiA \tag{31}$$

Where:
- Q = peak discharge from the site of interest
- C = dimensionless runoff coefficient
- i = rainfall intensity for a given recurrence interval (in/hr)
- A = tributary area (acres)

The rainfall intensity (i) is determined from Figure F.18 or Table F.18 for the precipitation recurrence interval of interest and duration corresponding to the calculated time of concentration (refer to *Time of Concentration Estimation* section below).

Peak Rainfall Intensity Duration Frequency (IDF curves)

Rainfall intensity-duration-frequency (IDF) curves allow calculation of average design rainfall intensity for a given exceedance probability (recurrence interval) over a range of durations. Precipitation-frequency statistics presented in this appendix were analyzed using data from the City's 17-gauge precipitation measurement network within the City of Seattle, and the national NOAA cooperative gauge network 13. Durations of 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, 45 minutes, 60 minutes, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, and 7 days were analyzed to develop the IDF curves. IDF curves for storm durations up to 3 hours and applicable to sites within Seattle are shown in Figure F.21.

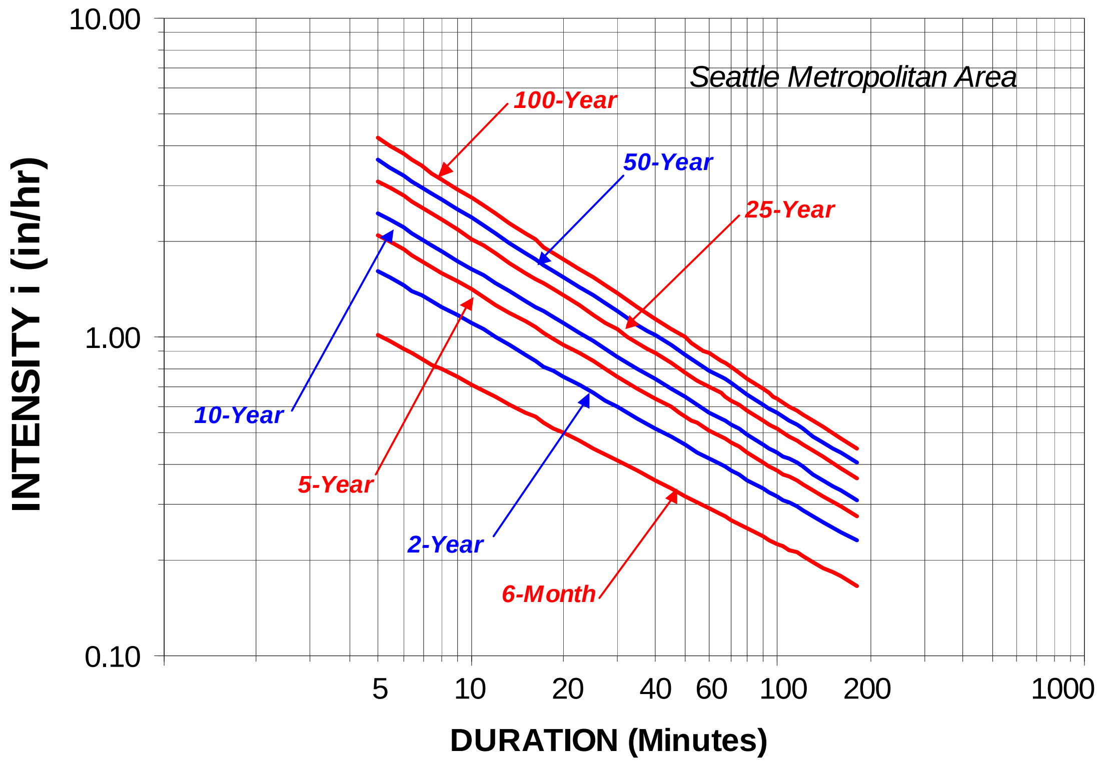


Figure F.18. Intensity-Duration-Frequency Curves for the City of Seattle.

Table F.18. Intensity-Duration-Frequency Values for 5- to 180-Minute Durations for Selected Recurrence Intervals for the City of Seattle.

Duration (minutes)	Precipitation Intensities (in/hr)							
	Recurrence Interval (years)							
	6-mo	2-yr	5-yr	10-yr	20-yr	25-yr	50-yr	100-yr
5	1.01	1.60	2.08	2.45	2.92	3.08	3.61	4.20
6	0.92	1.45	1.87	2.21	2.62	2.76	3.23	3.75
8	0.80	1.24	1.59	1.87	2.21	2.32	2.71	3.13
10	0.71	1.10	1.40	1.64	1.93	2.03	2.36	2.72
12	0.65	1.00	1.27	1.48	1.74	1.82	2.11	2.43
15	0.58	0.88	1.12	1.30	1.52	1.60	1.84	2.11
20	0.50	0.75	0.95	1.10	1.28	1.34	1.54	1.76
25	0.45	0.67	0.84	0.97	1.12	1.18	1.35	1.53
30	0.41	0.61	0.76	0.87	1.01	1.05	1.21	1.37
35	0.38	0.56	0.69	0.80	0.92	0.96	1.10	1.24
40	0.35	0.52	0.64	0.74	0.85	0.89	1.01	1.14
45	0.33	0.49	0.60	0.69	0.79	0.83	0.94	1.06
50	0.32	0.46	0.57	0.65	0.74	0.78	0.88	0.99
55	0.30	0.44	0.54	0.61	0.70	0.73	0.83	0.94
60	0.29	0.42	0.51	0.58	0.67	0.70	0.79	0.89
65	0.28	0.40	0.49	0.56	0.64	0.66	0.75	0.84

Table F.18 (continued). Intensity-Duration-Frequency Values for 5- to 180-minute Durations for Selected Recurrence Intervals for the City of Seattle.

Duration (minutes)	Precipitation Intensities (in/hr)							
	Recurrence Interval (years)							
	6-mo	2-yr	5-yr	10-yr	20-yr	25-yr	50-yr	100-yr
70	0.27	0.38	0.47	0.53	0.61	0.64	0.72	0.80
80	0.25	0.36	0.43	0.49	0.56	0.59	0.66	0.74
90	0.24	0.33	0.41	0.46	0.52	0.55	0.62	0.69
100	0.22	0.32	0.38	0.43	0.49	0.51	0.58	0.64
120	0.20	0.29	0.35	0.39	0.44	0.46	0.52	0.57
140	0.19	0.26	0.32	0.36	0.40	0.42	0.47	0.52
160	0.18	0.24	0.29	0.33	0.37	0.39	0.43	0.48
180	0.17	0.23	0.27	0.31	0.35	0.36	0.40	0.45

Runoff Coefficients

Runoff coefficients vary with the tributary land cover and to a certain extent, the total depth and intensity of the rainfall. The storm depth and intensity is typically neglected, and the runoff coefficient is based on land cover only (Table F.19). For watersheds containing several land cover types, an aggregate runoff coefficient can be developed by computing the area weighted average from all cover types present (equation 32):

$$C_c = (C_1A_1 + C_2A_2 + C_3A_3 + \ldots + C_nA_n) / A_t \qquad (32)$$

Where:

C_c = composite runoff coefficient for the site

$C_{1,\,2,\,,\ldots n}$ = runoff coefficient for each land cover type

$A_{1,\,2,\,,\ldots n}$ = area of each land cover type (acres)

A_t = total tributary area (acres)

Table F.19. Rational Equation Runoff Coefficients.

Land Cover	Runoff Coefficient (C)
Dense Forest	0.10
Light Forest	0.15
Pasture	0.20
Lawns	0.25
Gravel Areas	0.80
Pavement and Roofs	0.90
Open Water (Ponds Lakes and Wetlands)	1.00

Time of Concentration Estimation

Time of concentration (T_c) is defined as the time it takes for runoff to travel from the most hydraulically distant point of the drainage area to the outlet. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

$$T_c = T_1 + T_2 + T_3 + \ldots T_n \quad (33)$$

Where:
- T_c = time of concentration (minutes)
- $T_{1,2,3,\ldots n}$ = time for consecutive flow path segments with different land cover categories or flow path slope

Travel time for each segment is computed using the following equation:

$$T_t = L / V$$

Where:
- T_t = travel time (minutes)
- L = length of flow across a given segment (feet)
- V = average velocity across the land segment (ft/sec)

$$V = k_r \sqrt{S_o} \quad (34)$$

Where:
- k_r = Velocity factor (Table F.20)
- S_0 = Slope of flow path (feet/feet)

Table F.20. Coefficients for Average Velocity Equation.

Land Cover	Velocity Factor (k_r)
Forest with Heavy Ground Cover and Meadow	2.5
Grass, Pasture, and Lawns	7.0
Nearly Bare Ground	10.1
Grassed Swale or Channel	15.0
Paved Areas	20.0

F-7. Risk-Based Hydrologic Design Concepts

Risk-based concepts and analytical approaches are being used more frequently in hydrologic design. A risk-based approach focuses on evaluating the two components of risk: the probability, and consequences of failure. Failure may be broadly defined and includes failure to meet a project goal, failure to meet a regulatory requirement, or the physical failure of a project element. Consequences of failure vary with the project type and features and may include economic, life safety, environmental, and political consequences.

Risk can be described qualitatively or quantitatively. For example, qualitative risk is often expressed as low, moderate, high, or very high, based on various combinations of the probability of failure and the consequences of failure. Quantitative risk assessment requires more detailed analysis to provide numerical measures of the probability of failure and consequences of failure. Quantitative units of measure for risk include loss of life per year for life safety risk, and dollars per year for consequences that can be expressed in economic terms.

Risk concepts are often used in design where the design target, level-of-service, etc., is based on the consequences of failure or upon some adopted level of qualitative or quantitative risk. The design targets and level of conservatism of design are typically set based on the tolerable level of risk for a given project type or consideration of the regulatory requirements.

When applying a risk-based approach, engineers and hydrologists primarily evaluate the probability of failure (or probability of being in compliance) and may assess how and which uncertainties affect the probability of failure (or probability of being in compliance). Application of hydrologic computer models and detailed numerical descriptions of hydrologic/hydraulic system components are an integral part of assessing the probability of being in compliance.

Uncertainty

Historically, uncertainty in hydrologic simulation analyses and the consequences for analysis results are rarely quantified as part of stormwater engineering design. Factors of safety have typically been applied at the end of a hydrologic analysis to account for uncertainties in the analysis. The same factor of safety is typically used regardless of the level of uncertainty or the confidence in the hydrologic model's ability to realistically simulate runoff. For many projects, the fixed safety factor approach is adequate. However, for projects where the consequences of failure (an erroneous design) are large, quantifying the analysis uncertainty and risk of not meeting the design standard may be beneficial in selecting an appropriate level of design conservatism.

F-8. References

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Attachment 1

Design Storm Dimensionless Hyetograph Ordinates

ATTACHMENT 1 – DESIGN STORM DIMENSIONLESS HYETOGRAPH ORDINATES

Table 1. Dimensionless Ordinates of the Short-Duration Design Storm.

DIMENSIONLESS ORDINATES OF SHORT-DURATION DESIGN STORM		
ELAPSED TIME (min)	INCREMENTAL ORDINATES	CUMULATIVE ORDINATES
0	0.0000	0.0000
5	0.0045	0.0045
10	0.0055	0.0100
15	0.0075	0.0175
20	0.0086	0.0261
25	0.0102	0.0363
30	0.0134	0.0497
35	0.0173	0.0670
40	0.0219	0.0889
45	0.0272	0.1161
50	0.0331	0.1492
55	0.0364	0.1856
60	0.0434	0.2290
65	0.0553	0.2843
70	0.0659	0.3502
75	0.1200	0.4702
80	0.1900	0.6602
85	0.1000	0.7602
90	0.0512	0.8114
95	0.0472	0.8586
100	0.0398	0.8984
105	0.0301	0.9285
110	0.0244	0.9529
115	0.0195	0.9724
120	0.0153	0.9877
125	0.0125	1.0002
130	0.0096	1.0098
135	0.0077	1.0175
140	0.0068	1.0243
145	0.0062	1.0305
150	0.0056	1.0361
155	0.0050	1.0411
160	0.0044	1.0455
165	0.0038	1.0493
170	0.0032	1.0525
175	0.0026	1.0551
180	0.0020	1.0571

Table 2. Dimensionless Ordinates of the Intermediate-Duration Design Storm.

DIMENSIONLESS ORDINATES OF INTERMEDIATE-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	6.17	0.0118	0.1972	12.17	0.0210	1.1731
0.17	0.0020	0.0020	6.33	0.0123	0.2095	12.33	0.0201	1.1932
0.33	0.0020	0.0040	6.50	0.0129	0.2224	12.50	0.0193	1.2125
0.50	0.0020	0.0060	6.67	0.0136	0.2360	12.67	0.0184	1.2309
0.67	0.0020	0.0080	6.83	0.0142	0.2502	12.83	0.0176	1.2485
0.83	0.0020	0.0100	7.00	0.0150	0.2652	13.00	0.0168	1.2653
1.00	0.0021	0.0121	7.17	0.0163	0.2815	13.17	0.0154	1.2807
1.17	0.0021	0.0142	7.33	0.0171	0.2986	13.33	0.0147	1.2954
1.33	0.0021	0.0163	7.50	0.0180	0.3166	13.50	0.0140	1.3094
1.50	0.0021	0.0184	7.67	0.0188	0.3354	13.67	0.0132	1.3226
1.67	0.0021	0.0205	7.83	0.0197	0.3551	13.83	0.0127	1.3353
1.83	0.0022	0.0227	8.00	0.0205	0.3756	14.00	0.0121	1.3474
2.00	0.0022	0.0249	8.17	0.0215	0.3971	14.17	0.0116	1.3590
2.17	0.0023	0.0272	8.33	0.0224	0.4195	14.33	0.0113	1.3703
2.33	0.0023	0.0295	8.50	0.0229	0.4424	14.50	0.0111	1.3814
2.50	0.0024	0.0319	8.67	0.0232	0.4656	14.67	0.0109	1.3923
2.67	0.0025	0.0344	8.83	0.0237	0.4893	14.83	0.0107	1.4030
2.83	0.0028	0.0372	9.00	0.0257	0.5150	15.00	0.0105	1.4135
3.00	0.0030	0.0402	9.17	0.0290	0.5440	15.17	0.0103	1.4238
3.17	0.0034	0.0436	9.33	0.0320	0.5760	15.33	0.0098	1.4336
3.33	0.0038	0.0474	9.50	0.0338	0.6098	15.50	0.0093	1.4429
3.50	0.0042	0.0516	9.67	0.0349	0.6447	15.67	0.0085	1.4514
3.67	0.0046	0.0562	9.83	0.0411	0.6858	15.83	0.0078	1.4592
3.83	0.0054	0.0616	10.00	0.0540	0.7398	16.00	0.0070	1.4662
4.00	0.0062	0.0678	10.17	0.0760	0.8158	16.17	0.0062	1.4724
4.17	0.0070	0.0748	10.33	0.0470	0.8628	16.33	0.0054	1.4778
4.33	0.0079	0.0827	10.50	0.0372	0.9000	16.50	0.0049	1.4827
4.50	0.0085	0.0912	10.67	0.0347	0.9347	16.67	0.0044	1.4871
4.67	0.0090	0.1002	10.83	0.0337	0.9684	16.83	0.0039	1.4910
4.83	0.0095	0.1097	11.00	0.0330	1.0014	17.00	0.0035	1.4945
5.00	0.0100	0.1197	11.17	0.0308	1.0322	17.17	0.0032	1.4977
5.17	0.0104	0.1301	11.33	0.0269	1.0591	17.33	0.0029	1.5006
5.33	0.0107	0.1408	11.50	0.0247	1.0838	17.50	0.0026	1.5032
5.50	0.0109	0.1517	11.67	0.0237	1.1075	17.67	0.0024	1.5056
5.67	0.0110	0.1627	11.83	0.0228	1.1303	17.83	0.0024	1.5080
5.83	0.0113	0.1740	12.00	0.0218	1.1521	18.00	0.0023	1.5103
6.00	0.0114	0.1854						

Table 3. Dimensionless Ordinates of Front-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF INTERMEDIATE-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	7.17	0.0018	0.0569	14.17	0.0072	0.2570
0.17	0.0001	0.0001	7.33	0.0019	0.0588	14.33	0.0073	0.2643
0.33	0.0003	0.0004	7.50	0.0019	0.0607	14.50	0.0074	0.2717
0.50	0.0005	0.0009	7.67	0.0020	0.0627	14.67	0.0075	0.2792
0.67	0.0007	0.0016	7.83	0.0022	0.0649	14.83	0.0076	0.2868
0.83	0.0009	0.0025	8.00	0.0024	0.0673	15.00	0.0077	0.2945
1.00	0.0010	0.0035	8.17	0.0026	0.0699	15.17	0.0078	0.3023
1.17	0.0011	0.0046	8.33	0.0028	0.0727	15.33	0.0078	0.3101
1.33	0.0012	0.0058	8.50	0.0030	0.0757	15.50	0.0078	0.3179
1.50	0.0013	0.0071	8.67	0.0032	0.0789	15.67	0.0079	0.3258
1.67	0.0013	0.0084	8.83	0.0034	0.0823	15.83	0.0079	0.3337
1.83	0.0013	0.0097	9.00	0.0036	0.0859	16.00	0.0079	0.3416
2.00	0.0013	0.0110	9.17	0.0038	0.0897	16.17	0.0081	0.3497
2.17	0.0013	0.0123	9.33	0.0040	0.0937	16.33	0.0082	0.3579
2.33	0.0013	0.0136	9.50	0.0042	0.0979	16.50	0.0082	0.3661
2.50	0.0014	0.0150	9.67	0.0045	0.1024	16.67	0.0093	0.3754
2.67	0.0014	0.0164	9.83	0.0047	0.1071	16.83	0.0099	0.3853
2.83	0.0014	0.0178	10.00	0.0048	0.1119	17.00	0.0102	0.3955
3.00	0.0014	0.0192	10.17	0.0049	0.1168	17.17	0.0104	0.4059
3.17	0.0014	0.0206	10.33	0.0049	0.1217	17.33	0.0107	0.4166
3.33	0.0014	0.0220	10.50	0.0049	0.1266	17.50	0.0114	0.4280
3.50	0.0014	0.0234	10.67	0.0050	0.1316	17.67	0.0118	0.4398
3.67	0.0014	0.0248	10.83	0.0051	0.1367	17.83	0.0142	0.4540
3.83	0.0014	0.0262	11.00	0.0051	0.1418	18.00	0.0220	0.4760
4.00	0.0014	0.0276	11.17	0.0053	0.1471	18.17	0.0290	0.5050
4.17	0.0014	0.0290	11.33	0.0053	0.1524	18.33	0.0160	0.5210
4.33	0.0015	0.0305	11.50	0.0054	0.1578	18.50	0.0127	0.5337
4.50	0.0015	0.0320	11.67	0.0054	0.1632	18.67	0.0116	0.5453
4.67	0.0015	0.0335	11.83	0.0054	0.1686	18.83	0.0110	0.5563
4.83	0.0015	0.0350	12.00	0.0055	0.1741	19.00	0.0106	0.5669
5.00	0.0015	0.0365	12.17	0.0055	0.1796	19.17	0.0102	0.5771
5.17	0.0015	0.0380	12.33	0.0056	0.1852	19.33	0.0096	0.5867
5.33	0.0015	0.0395	12.50	0.0057	0.1909	19.50	0.0082	0.5949
5.50	0.0015	0.0410	12.67	0.0058	0.1967	19.67	0.0082	0.6031
5.67	0.0015	0.0425	12.83	0.0060	0.2027	19.83	0.0082	0.6113
5.83	0.0015	0.0440	13.00	0.0062	0.2089	20.00	0.0081	0.6194
6.00	0.0015	0.0455	13.17	0.0064	0.2153	20.17	0.0080	0.6274
6.17	0.0015	0.0470	13.33	0.0066	0.2219	20.33	0.0079	0.6353
6.33	0.0015	0.0485	13.50	0.0068	0.2287	20.50	0.0079	0.6432

Table 3 (continued). Dimensionless Ordinates of Front-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF INTERMEDIATE-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
6.50	0.0016	0.0501	13.67	0.0069	0.2356	20.67	0.0078	0.6510
6.67	0.0016	0.0517	13.83	0.0070	0.2426	20.83	0.0078	0.6588
6.83	0.0017	0.0534	14.00	0.0072	0.2498	21.00	0.0077	0.6665
7.00	0.0017	0.0551						
21.17	0.0077	0.6742	30.17	0.0050	1.0069	39.17	0.0000	1.0984
21.33	0.0077	0.6819	30.33	0.0049	1.0118	39.33	0.0000	1.0984
21.50	0.0077	0.6896	30.50	0.0049	1.0167	39.50	0.0000	1.0984
21.67	0.0076	0.6972	30.67	0.0049	1.0216	39.67	0.0000	1.0984
21.83	0.0075	0.7047	30.83	0.0049	1.0265	39.83	0.0000	1.0984
22.00	0.0075	0.7122	31.00	0.0048	1.0313	40.00	0.0000	1.0984
22.17	0.0074	0.7196	31.17	0.0048	1.0361	40.17	0.0000	1.0984
22.33	0.0074	0.7270	31.33	0.0048	1.0409	40.33	0.0000	1.0984
22.50	0.0073	0.7343	31.50	0.0047	1.0456	40.50	0.0000	1.0984
22.67	0.0073	0.7416	31.67	0.0046	1.0502	40.67	0.0000	1.0984
22.83	0.0073	0.7489	31.83	0.0045	1.0547	40.83	0.0000	1.0984
23.00	0.0072	0.7561	32.00	0.0044	1.0591	41.00	0.0000	1.0984
23.17	0.0072	0.7633	32.17	0.0043	1.0634	41.17	0.0000	1.0984
23.33	0.0072	0.7705	32.33	0.0042	1.0676	41.33	0.0000	1.0984
23.50	0.0071	0.7776	32.50	0.0041	1.0717	41.50	0.0000	1.0984
23.67	0.0071	0.7847	32.67	0.0039	1.0756	41.67	0.0000	1.0984
23.83	0.0070	0.7917	32.83	0.0038	1.0794	41.83	0.0000	1.0984
24.00	0.0070	0.7987	33.00	0.0037	1.0831	42.00	0.0000	1.0984
24.17	0.0069	0.8056	33.17	0.0033	1.0864	42.17	0.0000	1.0984
24.33	0.0068	0.8124	33.33	0.0029	1.0893	42.33	0.0000	1.0984
24.50	0.0067	0.8191	33.50	0.0025	1.0918	42.50	0.0000	1.0984
24.67	0.0067	0.8258	33.67	0.0021	1.0939	42.67	0.0000	1.0984
24.83	0.0066	0.8324	33.83	0.0017	1.0956	42.83	0.0000	1.0984
25.00	0.0065	0.8389	34.00	0.0013	1.0969	43.00	0.0000	1.0984
25.17	0.0062	0.8451	34.17	0.0009	1.0978	43.17	0.0000	1.0984
25.33	0.0062	0.8513	34.33	0.0005	1.0983	43.33	0.0000	1.0984
25.50	0.0060	0.8573	34.50	0.0001	1.0984	43.50	0.0000	1.0984
25.67	0.0059	0.8632	34.67	0.0000	1.0984	43.67	0.0000	1.0984
25.83	0.0059	0.8691	34.83	0.0000	1.0984	43.83	0.0000	1.0984
26.00	0.0058	0.8749	35.00	0.0000	1.0984	44.00	0.0000	1.0984
26.17	0.0057	0.8806	35.17	0.0000	1.0984	44.17	0.0000	1.0984
26.33	0.0056	0.8862	35.33	0.0000	1.0984	44.33	0.0000	1.0984
26.50	0.0055	0.8917	35.50	0.0000	1.0984	44.50	0.0000	1.0984
26.67	0.0055	0.8972	35.67	0.0000	1.0984	44.67	0.0000	1.0984

Table 3 (continued). Dimensionless Ordinates of Front-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF INTERMEDIATE-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
26.83	0.0055	0.9027	35.83	0.0000	1.0984	44.83	0.0000	1.0984
27.00	0.0055	0.9082	36.00	0.0000	1.0984	45.00	0.0000	1.0984
27.17	0.0054	0.9136	36.17	0.0000	1.0984	45.17	0.0000	1.0984
27.33	0.0054	0.9190	36.33	0.0000	1.0984	45.33	0.0000	1.0984
27.50	0.0054	0.9244	36.50	0.0000	1.0984	45.50	0.0000	1.0984
27.67	0.0053	0.9297	36.67	0.0000	1.0984	45.67	0.0000	1.0984
27.83	0.0053	0.9350	36.83	0.0000	1.0984	45.83	0.0000	1.0984
28.00	0.0053	0.9403	37.00	0.0000	1.0984	46.00	0.0000	1.0984
28.17	0.0053	0.9456	37.17	0.0000	1.0984	46.17	0.0000	1.0984
28.33	0.0052	0.9508	37.33	0.0000	1.0984	46.33	0.0000	1.0984
28.50	0.0052	0.9560	37.50	0.0000	1.0984	46.50	0.0000	1.0984
28.67	0.0052	0.9612	37.67	0.0000	1.0984	46.67	0.0000	1.0984
28.83	0.0052	0.9664	37.83	0.0000	1.0984	46.83	0.0000	1.0984
29.00	0.0052	0.9716	38.00	0.0000	1.0984	47.00	0.0000	1.0984
29.17	0.0051	0.9767	38.17	0.0000	1.0984	47.17	0.0000	1.0984
29.33	0.0051	0.9818	38.33	0.0000	1.0984	47.33	0.0000	1.0984
29.50	0.0051	0.9869	38.50	0.0000	1.0984	47.50	0.0000	1.0984
29.67	0.0050	0.9919	38.67	0.0000	1.0984	47.67	0.0001	1.0985
29.83	0.0050	0.9969	38.83	0.0000	1.0984	47.83	0.0002	1.0987
30.00	0.0050	1.0019	39.00	0.0000	1.0984	48.00	0.0003	1.0990
48.17	0.0004	1.0994	56.17	0.0026	1.2422			
48.33	0.0005	1.0999	56.33	0.0024	1.2446			
48.50	0.0006	1.1005	56.50	0.0023	1.2469			
48.67	0.0007	1.1012	56.67	0.0023	1.2492			
48.83	0.0007	1.1019	56.83	0.0022	1.2514			
49.00	0.0007	1.1026	57.00	0.0021	1.2535			
49.17	0.0007	1.1033	57.17	0.0019	1.2554			
49.33	0.0007	1.1040	57.33	0.0017	1.2571			
49.50	0.0007	1.1047	57.50	0.0016	1.2587			
49.67	0.0007	1.1054	57.67	0.0015	1.2602			
49.83	0.0007	1.1061	57.83	0.0015	1.2617			
50.00	0.0007	1.1068	58.00	0.0015	1.2632			
50.17	0.0007	1.1075	58.17	0.0015	1.2647			
50.33	0.0008	1.1083	58.33	0.0015	1.2662			
50.50	0.0009	1.1092	58.50	0.0015	1.2677			
50.67	0.0010	1.1102	58.67	0.0014	1.2691			
50.83	0.0011	1.1113	58.83	0.0014	1.2705			
51.00	0.0012	1.1125	59.00	0.0013	1.2718			

Table 3 (continued). Dimensionless Ordinates of Front-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF INTERMEDIATE-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
51.17	0.0013	1.1138	59.17	0.0013	1.2731			
51.33	0.0014	1.1152	59.33	0.0012	1.2743			
51.50	0.0014	1.1166	59.50	0.0012	1.2755			
51.67	0.0014	1.1180	59.67	0.0011	1.2766			
51.83	0.0014	1.1194	59.83	0.0010	1.2776			
52.00	0.0015	1.1209	60.00	0.0009	1.2785			
52.17	0.0016	1.1225	60.17	0.0009	1.2794			
52.33	0.0018	1.1243	60.33	0.0008	1.2802			
52.50	0.0020	1.1263	60.50	0.0008	1.2810			
52.67	0.0021	1.1284	60.67	0.0007	1.2817			
52.83	0.0023	1.1307	60.83	0.0007	1.2824			
53.00	0.0023	1.1330	61.00	0.0007	1.2831			
53.17	0.0024	1.1354	61.17	0.0007	1.2838			
53.33	0.0026	1.1380	61.33	0.0007	1.2845			
53.50	0.0028	1.1408	61.50	0.0007	1.2852			
53.67	0.0032	1.1440	61.67	0.0007	1.2859			
53.83	0.0039	1.1479	61.83	0.0007	1.2866			
54.00	0.0048	1.1527	62.00	0.0007	1.2873			
54.17	0.0056	1.1583	62.17	0.0007	1.2880			
54.33	0.0076	1.1659	62.33	0.0007	1.2887			
54.50	0.0096	1.1755	62.50	0.0007	1.2894			
54.67	0.0133	1.1888	62.67	0.0006	1.2900			
54.83	0.0133	1.2021	62.83	0.0005	1.2905			
55.00	0.0096	1.2117	63.00	0.0004	1.2909			
55.17	0.0076	1.2193	63.17	0.0003	1.2912			
55.33	0.0056	1.2249	63.33	0.0002	1.2914			
55.50	0.0048	1.2297	63.50	0.0001	1.2915			
55.67	0.0039	1.2336	63.67	0.0000	1.2915			
55.83	0.0032	1.2368	63.83	0.0000	1.2915			
56.00	0.0028	1.2396	64.00	0.0000	1.2915			

Table 4. Dimensionless Ordinates of Back-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF BACK-LOADED LONG-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	8.17	0.0039	0.1352	16.17	0.0000	0.1931
0.17	0.0001	0.0001	8.33	0.0032	0.1384	16.33	0.0000	0.1931
0.33	0.0002	0.0003	8.50	0.0028	0.1412	16.50	0.0000	0.1931
0.50	0.0003	0.0006	8.67	0.0026	0.1438	16.67	0.0000	0.1931
0.67	0.0004	0.0010	8.83	0.0024	0.1462	16.83	0.0000	0.1931
0.83	0.0005	0.0015	9.00	0.0023	0.1485	17.00	0.0000	0.1931
1.00	0.0006	0.0021	9.17	0.0023	0.1508	17.17	0.0000	0.1931
1.17	0.0007	0.0028	9.33	0.0022	0.1530	17.33	0.0000	0.1931
1.33	0.0007	0.0035	9.50	0.0021	0.1551	17.50	0.0000	0.1931
1.50	0.0007	0.0042	9.67	0.0019	0.1570	17.67	0.0000	0.1931
1.67	0.0007	0.0049	9.83	0.0017	0.1587	17.83	0.0000	0.1931
1.83	0.0007	0.0056	10.00	0.0016	0.1603	18.00	0.0000	0.1931
2.00	0.0007	0.0063	10.17	0.0015	0.1618	18.17	0.0000	0.1931
2.17	0.0007	0.0070	10.33	0.0015	0.1633	18.33	0.0000	0.1931
2.33	0.0007	0.0077	10.50	0.0015	0.1648	18.50	0.0000	0.1931
2.50	0.0007	0.0084	10.67	0.0015	0.1663	18.67	0.0000	0.1931
2.67	0.0007	0.0091	10.83	0.0015	0.1678	18.83	0.0000	0.1931
2.83	0.0008	0.0099	11.00	0.0015	0.1693	19.00	0.0000	0.1931
3.00	0.0009	0.0108	11.17	0.0014	0.1707	19.17	0.0000	0.1931
3.17	0.0010	0.0118	11.33	0.0014	0.1721	19.33	0.0000	0.1931
3.33	0.0011	0.0129	11.50	0.0013	0.1734	19.50	0.0000	0.1931
3.50	0.0012	0.0141	11.67	0.0013	0.1747	19.67	0.0000	0.1931
3.67	0.0013	0.0154	11.83	0.0012	0.1759	19.83	0.0000	0.1931
3.83	0.0014	0.0168	12.00	0.0012	0.1771	20.00	0.0000	0.1931
4.00	0.0014	0.0182	12.17	0.0011	0.1782	20.17	0.0000	0.1931
4.17	0.0014	0.0196	12.33	0.0010	0.1792	20.33	0.0000	0.1931
4.33	0.0014	0.0210	12.50	0.0009	0.1801	20.50	0.0000	0.1931
4.50	0.0015	0.0225	12.67	0.0009	0.1810	20.67	0.0000	0.1931
4.67	0.0016	0.0241	12.83	0.0008	0.1818	20.83	0.0000	0.1931
4.83	0.0018	0.0259	13.00	0.0008	0.1826	21.00	0.0000	0.1931
5.00	0.0020	0.0279	13.17	0.0007	0.1833	21.17	0.0000	0.1931
5.17	0.0021	0.0300	13.33	0.0007	0.1840	21.33	0.0000	0.1931
5.33	0.0023	0.0323	13.50	0.0007	0.1847	21.50	0.0000	0.1931
5.50	0.0023	0.0346	13.67	0.0007	0.1854	21.67	0.0000	0.1931
5.67	0.0024	0.0370	13.83	0.0007	0.1861	21.83	0.0000	0.1931
5.83	0.0026	0.0396	14.00	0.0007	0.1868	22.00	0.0000	0.1931
6.00	0.0028	0.0424	14.17	0.0007	0.1875	22.17	0.0000	0.1931
6.17	0.0032	0.0456	14.33	0.0007	0.1882	22.33	0.0000	0.1931
6.33	0.0039	0.0495	14.50	0.0007	0.1889	22.50	0.0000	0.1931
6.50	0.0048	0.0543	14.67	0.0007	0.1896	22.67	0.0000	0.1931

Table 4 (continued). Dimensionless Ordinates of Back-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF BACK-LOADED LONG-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
6.67	0.0056	0.0599	14.83	0.0007	0.1903	22.83	0.0000	0.1931
6.83	0.0076	0.0675	15.00	0.0007	0.1910	23.00	0.0000	0.1931
7.00	0.0096	0.0771	15.17	0.0006	0.1916	23.17	0.0000	0.1931
7.17	0.0133	0.0904	15.33	0.0005	0.1921	23.33	0.0000	0.1931
7.33	0.0133	0.1037	15.50	0.0004	0.1925	23.50	0.0000	0.1931
7.50	0.0096	0.1133	15.67	0.0003	0.1928	23.67	0.0000	0.1931
7.67	0.0076	0.1209	15.83	0.0002	0.1930	23.83	0.0000	0.1931
7.83	0.0056	0.1265	16.00	0.0001	0.1931	24.00	0.0000	0.1931
8.00	0.0048	0.1313						
24.17	0.0000	0.1931	32.17	0.0014	0.2137	40.17	0.0053	0.3402
24.33	0.0000	0.1931	32.33	0.0014	0.2151	40.33	0.0053	0.3455
24.50	0.0000	0.1931	32.50	0.0014	0.2165	40.50	0.0054	0.3509
24.67	0.0000	0.1931	32.67	0.0014	0.2179	40.67	0.0054	0.3563
24.83	0.0000	0.1931	32.83	0.0014	0.2193	40.83	0.0054	0.3617
25.00	0.0000	0.1931	33.00	0.0014	0.2207	41.00	0.0055	0.3672
25.17	0.0000	0.1931	33.17	0.0014	0.2221	41.17	0.0055	0.3727
25.33	0.0000	0.1931	33.33	0.0015	0.2236	41.33	0.0056	0.3783
25.50	0.0000	0.1931	33.50	0.0015	0.2251	41.50	0.0057	0.3840
25.67	0.0000	0.1931	33.67	0.0015	0.2266	41.67	0.0058	0.3898
25.83	0.0000	0.1931	33.83	0.0015	0.2281	41.83	0.0060	0.3958
26.00	0.0000	0.1931	34.00	0.0015	0.2296	42.00	0.0062	0.4020
26.17	0.0000	0.1931	34.17	0.0015	0.2311	42.17	0.0064	0.4084
26.33	0.0000	0.1931	34.33	0.0015	0.2326	42.33	0.0066	0.4150
26.50	0.0000	0.1931	34.50	0.0015	0.2341	42.50	0.0068	0.4218
26.67	0.0000	0.1931	34.67	0.0015	0.2356	42.67	0.0069	0.4287
26.83	0.0000	0.1931	34.83	0.0015	0.2371	42.83	0.0070	0.4357
27.00	0.0000	0.1931	35.00	0.0015	0.2386	43.00	0.0072	0.4429
27.17	0.0000	0.1931	35.17	0.0015	0.2401	43.17	0.0072	0.4501
27.33	0.0000	0.1931	35.33	0.0015	0.2416	43.33	0.0073	0.4574
27.50	0.0000	0.1931	35.50	0.0016	0.2432	43.50	0.0074	0.4648
27.67	0.0000	0.1931	35.67	0.0016	0.2448	43.67	0.0075	0.4723
27.83	0.0000	0.1931	35.83	0.0017	0.2465	43.83	0.0076	0.4799
28.00	0.0000	0.1931	36.00	0.0017	0.2482	44.00	0.0077	0.4876
28.17	0.0000	0.1931	36.17	0.0018	0.2500	44.17	0.0078	0.4954
28.33	0.0000	0.1931	36.33	0.0019	0.2519	44.33	0.0078	0.5032
28.50	0.0000	0.1931	36.50	0.0019	0.2538	44.50	0.0078	0.5110
28.67	0.0000	0.1931	36.67	0.0020	0.2558	44.67	0.0079	0.5189
28.83	0.0000	0.1931	36.83	0.0022	0.2580	44.83	0.0079	0.5268
29.00	0.0000	0.1931	37.00	0.0024	0.2604	45.00	0.0079	0.5347

Table 4 (continued). Dimensionless Ordinates of Back-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF BACK-LOADED LONG-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
29.17	0.0001	0.1932	37.17	0.0026	0.2630	45.17	0.0081	0.5428
29.33	0.0003	0.1935	37.33	0.0028	0.2658	45.33	0.0082	0.5510
29.50	0.0005	0.1940	37.50	0.0030	0.2688	45.50	0.0082	0.5592
29.67	0.0007	0.1947	37.67	0.0032	0.2720	45.67	0.0093	0.5685
29.83	0.0009	0.1956	37.83	0.0034	0.2754	45.83	0.0099	0.5784
30.00	0.0010	0.1966	38.00	0.0036	0.2790	46.00	0.0102	0.5886
30.17	0.0011	0.1977	38.17	0.0038	0.2828	46.17	0.0104	0.5990
30.33	0.0012	0.1989	38.33	0.0040	0.2868	46.33	0.0107	0.6097
30.50	0.0013	0.2002	38.50	0.0042	0.2910	46.50	0.0114	0.6211
30.67	0.0013	0.2015	38.67	0.0045	0.2955	46.67	0.0118	0.6329
30.83	0.0013	0.2028	38.83	0.0047	0.3002	46.83	0.0142	0.6471
31.00	0.0013	0.2041	39.00	0.0048	0.3050	47.00	0.0220	0.6691
31.17	0.0013	0.2054	39.17	0.0049	0.3099	47.17	0.0290	0.6981
31.33	0.0013	0.2067	39.33	0.0049	0.3148	47.33	0.0160	0.7141
31.50	0.0014	0.2081	39.50	0.0049	0.3197	47.50	0.0127	0.7268
31.67	0.0014	0.2095	39.67	0.0050	0.3247	47.67	0.0116	0.7384
31.83	0.0014	0.2109	39.83	0.0051	0.3298	47.83	0.0110	0.7494
32.00	0.0014	0.2123	40.00	0.0051	0.3349	48.00	0.0106	0.7600
48.17	0.0102	0.7702	56.17	0.0054	1.1067			
48.33	0.0096	0.7798	56.33	0.0054	1.1121			
48.50	0.0082	0.7880	56.50	0.0054	1.1175			
48.67	0.0082	0.7962	56.67	0.0053	1.1228			
48.83	0.0082	0.8044	56.83	0.0053	1.1281			
49.00	0.0081	0.8125	57.00	0.0053	1.1334			
49.17	0.0080	0.8205	57.17	0.0053	1.1387			
49.33	0.0079	0.8284	57.33	0.0052	1.1439			
49.50	0.0079	0.8363	57.50	0.0052	1.1491			
49.67	0.0078	0.8441	57.67	0.0052	1.1543			
49.83	0.0078	0.8519	57.83	0.0052	1.1595			
50.00	0.0077	0.8596	58.00	0.0052	1.1647			
50.17	0.0077	0.8673	58.17	0.0051	1.1698			
50.33	0.0077	0.8750	58.33	0.0051	1.1749			
50.50	0.0077	0.8827	58.50	0.0051	1.1800			
50.67	0.0076	0.8903	58.67	0.0050	1.1850			
50.83	0.0075	0.8978	58.83	0.0050	1.1900			
51.00	0.0075	0.9053	59.00	0.0050	1.1950			
51.17	0.0074	0.9127	59.17	0.0050	1.2000			
51.33	0.0074	0.9201	59.33	0.0049	1.2049			
51.50	0.0073	0.9274	59.50	0.0049	1.2098			

Table 4 (continued). Dimensionless Ordinates of Back-Loaded Long-Duration Design Storm.

DIMENSIONLESS ORDINATES OF BACK-LOADED LONG-DURATION DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
51.67	0.0073	0.9347	59.67	0.0049	1.2147			
51.83	0.0073	0.9420	59.83	0.0049	1.2196			
52.00	0.0072	0.9492	60.00	0.0048	1.2244			
52.17	0.0072	0.9564	60.17	0.0048	1.2292			
52.33	0.0072	0.9636	60.33	0.0048	1.2340			
52.50	0.0071	0.9707	60.50	0.0047	1.2387			
52.67	0.0071	0.9778	60.67	0.0046	1.2433			
52.83	0.0070	0.9848	60.83	0.0045	1.2478			
53.00	0.0070	0.9918	61.00	0.0044	1.2522			
53.17	0.0069	0.9987	61.17	0.0043	1.2565			
53.33	0.0068	1.0055	61.33	0.0042	1.2607			
53.50	0.0067	1.0122	61.50	0.0041	1.2648			
53.67	0.0067	1.0189	61.67	0.0039	1.2687			
53.83	0.0066	1.0255	61.83	0.0038	1.2725			
54.00	0.0065	1.0320	62.00	0.0037	1.2762			
54.17	0.0062	1.0382	62.17	0.0033	1.2795			
54.33	0.0062	1.0444	62.33	0.0029	1.2824			
54.50	0.0060	1.0504	62.50	0.0025	1.2849			
54.67	0.0059	1.0563	62.67	0.0021	1.2870			
54.83	0.0059	1.0622	62.83	0.0017	1.2887			
55.00	0.0058	1.0680	63.00	0.0013	1.2900			
55.17	0.0057	1.0737	63.17	0.0009	1.2909			
55.33	0.0056	1.0793	63.33	0.0005	1.2914			
55.50	0.0055	1.0848	63.50	0.0001	1.2915			
55.67	0.0055	1.0903	63.67	0.0000	1.2915			
55.83	0.0055	1.0958	63.83	0.0000	1.2915			
56.00	0.0055	1.1013	64.00	0.0000	1.2915			

Table 5. Dimensionless Ordinates of 24-Hour Design Storm.

DIMENSIONLESS ORDINATES OF 24-HOUR DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
0.00	0.0000	0.0000	7.17	0.0080	0.2596	14.17	0.0072	0.6769
0.17	0.0036	0.0036	7.33	0.0082	0.2678	14.33	0.0072	0.6841
0.33	0.0038	0.0074	7.50	0.0084	0.2762	14.50	0.0072	0.6913
0.50	0.0040	0.0114	7.67	0.0088	0.2850	14.67	0.0071	0.6984
0.67	0.0042	0.0156	7.83	0.0093	0.2943	14.83	0.0071	0.7055
0.83	0.0045	0.0201	8.00	0.0099	0.3042	15.00	0.0070	0.7125
1.00	0.0047	0.0248	8.17	0.0102	0.3144	15.17	0.0070	0.7195
1.17	0.0048	0.0296	8.33	0.0104	0.3248	15.33	0.0069	0.7264
1.33	0.0049	0.0345	8.50	0.0107	0.3355	15.50	0.0068	0.7332
1.50	0.0049	0.0394	8.67	0.0114	0.3469	15.67	0.0067	0.7399
1.67	0.0049	0.0443	8.83	0.0127	0.3596	15.83	0.0066	0.7465
1.83	0.0050	0.0493	9.00	0.0142	0.3738	16.00	0.0065	0.7530
2.00	0.0051	0.0544	9.17	0.0220	0.3958	16.17	0.0064	0.7594
2.17	0.0051	0.0595	9.33	0.0290	0.4248	16.33	0.0063	0.7657
2.33	0.0053	0.0648	9.50	0.0160	0.4408	16.50	0.0062	0.7719
2.50	0.0053	0.0701	9.67	0.0127	0.4535	16.67	0.0060	0.7779
2.67	0.0054	0.0755	9.83	0.0116	0.4651	16.83	0.0059	0.7838
2.83	0.0054	0.0809	10.00	0.0110	0.4761	17.00	0.0059	0.7897
3.00	0.0054	0.0863	10.17	0.0106	0.4867	17.17	0.0058	0.7955
3.17	0.0055	0.0918	10.33	0.0102	0.4969	17.33	0.0057	0.8012
3.33	0.0055	0.0973	10.50	0.0096	0.5065	17.50	0.0056	0.8068
3.50	0.0056	0.1029	10.67	0.0089	0.5154	17.67	0.0055	0.8123
3.67	0.0057	0.1086	10.83	0.0085	0.5239	17.83	0.0055	0.8178
3.83	0.0058	0.1144	11.00	0.0083	0.5322	18.00	0.0055	0.8233
4.00	0.0060	0.1204	11.17	0.0082	0.5404	18.17	0.0055	0.8288
4.17	0.0062	0.1266	11.33	0.0081	0.5485	18.33	0.0054	0.8342
4.33	0.0064	0.1330	11.50	0.0080	0.5565	18.50	0.0054	0.8396
4.50	0.0066	0.1396	11.67	0.0079	0.5644	18.67	0.0054	0.8450
4.67	0.0068	0.1464	11.83	0.0078	0.5722	18.83	0.0053	0.8503
4.83	0.0069	0.1533	12.00	0.0078	0.5800	19.00	0.0053	0.8556
5.00	0.0070	0.1603	12.17	0.0077	0.5877	19.17	0.0053	0.8609
5.17	0.0072	0.1675	12.33	0.0077	0.5954	19.33	0.0053	0.8662
5.33	0.0072	0.1747	12.50	0.0076	0.6030	19.50	0.0052	0.8714
5.50	0.0073	0.1820	12.67	0.0076	0.6106	19.67	0.0052	0.8766
5.67	0.0074	0.1894	12.83	0.0075	0.6181	19.83	0.0052	0.8818
5.83	0.0075	0.1969	13.00	0.0075	0.6256	20.00	0.0052	0.8870
6.00	0.0076	0.2045	13.17	0.0074	0.6330	20.17	0.0052	0.8922
6.17	0.0077	0.2122	13.33	0.0074	0.6404	20.33	0.0051	0.8973
6.33	0.0078	0.2200	13.50	0.0074	0.6478	20.50	0.0051	0.9024
6.50	0.0078	0.2278	13.67	0.0073	0.6551	20.67	0.0051	0.9075

Table 5 (continued). Dimensionless Ordinates of 24-Hour Design Storm.

DIMENSIONLESS ORDINATES OF 24-HOUR DESIGN STORM								
ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE	ELAPSED TIME (Hr)	INCRM ORDINATE	SUM ORDINATE
6.67	0.0079	0.2357	13.83	0.0073	0.6624	20.83	0.0050	0.9125
6.83	0.0079	0.2436	14.00	0.0073	0.6697	21.00	0.0050	0.9175
7.00	0.0080	0.2516						
21.17	0.0050	0.9225						
21.33	0.0050	0.9275						
21.50	0.0049	0.9324						
21.67	0.0049	0.9373						
21.83	0.0049	0.9422						
22.00	0.0049	0.9471						
22.17	0.0048	0.9519						
22.33	0.0048	0.9567						
22.50	0.0048	0.9615						
22.67	0.0047	0.9662						
22.83	0.0046	0.9708						
23.00	0.0045	0.9753						
23.17	0.0044	0.9797						
23.33	0.0043	0.9840						
23.50	0.0042	0.9882						
23.67	0.0041	0.9923						
23.83	0.0039	0.9962						
24.00	0.0038	1.0000						

Attachment 2

Precipitation Magnitude-Frequency Estimates for SPU Rain Gauge Locations

Attachment 2 – Precipitation Magnitude-Frequency Estimates for SPU Rain Gauge Locations

This appendix contains adapted text and excerpted tables and figures from *Analysis of Precipitation-Frequency and Storm Characteristics for the City of Seattle* (MGS Engineering Consultants, Inc. for Seattle Public Utilities, January 2013). A majority of the analysis presented here is from rain gauge data ending in 2012. Tables 1, 3, and 4 were updated based on a study performed in 2020.

The results of homogeneity analyses indicate that at-site mean values for precipitation do not vary across the Seattle Metropolitan Area for durations of 3 hours and less. Accordingly, one set of intensity-duration-frequency (IDF) curves can be developed that are applicable to the Seattle Metropolitan Area. Table 1 and Figures 1 and 2 provide precipitation intensities and IDF curves representative of the Seattle Metropolitan Area for durations from 5 to 180 minutes.

Table 1. Intensity-Duration-Frequency Values for Durations from 5 Minutes Through 180 Minutes for Selected Recurrence Intervals for the Seattle Metropolitan Area.

DURATION (minutes)	DURATION (hours)	PRECIPITATION INTENSITIES (in/hr)							
		RECURRENCE INTERVAL (years)							
		6-Month	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
5	0.0833	1.02	1.31	1.62	2.06	2.39	2.79	2.92	3.35
6	0.1000	0.97	1.23	1.52	1.93	2.23	2.60	2.72	3.10
8	0.1333	0.86	1.08	1.33	1.67	1.94	2.25	2.35	2.68
10	0.1667	0.76	0.96	1.17	1.48	1.70	1.98	2.07	2.36
12	0.2000	0.69	0.86	1.05	1.32	1.53	1.77	1.85	2.11
15	0.2500	0.60	0.75	0.92	1.15	1.33	1.54	1.61	1.83
20	0.3333	0.51	0.63	0.77	0.96	1.11	1.28	1.34	1.53
25	0.4167	0.45	0.56	0.67	0.84	0.96	1.11	1.16	1.32
30	0.5000	0.41	0.50	0.60	0.75	0.86	1.00	1.04	1.18
35	0.5833	0.37	0.46	0.55	0.69	0.79	0.91	0.95	1.07
40	0.6667	0.35	0.43	0.51	0.64	0.73	0.84	0.87	0.99
45	0.7500	0.33	0.40	0.48	0.60	0.68	0.78	0.82	0.92
50	0.8333	0.31	0.38	0.46	0.56	0.64	0.74	0.77	0.87
55	0.9167	0.30	0.36	0.43	0.53	0.61	0.70	0.73	0.82
60	1.0000	0.29	0.35	0.42	0.51	0.58	0.66	0.69	0.78
65	1.0833	0.28	0.34	0.40	0.49	0.56	0.63	0.66	0.74
70	1.1667	0.27	0.32	0.38	0.47	0.53	0.61	0.63	0.71
80	1.3333	0.25	0.30	0.36	0.44	0.50	0.57	0.59	0.66
90	1.5000	0.24	0.29	0.34	0.41	0.47	0.53	0.55	0.62
100	1.6667	0.23	0.27	0.32	0.39	0.44	0.50	0.52	0.58
120	2.0000	0.21	0.25	0.30	0.36	0.40	0.46	0.47	0.53
140	2.3333	0.20	0.24	0.28	0.33	0.37	0.42	0.44	0.49
160	2.6667	0.19	0.22	0.26	0.31	0.35	0.39	0.41	0.45
180	3.0000	0.18	0.21	0.25	0.29	0.33	0.37	0.38	0.42

Table 2. Two-Hour Precipitation Magnitude-Frequency Values for Selected Recurrence Intervals for the Seattle Metropolitan Area.

Recurrence Interval	2-Hour Total (inches)
6-month	0.40
2-yr	0.58
5-yr	0.70
10-yr	0.78
20-yr	0.88
25-yr	0.92
50-yr	1.04
100-yr	1.14

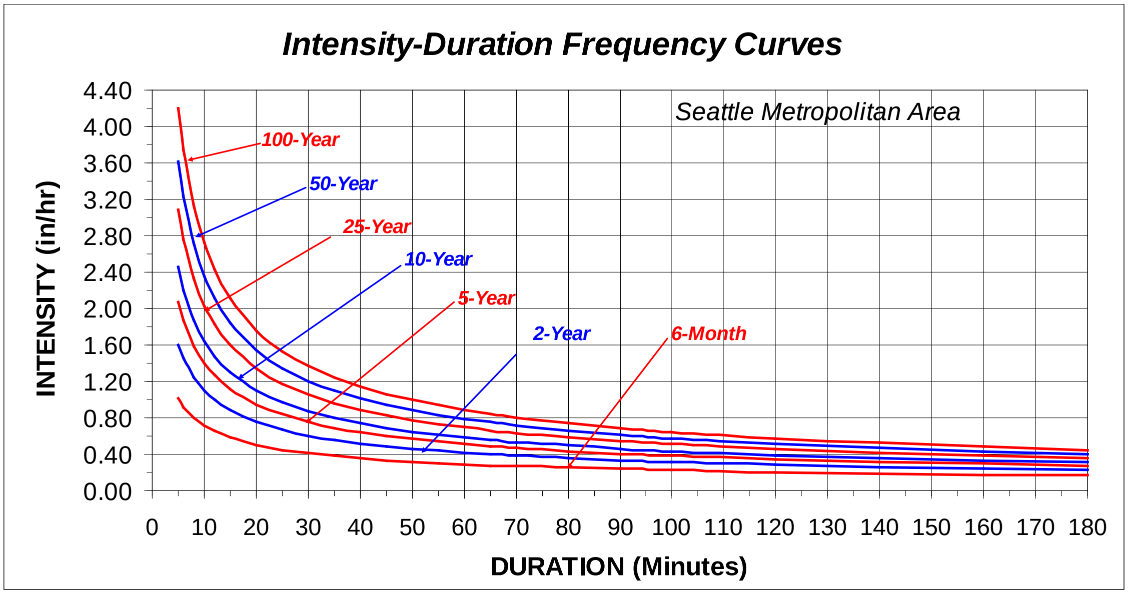

Figure 1. Intensity-Duration-Frequency Curves for the Seattle Metropolitan Area.

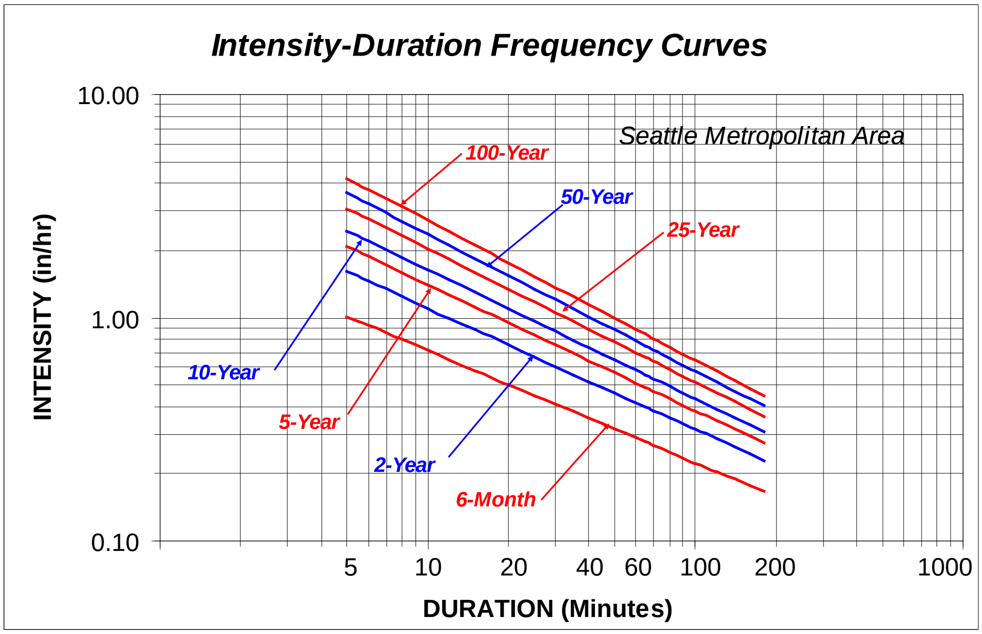

Figure 2. Intensity-Duration-Frequency Curves for the Seattle Metropolitan Area.

The following tables and figures contain estimates of precipitation-frequency values for durations of 6 hours, 12 hours, 24 hours, 48 hours, and 7 days for locations of SPU precipitation gauges (Table 2) in both tabular format and as magnitude-frequency curves. These precipitation values are based on estimates of the at-site mean values for the location of SPU gauges (Table 3) based on the spatial analysis of precipitation (gridded datasets) and the applicable regional growth curves obtained from the regional frequency analyses. Corrections have been applied to provide equivalent partial duration series estimates for frequently occurring events (5 times/year, 2 times/year, once/year, 2-year, and 5-year recurrence intervals).

Table 3. Listing of City of Seattle (SPU) Precipitation Gauges.

Station ID	Station Name	Latitude	Longitude	Year Start	Year End	Gauge Type
RG01	Haller Lake Shop	47.7211	122.3431	1965	2020	TB
RG02	Mathews Beach Pump Stn	47.6950	122.2731	1969	2020	TB
RG03	UW Hydraulics Lab	47.6481	122.3081	1965	2020	TB
RG04	Maple Leaf Reservoir	47.6900	122.3119	1965	2020	TB
RG05	Fauntleroy Ferry Dock	47.5231	122.3919	1968	2020	TB
RG07	Whitman Middle School	47.6961	122.3769	1965	2020	TB
RG08	Ballard Locks	47.6650	122.3969	1965	2020	TB
RG09	Woodland Park Zoo	47.6681	122.3539	1965	2020	TB
RG10	Rainier Ave Elementary	47.5000	122.2600	1968	2010	TB
RG11	Metro-KC Denny Regulating	47.6169	122.3550	1970	2020	TB
RG12	Catherine Blaine Jr	47.6419	122.3969	1965	2020	TB
RG14	West Seattle High School	47.5781	122.3819	1965	2020	TB
RG15	Metro-KC Diagonal Pump	47.5619	122.3400	1965	2020	TB
RG16	Metro-KC E Marginal Way	47.5350	122.3139	1970	2020	TB
RG17	West Seattle Engr Shop	47.5211	122.3450	1965	2020	TB
RG18	Hillman Engr Shop	47.5481	122.2750	1965	2020	TB
RG20	TT Minor Elementary	47.6119	122.3069	1975	2011	TB
RG25	Garfield Community Center	47.6076	-122.3020	2010	2020	TB
RG30	Rainier Beach Public Library	47.5214	-122.2700	2011	2020	TB
RG32	Beacon Telemetry Shack	47.5698	-122.3080	2016	2020	TB
RG33	Fire Station #38	47.6688	-122.2840	2016	2020	TB
RG34	Fire Station #39	47.7213	-122.2970	2016	2020	TB
RG35	Capitol Hill Library	47.6229	-122.3220	2016	2020	TB
RG36	High Point Library	47.5480	-122.3760	2016	2020	TB
45-7473	Seattle Tacoma Airport	47.4500	122.3000	1940	2020	HR

TB – Tipping Bucket
HR – NOAA Hourly Gauge

Table 4. Listing of Best Estimate At-site Mean Values for City of Seattle (SPU) Precipitation Gauges.

Best Estimate At-Site Mean Values (inches)							
Station ID	**Station Name**	**6 Hr**	**12 Hr**	**24 Hr**	**48 Hr**	**72 Hr**	**7 Day**
RG01	Haller Lake Shop	1.020	1.495	2.000	2.465	2.985	4.290
RG02	Mathews Beach Pump Stn	1.030	1.525	2.105	2.595	3.085	4.470
RG03	UW Hydraulics Lab	1.055	1.535	2.075	2.570	3.060	4.330
RG04	Maple Leaf Reservoir	1.035	1.520	2.065	2.585	3.105	4.435
RG05	Fauntleroy Ferry Dock	1.070	1.560	2.115	2.675	3.105	4.260
RG07	Whitman Middle School	1.050	1.535	2.050	2.535	3.095	4.510
RG08	Ballard Locks	1.055	1.545	2.065	2.545	3.045	4.335
RG09	Woodland Park Zoo	1.020	1.480	1.980	2.465	2.935	4.190
RG10	Rainier Ave Elementary	1.100	1.595	2.250	2.825	3.345	4.630
RG11	Metro-KC Denny Regulating	1.025	1.500	2.020	2.520	2.955	4.100
RG12	Catherine Blaine Jr	1.045	1.530	2.045	2.550	3.080	4.435
RG14	West Seattle High School	1.065	1.570	2.110	2.665	3.205	4.495
RG15	Metro-KC Diagonal Pump	1.055	1.535	2.095	2.655	3.135	4.335
RG16	Metro-KC E Marginal Way	1.065	1.545	2.160	2.700	3.205	4.440
RG17	West Seattle Engr Shop	1.100	1.590	2.210	2.785	3.325	4.665
RG18	Hillman Engr Shop	1.080	1.560	2.165	2.735	3.235	4.510
RG20	TT Minor Elementary	1.080	1.595	2.150	2.720	3.170	4.440
RG25	Garfield Community Center	1.080	1.565	2.150	2.720	3.170	4.440
RG30	Rainier Beach Public Library	1.100	1.595	2.250	2.825	3.345	4.630
RG32	Beacon Telemetry Shack	1.070	1.555	2.150	2.700	3.195	4.465
RG33	Fire Station #38	1.045	1.525	2.090	2.600	3.100	4.430
RG34	Fire Station #39	1.025	1.510	2.045	2.525	3.030	4.390
RG35	Capitol Hill Library	1.055	1.540	2.100	2.625	3.125	4.415
RG36	High Point Library	1.070	1.560	2.120	2.670	3.165	4.400

Table 5. Precipitation-Magnitude-Frequency Estimates for of SPU Gauge 01.

Duration (hr)	Precipitation (in)								
	Recurrence Interval (years)								
	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6	0.75	0.89	1.03	1.23	1.37		1.58	1.74	1.91	2.31
12	1.05	1.26	1.48	1.78	1.99		2.32	2.56	2.81	3.40
24	1.39	1.70	2.01	2.44	2.75		3.22	3.58	3.94	4.83
48	1.67	2.05	2.45	2.98	3.37		3.96	4.41	4.86	5.97
72	2.05	2.50	2.95	3.56	3.99		4.63	5.11	5.59	6.72
168	2.92	3.55	4.18	4.98	5.53		6.32	6.89	7.44	8.67

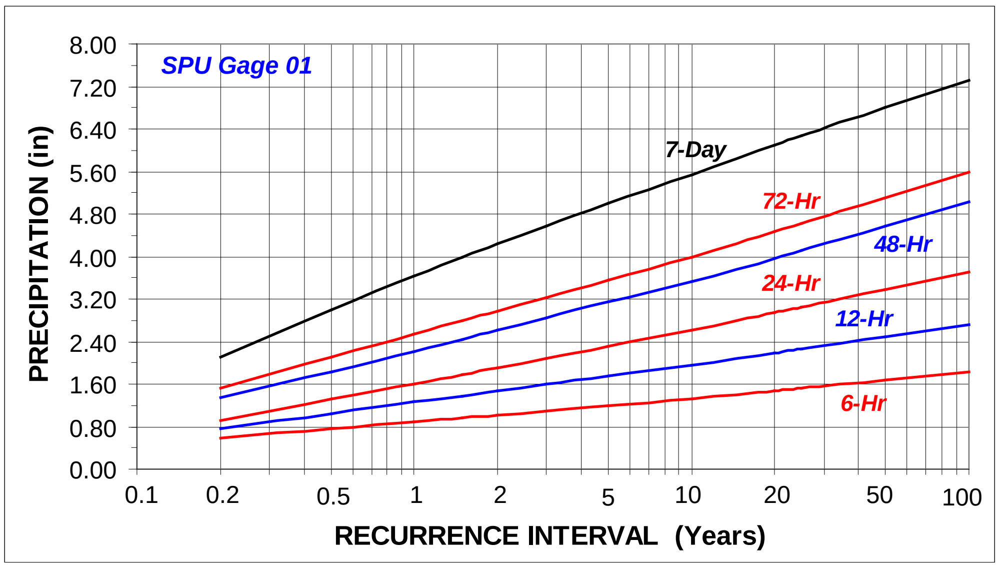

Figure 3. Precipitation-Magnitude-Frequency Estimates for of SPU Gauge 01.

Table 6. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 02.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.77	0.91	1.06	1.26	1.40		1.62	1.78	1.95	2.36
12		1.08	1.30	1.53	1.83	2.05		2.38	2.64	2.89	3.50
24		1.44	1.75	2.07	2.51	2.83		3.31	3.68	4.06	4.97
48		1.73	2.12	2.53	3.08	3.49		4.09	4.56	5.03	6.18
72		2.13	2.59	3.06	3.69	4.13		4.80	5.30	5.79	6.97
168		3.03	3.69	4.34	5.17	5.75		6.57	7.16	7.74	9.01

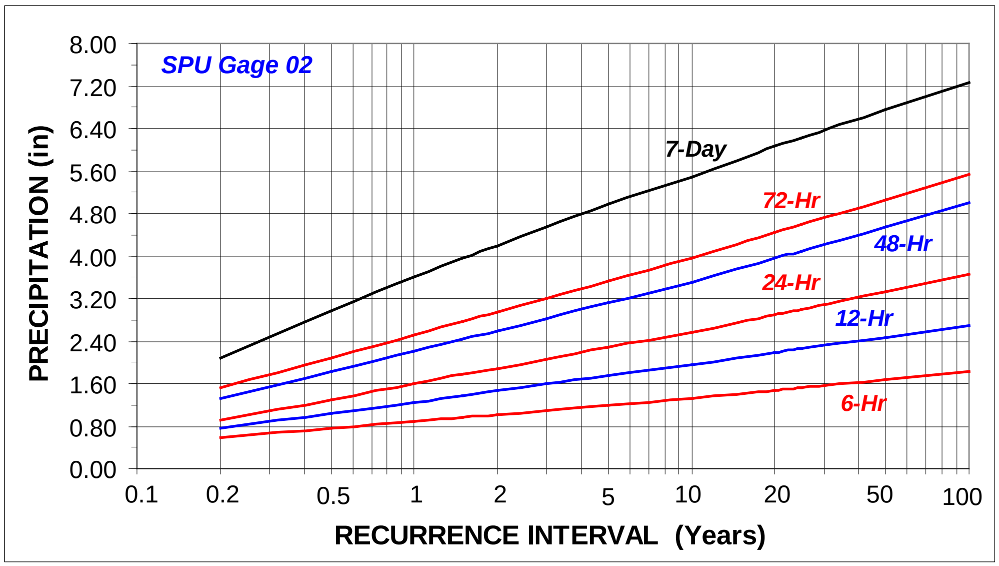

Figure 4. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 02.

Table 7. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 03.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.77	0.91	1.06	1.26	1.41		1.62	1.79	1.96	2.37
12		1.09	1.31	1.53	1.84	2.06		2.39	2.65	2.90	3.52
24		1.44	1.75	2.08	2.52	2.84		3.33	3.70	4.08	4.99
48		1.74	2.14	2.55	3.10	3.51		4.12	4.59	5.06	6.22
72		2.14	2.60	3.08	3.71	4.16		4.83	5.33	5.83	7.01
168		3.05	3.71	4.37	5.21	5.79		6.61	7.21	7.78	9.07

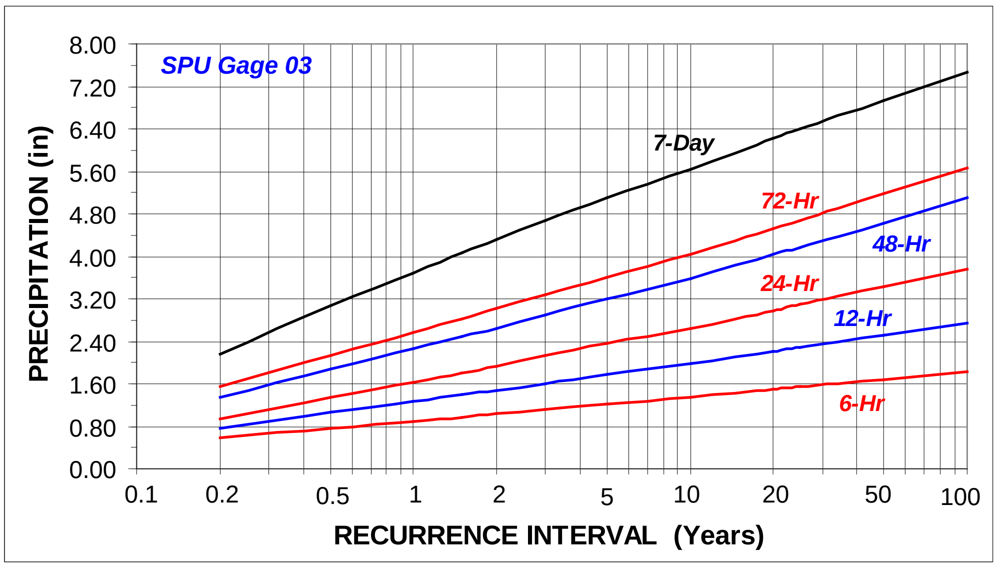

Figure 5. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 03.

Table 8. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 04.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.77	0.91	1.06	1.26	1.40		1.62	1.78	1.95	2.36
12		1.08	1.30	1.53	1.83	2.05		2.38	2.64	2.89	3.50
24		1.44	1.75	2.07	2.51	2.83		3.31	3.68	4.06	4.97
48		1.73	2.12	2.53	3.08	3.49		4.09	4.56	5.03	6.18
72		2.13	2.59	3.06	3.69	4.13		4.80	5.30	5.79	6.97
168		3.03	3.69	4.34	5.17	5.75		6.57	7.16	7.74	9.01

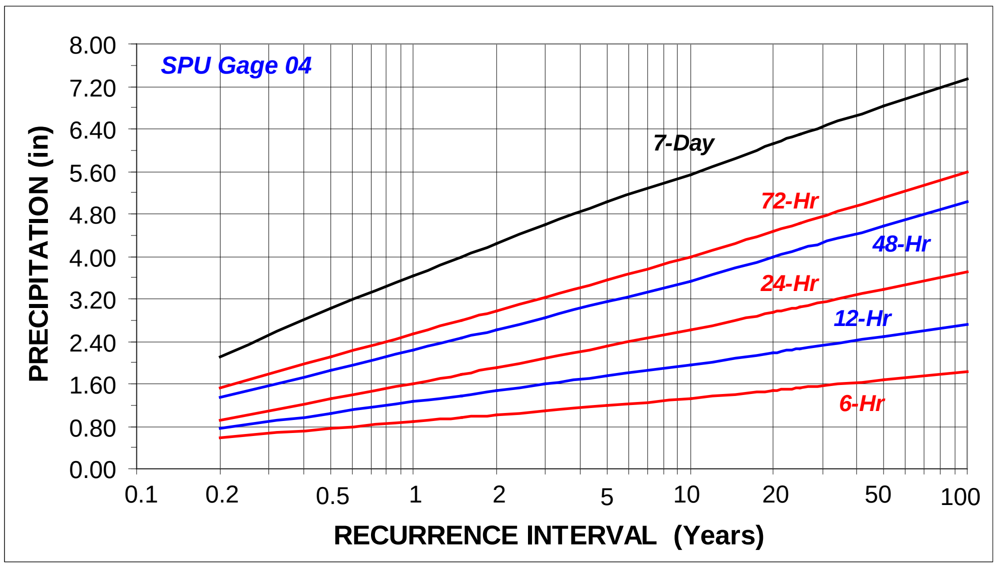

Figure 6. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 04.

Table 9. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 05.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.80	0.94	1.09	1.30	1.45		1.67	1.85	2.02	2.44
12		1.13	1.36	1.59	1.91	2.14		2.48	2.75	3.01	3.65
24		1.50	1.82	2.16	2.62	2.95		3.45	3.84	4.23	5.18
48		1.82	2.23	2.66	3.24	3.66		4.30	4.79	5.29	6.50
72		2.24	2.72	3.22	3.88	4.35		5.05	5.58	6.10	7.33
168		3.20	3.90	4.59	5.47	6.08		6.94	7.57	8.17	9.52

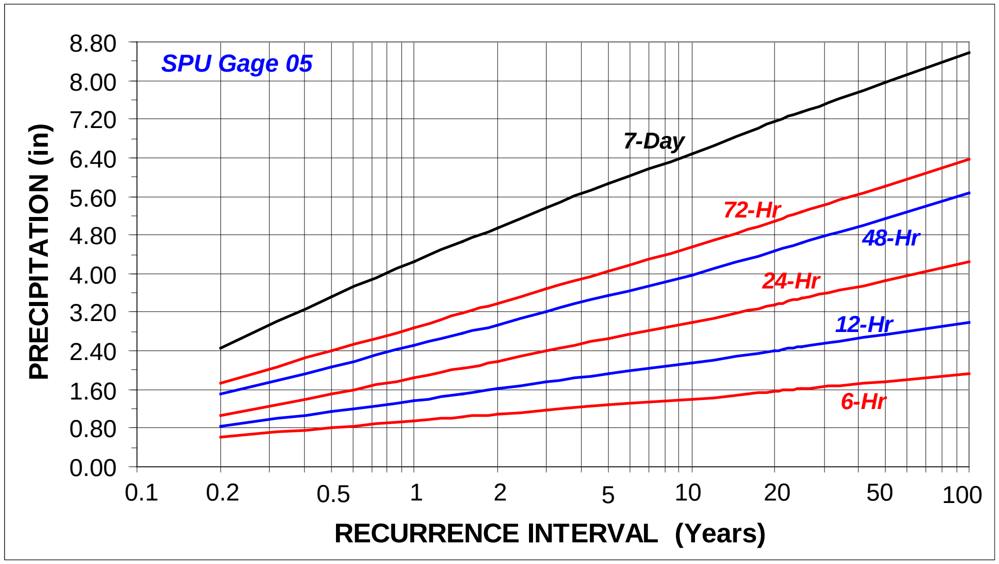

Figure 7. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 05.

Table 10. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 07.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.77	0.91	1.06	1.26	1.40		1.62	1.78	1.95	2.36
12		1.08	1.30	1.53	1.83	2.05		2.38	2.64	2.89	3.50
24		1.44	1.75	2.07	2.51	2.83		3.31	3.68	4.06	4.97
48		1.73	2.12	2.53	3.08	3.49		4.09	4.56	5.03	6.18
72		2.13	2.59	3.06	3.69	4.13		4.80	5.30	5.79	6.97
168		3.03	3.69	4.34	5.17	5.75		6.57	7.16	7.74	9.01

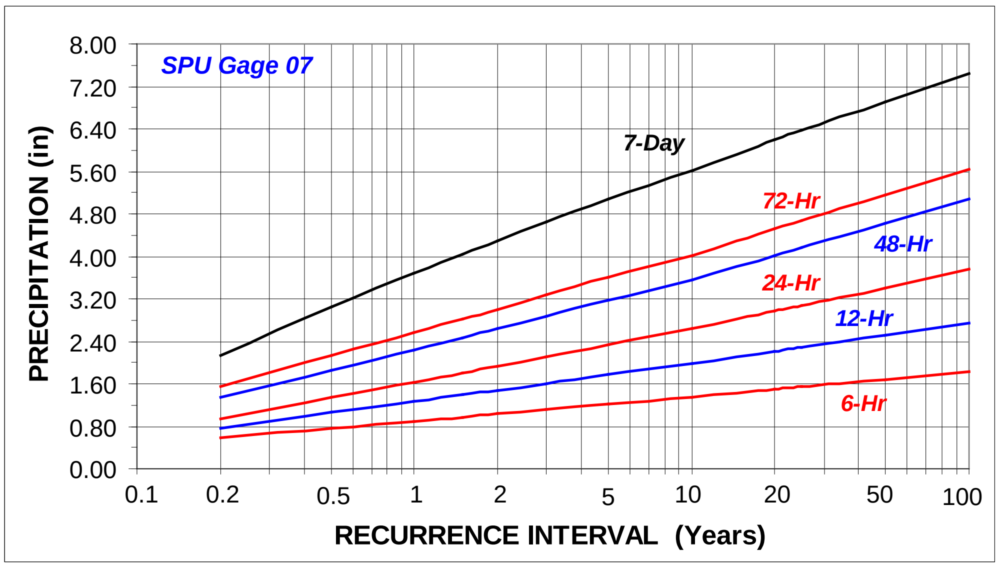

Figure 8. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 07.

Table 11. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 08.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.78	0.92	1.07	1.27	1.41		1.63	1.80	1.97	2.38
12		1.09	1.31	1.54	1.85	2.07		2.41	2.66	2.92	3.53
24		1.45	1.76	2.09	2.53	2.86		3.34	3.72	4.10	5.01
48		1.75	2.15	2.56	3.12	3.53		4.14	4.61	5.09	6.25
72		2.15	2.62	3.09	3.73	4.18		4.85	5.36	5.86	7.05
168		3.07	3.74	4.40	5.24	5.82		6.65	7.25	7.83	9.12

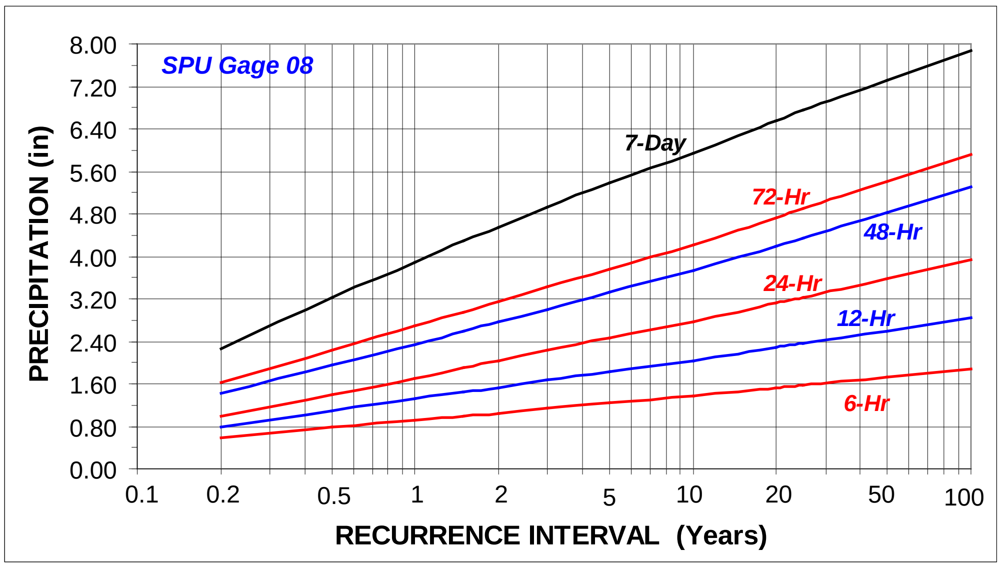

Figure 9. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 08.

Table 12. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 09.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.77	0.91	1.06	1.26	1.41		1.62	1.79	1.96	2.37
12		1.09	1.31	1.53	1.84	2.06		2.39	2.65	2.90	3.52
24		1.44	1.75	2.08	2.52	2.84		3.33	3.70	4.08	4.99
48		1.74	2.14	2.55	3.10	3.51		4.12	4.59	5.06	6.22
72		2.14	2.60	3.08	3.71	4.16		4.83	5.33	5.83	7.01
168		3.05	3.71	4.37	5.21	5.79		6.61	7.21	7.78	9.07

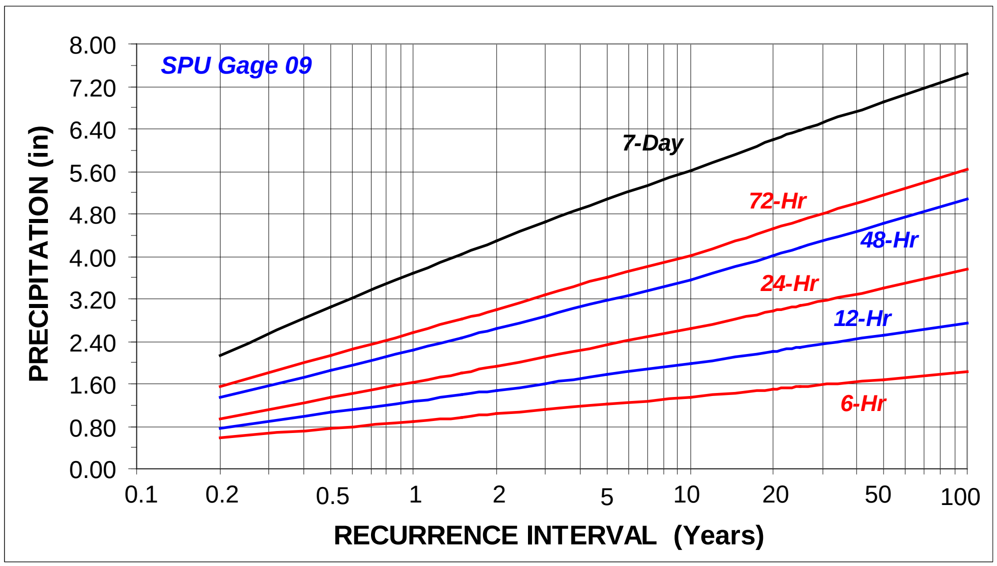

Figure 10. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 09.

Table 13. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 10.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.81	0.96	1.12	1.33	1.48		1.71	1.89	2.07	2.50
12		1.16	1.39	1.63	1.96	2.20		2.55	2.82	3.09	3.74
24		1.54	1.87	2.22	2.69	3.04		3.55	3.95	4.36	5.33
48		1.88	2.30	2.75	3.35	3.78		4.44	4.95	5.46	6.71
72		2.31	2.81	3.33	4.01	4.50		5.22	5.76	6.30	7.58
168		3.32	4.04	4.75	5.66	6.29		7.19	7.84	8.46	9.86

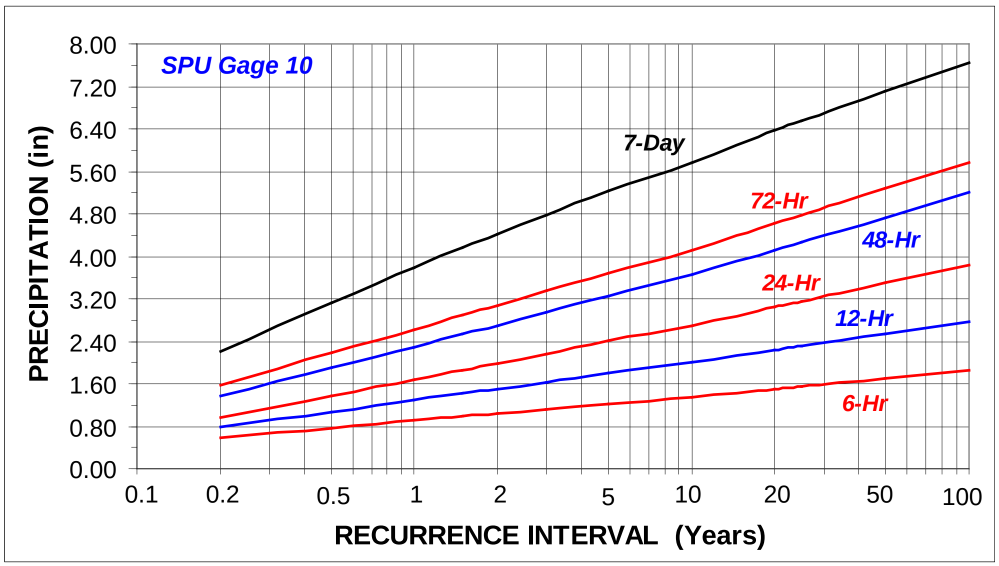

Figure 11. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 10.

Table 14. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 11.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.78	0.92	1.07	1.27	1.42		1.64	1.80	1.98	2.39
12		1.10	1.32	1.55	1.86	2.08		2.42	2.67	2.93	3.55
24		1.46	1.77	2.10	2.55	2.87		3.36	3.73	4.12	5.04
48		1.76	2.16	2.57	3.14	3.55		4.16	4.64	5.12	6.29
72		2.16	2.63	3.11	3.75	4.21		4.88	5.39	5.90	7.09
168		3.09	3.76	4.42	5.27	5.86		6.70	7.30	7.88	9.18

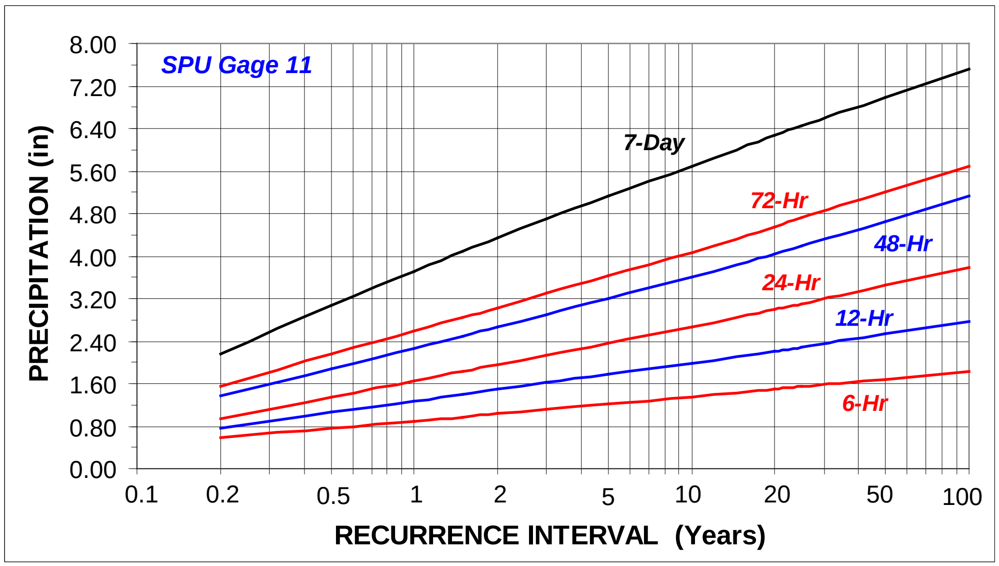

Figure 12. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 11.

Table 15. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 12.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.78	0.92	1.07	1.27	1.41		1.63	1.80	1.97	2.38
12		1.09	1.31	1.54	1.85	2.07		2.41	2.66	2.92	3.53
24		1.45	1.76	2.09	2.53	2.86		3.34	3.72	4.10	5.01
48		1.75	2.15	2.56	3.12	3.53		4.14	4.61	5.09	6.25
72		2.15	2.62	3.09	3.73	4.18		4.85	5.36	5.86	7.05
168		3.07	3.74	4.40	5.24	5.82		6.65	7.25	7.83	9.12

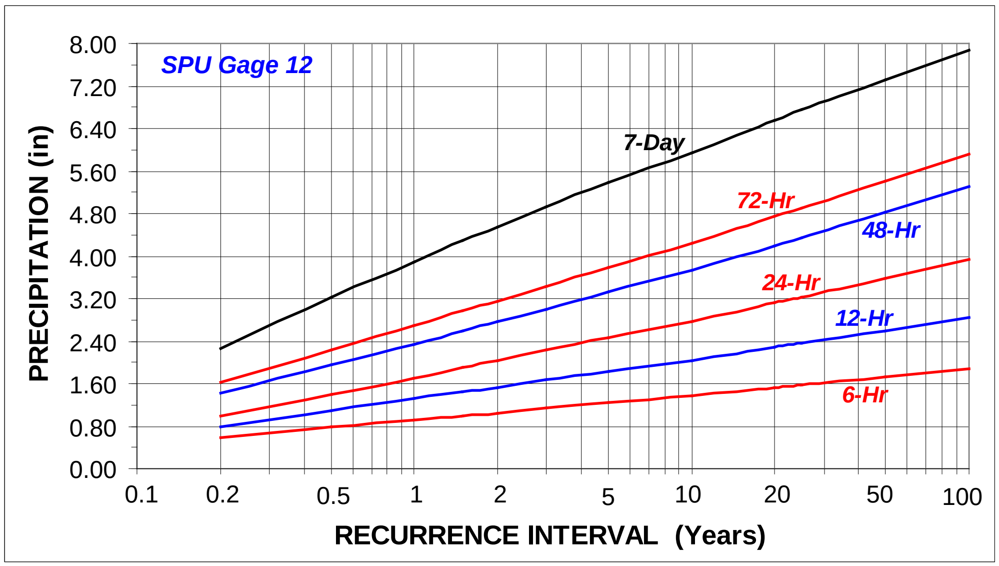

Figure 13. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 12.

Table 16. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 14.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.79	0.93	1.09	1.29	1.44		1.66	1.83	2.01	2.43
12		1.12	1.34	1.58	1.89	2.12		2.46	2.72	2.99	3.61
24		1.49	1.81	2.14	2.60	2.93		3.43	3.81	4.20	5.14
48		1.80	2.21	2.63	3.21	3.62		4.26	4.74	5.23	6.43
72		2.21	2.69	3.18	3.84	4.30		4.99	5.51	6.03	7.25
168		3.17	3.85	4.53	5.40	6.00		6.86	7.48	8.08	9.41

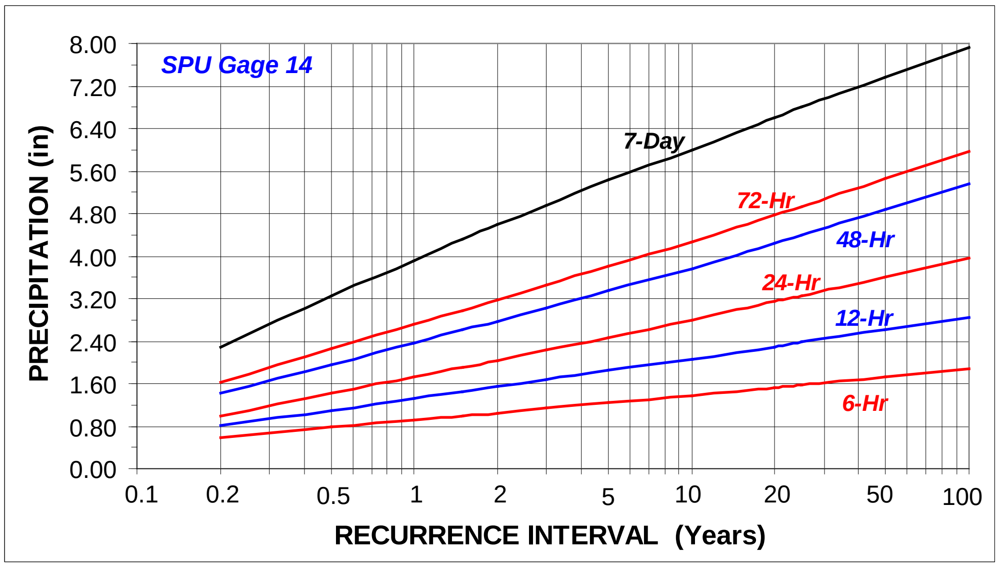

Figure 14. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 14.

Table 17. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 15.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.78	0.92	1.07	1.28	1.42		1.64	1.81	1.98	2.40
12		1.10	1.32	1.56	1.87	2.09		2.43	2.69	2.95	3.56
24		1.46	1.78	2.11	2.56	2.88		3.38	3.75	4.14	5.06
48		1.77	2.17	2.59	3.15	3.57		4.19	4.66	5.15	6.32
72		2.18	2.65	3.13	3.77	4.23		4.91	5.42	5.93	7.13
168		3.11	3.78	4.45	5.30	5.90		6.74	7.34	7.93	9.24

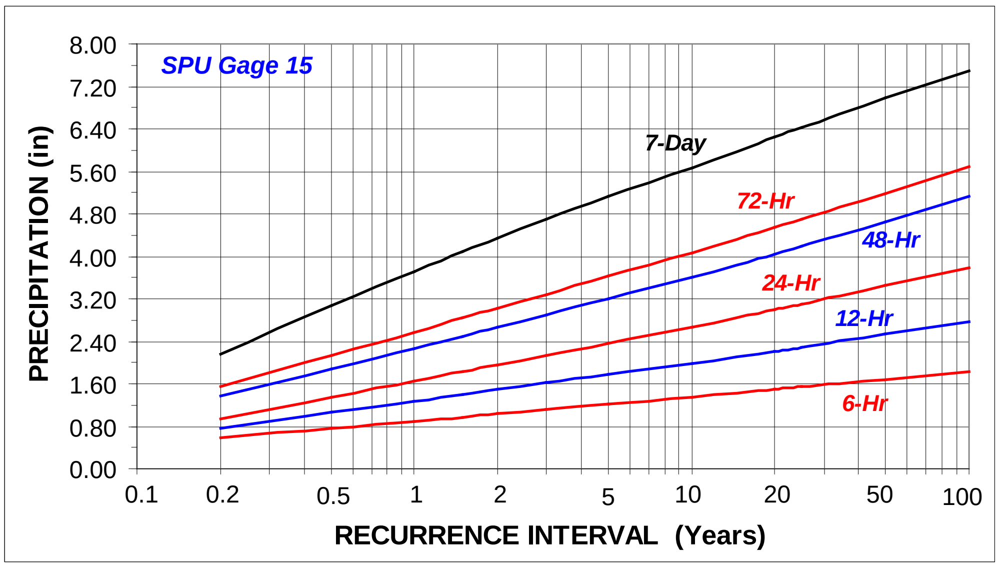

Figure 15. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 15.

Table 18. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 16.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.79	0.93	1.08	1.29	1.43		1.65	1.82	2.00	2.42
12		1.11	1.34	1.57	1.88	2.11		2.45	2.71	2.97	3.60
24		1.48	1.80	2.13	2.59	2.91		3.41	3.79	4.18	5.12
48		1.79	2.20	2.62	3.19	3.60		4.23	4.72	5.21	6.39
72		2.20	2.68	3.17	3.82	4.28		4.97	5.48	6.00	7.21
168		3.15	3.83	4.51	5.37	5.97		6.82	7.43	8.03	9.35

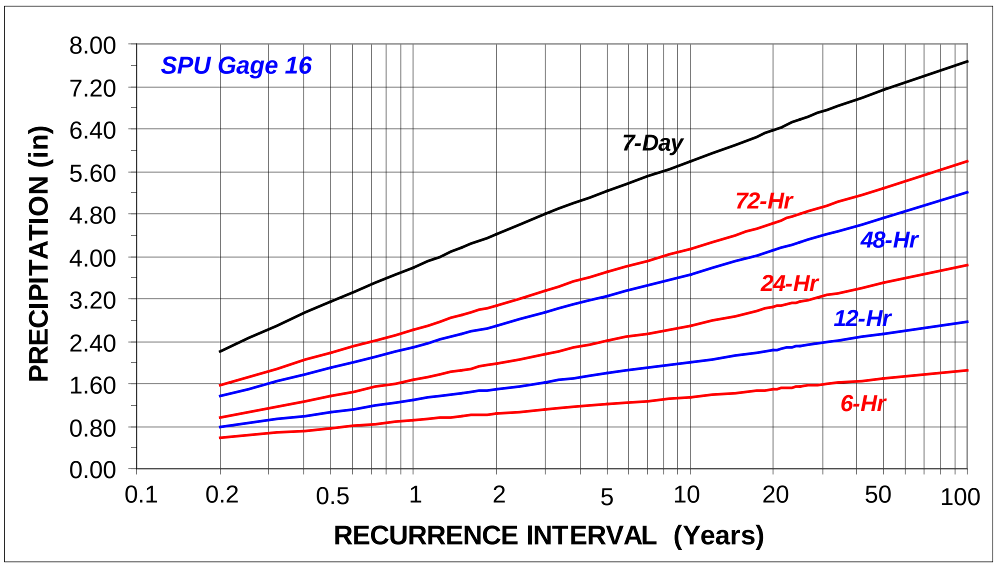

Figure 16. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 16.

Table 19. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 17.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.81	0.96	1.12	1.33	1.48		1.71	1.89	2.07	2.50
12		1.16	1.39	1.63	1.96	2.20		2.55	2.82	3.09	3.74
24		1.54	1.87	2.22	2.69	3.04		3.55	3.95	4.36	5.33
48		1.88	2.30	2.75	3.35	3.78		4.44	4.95	5.46	6.71
72		2.31	2.81	3.33	4.01	4.50		5.22	5.76	6.30	7.58
168		3.32	4.04	4.75	5.66	6.29		7.19	7.84	8.46	9.86

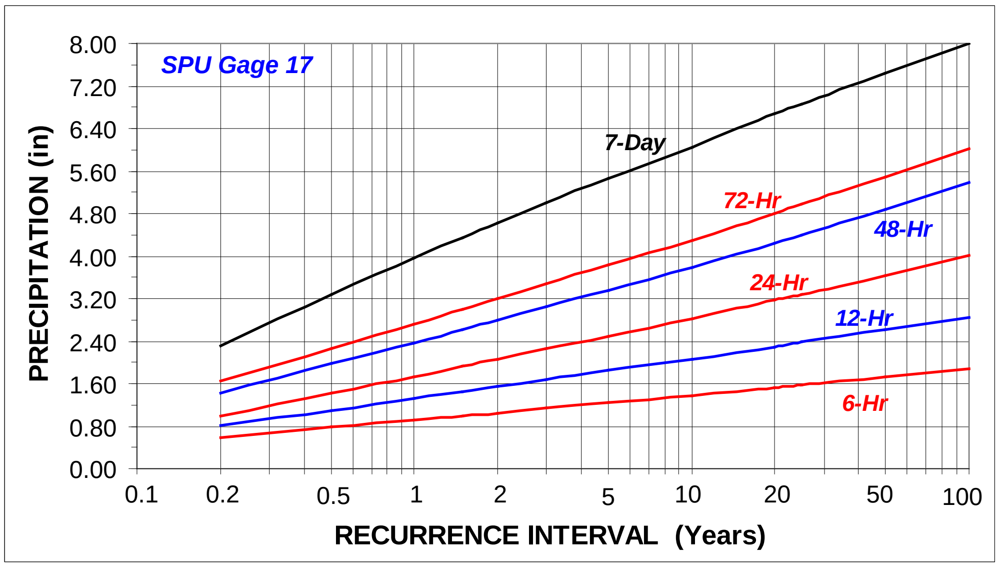

Figure 17. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 17.

Table 20. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 18.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.79	0.93	1.08	1.28	1.43		1.65	1.82	1.99	2.41
12		1.11	1.33	1.56	1.87	2.10		2.44	2.70	2.96	3.58
24		1.47	1.79	2.12	2.57	2.90		3.39	3.77	4.16	5.09
48		1.78	2.18	2.60	3.17	3.59		4.21	4.69	5.18	6.36
72		2.19	2.66	3.15	3.79	4.26		4.94	5.45	5.96	7.17
168		3.13	3.81	4.48	5.34	5.93		6.78	7.39	7.98	9.29

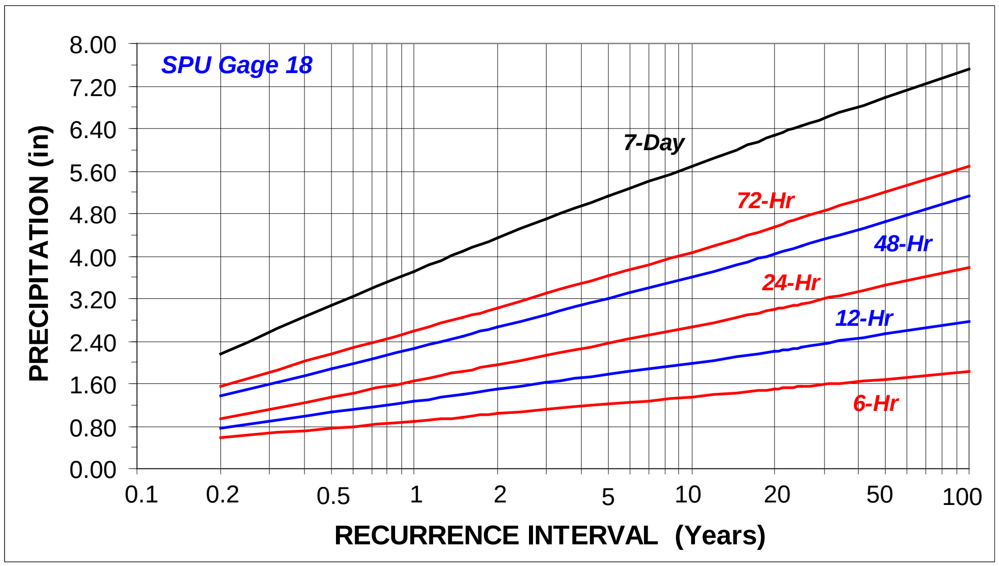

Figure 18. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 18.

Table 21. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 25.

Duration (hr)	Precipitation (in)										
	Recurrence Interval (years)										
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.79	0.93	1.08	1.28	1.43		1.65	1.82	1.99	2.41
12		1.11	1.33	1.56	1.87	2.10		2.44	2.70	2.96	3.58
24		1.47	1.79	2.12	2.57	2.90		3.39	3.77	4.16	5.09
48		1.78	2.18	2.60	3.17	3.59		4.21	4.69	5.18	6.36
72		2.19	2.66	3.15	3.79	4.26		4.94	5.45	5.96	7.17
168		3.13	3.81	4.48	5.34	5.93		6.78	7.39	7.98	9.29

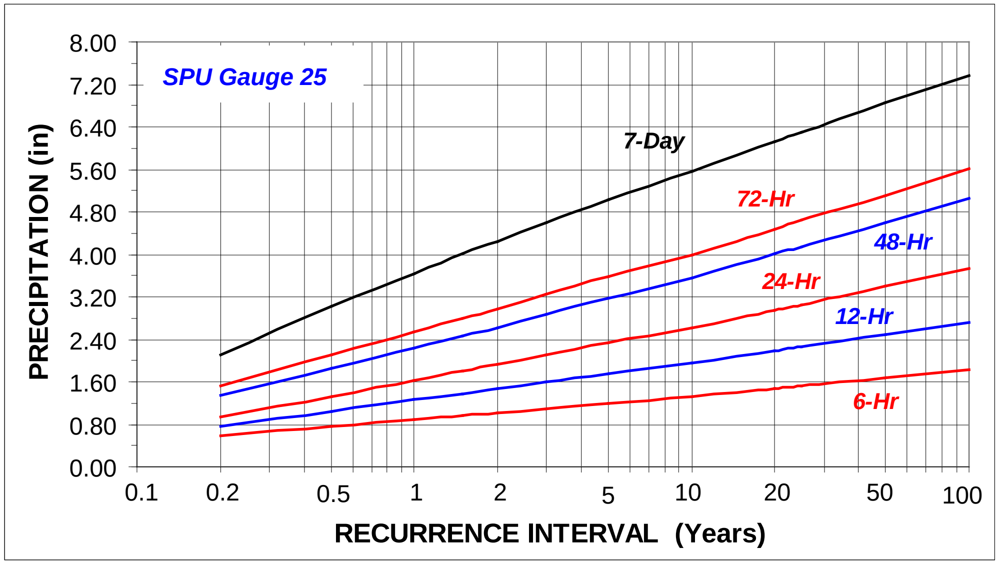

Figure 19. Precipitation-Magnitude-Frequency Estimates for SPU Gauge 25.

Table 22. Precipitation-Magnitude-Frequency Estimates for SeaTac.

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
		0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr		25-Yr	50-Yr	100-Yr	500-Yr
6		0.82	0.97	1.13	1.34	1.50		1.73	1.91	2.09	2.52
12		1.17	1.41	1.65	1.98	2.22		2.58	2.85	3.13	3.79
24		1.56	1.90	2.25	2.73	3.08		3.60	4.01	4.42	5.41
48		1.91	2.34	2.78	3.39	3.84		4.50	5.02	5.54	6.80
72		2.35	2.86	3.38	4.07	4.57		5.30	5.85	6.40	7.70
168		3.37	4.10	4.83	5.76	6.40		7.31	7.97	8.61	10.02

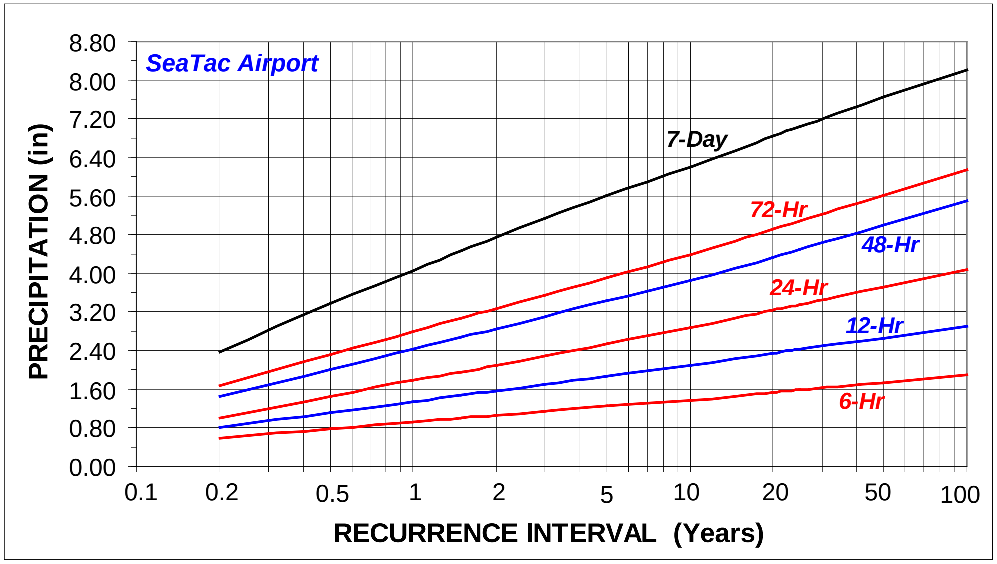

Figure 20. Precipitation-Magnitude-Frequency Estimates for SeaTac.

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City of Seattle

Appendix G - Stormwater Control Operations and Maintenance Requirements

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

This appendix contains the maintenance requirements for the following typical stormwater BMPs and components:

Refer to the *Stormwater Management Manual for Western Washington* (SWMMWW) (Ecology 2019) for maintenance requirements for the following BMP:

- Media filter drain (MFD)

All stormwater facilities, best management practices (BMPs), and drainage systems shall be kept in continuous working order consistent with their design and permitting. All stormwater facilities, BMPs, and drainage systems shall be kept accessible for maintenance and inspection at all times.

Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint shall be immediately corrected. This includes removing the source of the contamination as well as any contaminants that have been collected or deposited into the facility or conveyance system.

Training/written guidance is required for the proper operation and maintenance of many of the BMPs contained in this manual. Provide proper training and copies of the Operations and Maintenance Manuals to property owners, tenants and responsible individuals.

No. 1 – Detention Ponds

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Facility – General Requirements	A	Trash and debris	Any trash and debris which exceed 1 cubic foot per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size office garbage can)	Trash and debris cleared from site
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Top or Side Slopes of Dam, Berm or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes	Rodents removed or destroyed and dam or berm repaired
	A	Beaver dams	Dam results in change or function of the facility	Facility is returned to design function (coordinate trapping of beavers and removal of dams with appropriate permitting agencies)

No. 1 – Detention Ponds				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Top or Side Slopes of Dam, Berm or Embankment (continued)	A	Tree growth	• Tree growth threatens integrity of dams, berms, or slopes; does not allow maintenance access; or interferes with maintenance activity. • If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities
	A	Erosion	• Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion • Any erosion observed on a compacted slope	Slopes stabilized using appropriate erosion control measures If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
	A	Settlement	Any part of a dam, berm or embankment that has settled 4 inches lower than the design elevation	Top or side slope restored to design dimensions If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
Storage Area	A	Sediment accumulation	Accumulated sediment that exceeds 10 percent of the designed pond depth	• Sediment cleaned out to designed pond shape and depth • Pond reseeded if necessary to control erosion

No. 1 – Detention Ponds				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Storage Area (continued)	A	Liner damaged (if applicable)	Liner is visible or pond does not hold water as designed	Liner repaired or replaced
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Emergency Overflow/Spillway	A	Tree growth	Tree growth impedes flow or threatens stability of spillway	Trees removed
	A	Rock missing	Only one layer of rock exists above native soil in area 5 square feet or larger or any exposure of native soil on the spillway	Spillway restored to design standards

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 2 - Infiltration BMPs				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	A, W	Trash and debris	Any trash and debris which exceed 1 cubic foot per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size office garbage can)	Trash and debris cleared from site
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
	A, W, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	A	Grass/groundcover	Grass or groundcover exceeds 18 inches in height	Grass or groundcover mowed to a height no greater than 6 inches
Infiltration Pond, Top or Side Slopes of Dam, Berm or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes	Rodents removed or destroyed and dam or berm repaired

No. 2 - Infiltration BMPs				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Infiltration Pond, Top or Side Slopes of Dam, Berm or Embankment (continued)	A	Tree growth	• Tree growth threatens integrity of dams, berms or slopes, does not allow maintenance access, or interferes with maintenance activity • If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities
	A	Erosion	• Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion • Any erosion observed on a compacted slope	Slopes stabilized using appropriate erosion control measures If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
	A	Settlement	Any part of a dam, berm or embankment that has settled 4 inches lower than the design elevation	Top or side slope restored to design dimensions If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
Infiltration Pond, Tank, Vault, Trench, or Small Basin Storage Area	A	Sediment accumulation	If 2 inches or more sediment is present or a percolation test indicates facility is working at or less than 90 percent of design	Facility infiltrates as designed

No. 2 - Infiltration BMPs				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Infiltration Pond, Tank, Vault, Trench, or Small Basin Storage Area (continued)	A	Liner damaged (If Applicable)	Liner is visible or pond does not hold water as designed	Liner repaired or replaced
Infiltration Tank Structure	A	Plugged air vent	Any blockage of the vent	Tank or vault freely vents
	A	Tank bent out of shape	Any part of tank/pipe is bent out of shape more than 10 percent of its design shape	Tank repaired or replaced to design
	A	Gaps between sections, damaged joints or cracks or tears in wall	• A gap wider than ½ inch at the joint of any tank sections • Any evidence of soil particles entering the tank at a joint or through a wall	No water or soil entering tank through joints or walls
Infiltration Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil entering the structure through cracks • Qualified inspection personnel determines that the vault is not structurally sound	Vault is sealed and structurally sound
Inlet/Outlet Pipes	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes

No. 2 - Infiltration BMPs				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Inlet/Outlet Pipes (continued)	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Access Maintenance Hole	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open maintenance hole requires immediate maintenance**	Maintenance hole access cover/lid in place and secure
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment	Replace or repair access door so it can opened as designed
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered	Doors close flat and covers access opening completely

No. 2 - Infiltration BMPs				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Large Access Doors/Plate (continued)	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate	Lifting rings sufficient to lift or remove door or plate
Infiltration Pond, Tank, Vault, Trench, or Small Basin Filter Bags	A	Plugged	Filter bag more than 1/2 full	Replace filter bag or redesign system
Infiltration Pond, Tank, Vault, Trench, or Small Basin Pre-Settling Ponds and Vaults	A, W	Sediment accumulation	6 inches or more of sediment has accumulated	Pre-settling occurs as designed
Infiltration Pond, Rock Filter	A	Plugged	High water level on upstream side of filter remains for extended period of time or little or no water flows through filter during heavy rain storms	Rock filter replaced; evaluate need for filter and remove if not necessary
Infiltration Pond Emergency Overflow Spillway	A	Rock missing	• Only one layer of rock exists above native soil in area 5 square feet or larger, or any exposure of native soil at the top of out flow path of spillway • Rip-rap on inside slopes need not be replaced	Spillway restored to design standards
	A	Tree growth	Tree growth impedes flow or threatens stability of spillway	Trees removed

No. 2 - Infiltration BMPs				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Drain Rock	A, W	Water ponding	• If water enters the facility from the surface, inspect to see if water is ponding at the surface during storm events • If buried drain rock, observe drawdown through observation/ maintenance port or cleanout	• Clear piping through facility when ponding occurs • Replace rock material/sand reservoirs as necessary • Tilling of subgrade below reservoir may be necessary (for trenches) prior to backfill

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No. 3 - Detention Pipes and Vaults

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Pipe or Vault Storage Area	B, W, E	Trash and debris	Any trash and debris accumulated in vault or pipe (includes floatables and non-floatables)	No trash or debris in vault or pipe
	A	Sediment accumulation	Accumulated sediment depth exceeds 10 percent of the diameter of the storage area for ½ length of storage vault or any point depth exceeds 15 percent of diameter	All sediment removed from storage area
Pipe or Vault Structure	A	Plugged air vent	Any blockage of the vent	Pipe or vault freely vents
	A	Pipe bent out of shape	Any part of vault/pipe is bent out of shape more than 10 percent of its design shape	Pipe or vault repaired or replaced to design
	A	Gaps between sections, damaged joints or cracks or tears in wall	• A gap wider than ½ inch at the joint of any pipe or vault sections • Any evidence of soil particles entering the pipe or vault at a joint or through a wall	No water or soil entering pipe or vault through joints or walls

No. 3 - Detention Pipes and Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil entering the structure through cracks • Qualified inspection personnel determines that the vault is not structurally sound	Vault sealed and structurally sound
Inlet/Outlet Pipes	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Access Maintenance Hole	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open maintenance hole requires immediate maintenance**	Maintenance hole access cover/lid in place and secure
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools

No. 3 - Detention Pipes and Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Access Maintenance Hole (continued)	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment	Replace or repair access door so it can opened as designed
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered	Doors close flat and covers access opening completely
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate	Lifting rings sufficient to lift or remove door or plate

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No. 4 - Flow Control Structure & Control Device				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
The Flow Control Structure and Control Device shall conform with design criteria shown upon the approved plans or the design standards in place at the time of construction. This includes but is not limited to, orifice diameter(s), orifice elevation(s) overflow elevation. Reference Standard Plans No. 270, 271, and 272.				
Structure	A	Trash and debris	Trash or debris of more than ½ cubic foot which is located immediately in front of the structure opening or is blocking capacity of the structure by more than 10 percent	No trash or debris blocking or potentially blocking entrance to structure
			Trash or debris in the structure that exceeds 1/3 the depth from the bottom of basin to invert the lowest pipe into or out of the basin.	No trash or debris in the structure
			Deposits of garbage exceeding 1 cubic foot in volume	No condition present which would attract or support the breeding of insects or rodents
	A	Sediment	Sediment exceeds 60 percent of the depth from the bottom of the structure to the invert of the lowest pipe into or out of the structure or the bottom of the control device section or is within 6 inches of the invert of the lowest pipe into or out of the structure or the bottom of the control device section	Sump of structure contains no sediment

No. 4 - Flow Control Structure & Control Device				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Structure (continued)	A	Damage to frame and/or top slab	Corner of frame extends more than ¾ inch past curb face into the street (If applicable)	Frame is even with curb
			Top slab has holes larger than 2 square inches or cracks wider than ¼ inch	Top slab is free of holes and cracks
			Frame not sitting flush on top slab, i.e., separation of more than ¾ inch of the frame from the top slab	Frame is sitting flush on top slab
	A	Cracks in walls or bottom	• Cracks wider than ½ inch and longer than 3 feet • Any evidence of soil particles entering structure through cracks • Maintenance person judges that structure is unsound	Structure is sealed and structurally sound.
			• Cracks wider than ½ inch and longer than 1 foot at the joint of any inlet/outlet pipe • Any evidence of soil particles entering structure through cracks	No cracks more than ¼-inch wide at the joint of inlet/outlet pipe
	A	Settlement/ misalignment	Structure has settled more than 1 inch or has rotated more than 2 inches out of alignment	Basin replaced or repaired to design standards

No. 4 - Flow Control Structure & Control Device				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Structure (continued)	A	Damaged pipe joints	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering the structure at the joint of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of inlet/outlet pipes
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	A	Ladder rungs missing or unsafe	Ladder is unsafe due to missing rungs, misalignment, rust, cracks, or sharp edges	Ladder meets design standards and allows maintenance person safe access.
Control Device	A	Damaged or missing	Riser section is not securely attached to structure wall and outlet pipe structure should support at least 1,000 lbs of up or down pressure	T section securely attached to wall and outlet pipe
			Structure is not in upright position (allow up to 10 percent from plumb)	Structure in correct position
			Connections to outlet pipe are not watertight or show signs of deteriorated grout	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed
			Any holes—other than designed holes—in the structure	Structure has no holes other than designed holes

No. 4 - Flow Control Structure & Control Device				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Shear Gate (if applicable)	A	Damaged or missing	Cleanout gate is missing	Replace cleanout gate
			Cleanout gate is not watertight	Gate is watertight and works as designed.
			Gate cannot be moved up and down by one maintenance person	Gate moves up and down easily and is watertight.
			Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
Orifice Plate	A	Damaged or missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	A	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate	Plate is free of all obstructions and works as designed
Overflow Pipe	A	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe	Pipe is free of all obstructions and works as designed
	A	Deformed or damaged lip	Lip of overflow pipe is bent or deformed	Overflow pipe does not allow overflow at an elevation lower than design
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables).	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

No. 4 - Flow Control Structure & Control Device				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Metal Grates (If Applicable)	A	Unsafe grate opening	Grate with opening wider than 7/8 inch	Grate opening meets design standards
	B, W, E	Trash and debris	Trash and debris that is blocking more than 20 percent of grate surface	Grate free of trash and debris. footnote to guidelines for disposal
	A	Damaged or missing	Grate missing or broken member(s) of the grate	Grate is in place and meets design standards
Maintenance Hole Cover/Lid	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open structure requires urgent maintenance**	Cover/lid protects opening to structure
	A	Locking mechanism Not Working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to Remove	One maintenance person cannot remove cover/lid after applying 80 lbs. of lift	Cover/lid can be removed and reinstalled by one maintenance person

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No. 5 – Catch Basins and Maintenance Holes				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Structure	A	Sediment	Sediment exceeds 60 percent of the depth from the bottom of the catch basin to the invert of the lowest pipe into or out of the catch basin or is within 6 inches of the invert of the lowest pipe into or out of the catch basin	Sump of catch basin contains no sediment
	B, W, E	Trash and debris	Trash or debris of more than ½ cubic foot which is located immediately in front of the catch basin opening or is blocking capacity of the catch basin by more than 10 percent	No trash or debris blocking or potentially blocking entrance to catch basin
	A		Trash or debris in the catch basin that exceeds 1/3 the depth from the bottom of basin to invert the lowest pipe into or out of the basin	No trash or debris in the catch basin
	A		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane)	No dead animals or vegetation present within catch basin
	A		Deposits of garbage exceeding 1 cubic foot in volume	No condition present which would attract or support the breeding of insects or rodents

No. 5 – Catch Basins and Maintenance Holes				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Structure (continued)	A	Damage to frame and/or top slab	Corner of frame extends more than ¾ inch past curb face into the street (If applicable).	Frame is even with curb
			Top slab has holes larger than 2 square inches or cracks wider than ¼ inch.	Top slab is free of holes and cracks.
			Frame not sitting flush on top slab, i.e., separation of more than ¾ inch of the frame from the top slab	Frame is sitting flush on top slab.
	A	Cracks in walls or bottom	• Cracks wider than ½ inch and longer than 3 feet • Any evidence of soil particles entering catch basin through cracks • Maintenance person judges that catch basin is unsound	Catch basin is sealed and structurally sound
			• Cracks wider than ½ inch and longer than 1 foot at the joint of any inlet/outlet pipe • Any evidence of soil particles entering catch basin through cracks	No cracks more than ¼-inch wide at the joint of inlet/outlet pipe
	A	Settlement/ misalignment	Catch basin has settled more than 1 inch or has rotated more than 2 inches out of alignment	Basin replaced or repaired to design standards

No. 5 – Catch Basins and Maintenance Holes				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Structure (continued)	A	Damaged pipe joints	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering the catch basin at the joint of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of inlet/outlet pipes
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Catch Basin Outlet Trap (Reference Standard Plan No. 267)	A	Missing	When the required outlet trap is not installed upon the outlet pipe	Outlet trap installed and prevents floatables from being discharged
	A	Permanently installed	When the trap is grouted to the outlet pipe and is not removable to allow for maintenance and inspection	Outlet trap removable for maintenance and inspection

No. 5 - Catch Basins and Maintenance Holes				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Catch Basin Outlet Trap (Reference Standard Plan No. 267) (continued)	A	Damaged	Cracks, broken welds, seams or any other conditions that allows water to be discharged from other than the submerged portion of the trap	Water will be discharged from the submerged portion of the trap.
Metal Grates (Catch Basins)	A	Unsafe grate opening	Grate with opening wider than 7/8 inch	Grate opening meets design standards
	B, W, E	Trash and debris	Trash and debris that is blocking more than 20 percent of grate surface	Grate free of trash and debris. footnote to guidelines for disposal
	A	Damaged or missing	• Grate missing or broken member(s) of the grate • **Any open structure requires urgent maintenance**	Grate is in place and meets design standards
Maintenance Hole Cover/Lid	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open structure requires urgent maintenance**	Cover/lid protects opening to structure
	A	Locking mechanism Not Working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs. of lift	Cover/lid can be removed and reinstalled by one maintenance person

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No. 6 - Reserved			

No. 7 – Debris Barriers (e.g., Trash Racks)				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	B, W, E	Trash and debris	Trash or debris plugging more than 20 percent of the area of the barrier	Barrier clear to receive capacity flow
	A	Sediment accumulation	Sediment accumulation of greater than 20 percent of the area of the barrier	Barrier clear to receive capacity flow
Structure	A	Cracked, broken, or loose	• Structure which bars attach to is damaged • Pipe is loose or cracked • Concrete structure is cracked, broken, or loose	Sound structure barrier
Bars	A	Bar spacing	Bar spacing exceeds 6 inches	Bars have at most 6-inch spacing
	A	Damaged or missing bars	Bars bent out of shape more than 3 inches	Bars in place with no bends more than ¾ inch
			Bars missing or entire barrier missing	Bars in place according to design
			Bars loose and rust is causing 50 percent deterioration to any part of barrier	Repair or replace barrier to design standards

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No. 8 – Energy Dissipaters				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	B, W, E	Trash and debris	Trash and/or debris accumulation	Dissipater clear of trash and/or debris
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Rock Pad	A	Missing or moved rock	• One layer or less of rock exists above native soil area 5 square feet or more • Any exposed native soil	Rock pad prevents erosion
Dispersion Trench	A	Pipe plugged with sediment	Accumulated sediment that exceeds 20 percent of the design depth	Pipe cleaned/flushed so that it matches design
	A	Not discharging water properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a “sheet flow” of water along trench)	Water discharges from feature by sheet flow
	A	Perforations plugged	Over 1/4 of perforations in pipe are plugged with debris or sediment	Perforations freely discharge flow
	A	Water flows out top of “distributor” catch basin	Water flows out of distributor catch basin during any storm less than the design storm	No flow discharges from distributor catch basin
	A	Receiving area over-saturated	Water in receiving area is causing or has potential of causing landslide problems	No danger of landslides
Gabions	A	Damaged mesh	Mesh of gabion broken, twisted or deformed so structure is weakened or rock may fall out	Mesh is intact with no rock missing

No. 8 - Energy Dissipaters				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Gabions (continued)	A	Corrosion	Gabion mesh shows corrosion through more than ¼ of its gage	All gabion mesh capable of containing rock and retaining designed form
	A	Collapsed or deformed baskets	Gabion basket shape deformed due to any cause	All gabion baskets intact, structure stands as designed
	A	Missing rock	Any rock missing that could cause gabion to loose structural integrity	No rock missing
Maintenance Hole/Chamber	A	Worn or damaged post, baffles, or side of chamber	Structure dissipating flow deteriorates to ½ or original size or any concentrated worn spot exceeding 1 square foot, which would make structure unsound	Structure in no danger of failing
	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil entering the structure through cracks • Maintenance inspection personnel determines that the structure is not structurally sound	Maintenance hole/chamber sealed and structurally sound
	A	Damaged pipe joints	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering the structure at the joint of the inlet/outlet pipes	• No soil or water enters • No water discharges at the joint of inlet/outlet pipes

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No. 9 – Basic and Compost-Amended Biofiltration Swales				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	M	Trash and debris	Trash and/or debris accumulation	No trash or debris at the site
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Swale Section	B, E	Sediment accumulation	Sediment depth exceeds 2 inches in 10 percent of the swale treatment area	No sediment deposits in treatment area of the biofiltration swale
			Sediment inhibits grass growth over 10 percent of swale length	Grass growth not inhibited by sediment
			Sediment inhibits even spreading of flow	Flows are spread evenly over entire swale width
	B, E	Erosion/scouring	Eroded or scoured swale bottom due to channelization or high flows	• No eroded or scoured areas in biofiltration swale • Cause of erosion or scour addressed
	M	Poor vegetation coverage	Grass is sparse or bare or eroded patches occur in more than 10 percent of the swale bottom	• Swale has no bare spots • Grass is thick and healthy
	B	Grass too tall	• Grass is excessively tall (greater than 10 inches) • Grass is thin • Nuisance weeds and other vegetation has taken over	• Grass between 3 and 4 inches tall, thick and healthy • No clippings left in swale • No nuisance vegetation present

No. 9 – Basic and Compost-Amended Biofiltration Swales				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Swale Section (continued)	B	Excessive shade	Grass growth is poor because sunlight does not reach swale	• Healthy grass growth or • Swale converted to a wet biofiltration swale
	B	Constant baseflow	• Continuous flow through the swale, even when it has been dry for weeks or an eroded • Muddy channel has formed in the swale bottom	Baseflow removed from swale by a low-flow pea-gravel drain or bypassed around the swale
	B	Standing water	Water pools in the swale between storms or does not drain freely	Swale drains freely and no standing water in swale between storms
	B	Channelization	Flow concentrates and erodes channel through swale	No flow channels in swale
Flow Spreader	B	Concentrated flow	Flow from spreader not uniformly distributed across entire swale width	Flows are spread evenly over entire swale width
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

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No. 10 - Wet and Continuous Inflow Biofiltration Swales				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	M	Trash and debris	Any trash and/or debris accumulated at the site	No trash or debris at the site
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Swale Section	B, E	Sediment accumulation	Sediment depth exceeds 2 inches in 10 percent of the swale treatment area	No sediment deposits in treatment area
	B, E	Erosion/scouring	Eroded or scoured swale bottom due to channelization or high flows	• No eroded or scoured areas in biofiltration swale • Cause of erosion or scour addressed
	B	Water depth	Water not retained to a depth of about 4 inches during the wet season	Water depth of 4 inches throughout swale for most of wet season
	B	Vegetation ineffective	• Vegetation sparse; does not provide adequate filtration • Vegetation crowded out by very dense clumps of cattail or nuisance vegetation	• Wetland vegetation fully covers bottom of swale • No cattails or nuisance vegetation present
	B	Insufficient water	Wetland vegetation dies due to lack of water	Wetland vegetation remains healthy (may require converting to grass-lined biofiltration swale)
Flow Spreader	B	Concentrated flow	Flow from spreader not uniformly distributed across entire swale width	Flows are spread evenly over entire swale width

No. 10 – Wet and Continuous Inflow Biofiltration Swales				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

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No. 11 - Filter Strips (Basic and CAVFS)				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	M	Trash and debris	Any trash and/or debris accumulated at the site	No trash or debris at the site
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Grass Strip	B, E	Sediment accumulation	Sediment accumulation exceeds 2 inches depth	No sediment deposits in treatment area
	B, E	Erosion/scouring	Eroded or scoured areas due to channelization or high flows	• No eroded or scoured areas • Cause of erosion or scour addressed
	B	Vegetation ineffective	• Grass has died out • Grass has become excessively tall (greater than 10 inches) • Nuisance vegetation is taking over	• Grass is healthy; between 3 and 4 inches tall • No nuisance vegetation present
Flow Spreader	B	Concentrated flow	Flow from spreader not uniformly distributed across entire filter width	Flows are spread evenly over entire filter width
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes

No. 11 - Filter Strips (Basic and CAVFS)				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Inlet/Outlet Pipe (continued)	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 12 - Wet Ponds				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	A	Trash and debris	Any trash and/or debris accumulated at the site	No trash or debris at the site
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	2X: June – October	Grass/groundcover	Grass or groundcover exceeds 18 inches in height	Grass or groundcover mowed to a height no greater than 6 inches
Side Slopes of Dam, Berm, Internal Berm or Embankment	A	Rodent holes	• Any evidence of rodent holes if facility is acting as a dam or berm • Any evidence of water piping through dam or berm via rodent holes	• Rodents removed or destroyed • Dam or berm repaired

No. 12 - Wet Ponds				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Side Slopes of Dam, Berm, Internal Berm or Embankment (continued)	A	Tree growth	Tree growth threatens integrity of dams, berms or slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat to dam, berm or embankment integrity, are not interfering with access or maintenance, or leaves do not cause a plugging problem they do not need to be removed.	Trees do not hinder facility performance or maintenance activities
	A	Erosion	• Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion • Any erosion observed on a compacted slope	Slopes stabilized using appropriate erosion control measures If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
Top or Side Slopes of Dam, Berm, Internal Berm or Embankment	A	Settlement	Any part of a dam, berm or embankment that has settled 4 inches lower than the design elevation	Top or side slope restored to design dimensions If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
	A	Irregular surface on internal berm	Top of berm not uniform and level	Top of berm graded to design elevation.
Pond Areas	A	Sediment accumulation (except first wet pool cell)	Accumulated sediment that exceeds 10 percent of the designed pond depth	Sediment cleaned out to designed pond shape and depth.

No. 12 - Wet Ponds				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Pond Areas (continued)	A	Sediment accumulation (first wet pool cell)	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches	Sediment storage contains no sediment
	A	Liner damaged (if applicable)	• Liner is visible • Pond does not hold water as designed	Liner repaired or replaced.
	A, W	Water level (first wet pool cell)	First cell empty; does not hold water	Water retained in first cell for most of the year
	M (March – October)	Algae mats (first wet pool cell)	Algae mats develop over more than 10 percent of the water surface	Algae mats removed (usually in the late summer before fall rains)
Gravity Drain	A	Inoperable valve	Valve will not open and close	Valve opens and closes normally
	A	Valve will not seal	Valve does not seal completely	Valve completely seals closed
Emergency Overflow Spillway	A	Tree growth	Tree growth impedes flow or threatens stability of spillway	Trees removed
	A	Rock missing	• Only one layer of rock exists above native soil in area 5 square feet or larger • Any exposure of native soil at the top of out flow path of spillway (Rip-rap on inside slopes need not be replaced.)	Spillway restored to design standards
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes

No. 12 - Wet Ponds				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Inlet/Outlet Pipe (continued)	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 13 - Wet Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	A	Trash and debris	Trash and debris accumulation	Trash and debris removed from facility
Treatment Area	A	Trash and debris	Any trash and debris accumulated in vault (includes floatables and non-floatables)	No trash or debris in vault
	A	Sediment accumulation	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches	No sediment in vault
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil entering the structure through cracks • Vault does not retain water • Qualified inspection personnel determines that the vault is not structurally sound	Vault sealed and structurally sound
	A	Baffles damaged	• Baffles corroding, cracking, warping, and/or showing signs of failure • Baffle cannot be removed	Repair or replace baffles or walls to specifications
	A	Ventilation	Ventilation area blocked or plugged	No reduction of ventilation area exists

No. 13 – Wet Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Gravity Drain	A	Inoperable valve	Valve will not open and close	Valve opens and closes normally
	A	Valve will not seal	Valve does not seal completely	Valve completely seals closed
Access Maintenance Hole	A	Access cover/lid damaged or difficult to open	• Access cover/lid cannot be easily opened by one person • Corrosion/deformation of cover/lid	Access cover/lid can be opened by one person
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person
	A	Access doors/plate has gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered	Doors close flat and covers access opening completely

No. 13 - Wet Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Access Maintenance Hole (continued)	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate	Lifting rings sufficient to lift or remove door or plate
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 14 – Stormwater Treatment Wetlands				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	A	Trash and debris	Trash and debris accumulation	Trash and debris removed from facility
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	2X: June – October	Grass/groundcover	Grass or groundcover exceeds 18 inches in height	Grass or groundcover mowed to a height no greater than 6 inches
Side Slopes of Dam, Berm, Internal Berm, or Embankment	A	Rodent holes	Any evidence of rodent holes if facility is acting as a dam or berm Any evidence of water piping through dam or berm via rodent holes	• Rodents removed or destroyed • Dam or berm repaired

No. 14 – Stormwater Treatment Wetlands				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Side Slopes of Dam, Berm, Internal Berm, or Embankment (continued)	A	Tree growth	Tree growth threatens integrity of dams, berms or slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities
	A	Erosion	• Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion • Any erosion observed on a compacted slope	Slopes stabilized using appropriate erosion control measures If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
Top or Side Slopes of Dam, Berm, Internal Berm, or Embankment	A	Settlement	Any part of a dam, berm or embankment that has settled 4 inches lower than the design elevation	Top or side slope restored to design dimensions If settlement is significant, a licensed engineer should be consulted to determine the cause of the settlement.
	A	Irregular surface on internal berm	Top of berm not uniform and level	Top of berm graded flat to design elevation
Pond Areas	B	Sediment accumulation (first cell/forebay)	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches	Sediment storage contains no sediment

No. 14 – Stormwater Treatment Wetlands				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Pond Areas (continued)	B	Sediment accumulation (wetland cell)	Accumulated sediment that exceeds 10 percent of the designed pond depth	Sediment cleaned out to designed pond shape and depth
	A	Liner damaged (If Applicable)	Liner is visible or pond does not hold water as designed	Liner repaired or replaced
	A, W	Water level (first cell/forebay)	Cell does not hold 3 feet of water year round	3 feet of water retained year round
	A, W	Water level (wetland cell)	Cell does not retain water for at least 10 months of the year or wetland plants are not surviving.	Water retained at least 10 months of the year or wetland plants are surviving.
	M (March – October)	Algae mats (first cell/forebay)	Algae mats develop over more than 10 percent of the water	Algae mats removed (usually in the late summer before fall rains)
	B	Vegetation	Vegetation dead, dying, or overgrown (cattails) or not meeting original planting specifications	Plants in wetland cell surviving and not interfering with wetland function
Gravity Drain	A	Inoperable valve	Valve will not open and close	Valve opens and closes normally
	A	Valve will not seal	Valve does not seal completely	Valve completely seals closed
Emergency Overflow Spillway	A	Tree growth	Tree growth impedes flow or threatens stability of spillway	Trees removed
	A	Rock missing	• Only one layer of rock exists above native soil in area 5 square feet or larger • Any exposure of native soil at the top of out flow path of spillway (Rip-rap on inside slopes need not be replaced.)	Spillway restored to design standards
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment

No. 14 – Stormwater Treatment Wetlands				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Inlet/Outlet Pipe (continued)	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 15 – Sand Filter Basins				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	A, E	Trash and debris	Trash and debris accumulation	Trash and debris removed from facility
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	A	Grass/groundcover (not in the treatment area)	Grass or groundcover exceeds 18 inches in height	Grass or groundcover mowed to a height no greater than 6 inches
Pre-Treatment (if applicable)	A	Sediment accumulation	Sediment accumulations in pond bottom that exceeds the depth of sediment storage (1 foot) plus 6 inches	Sediment storage contains no sediment
	A	Liner damaged (If Applicable)	Liner is visible Pond does not hold water as designed	Liner repaired or replaced
	A, W	Water level	Cell empty; does not hold water.	Water retained in first cell for most of the year
	M (March – October)	Algae mats	Algae mats develop over more than 10 percent of the water surface	Algae mats removed

No. 15 – Sand Filter Basins				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Pond Area	B	Sediment accumulation	Sediment or crust depth exceeds ½ inch over 10 percent of surface area of sand filter	No sediment or crust deposit on sand filter that would impede permeability of the filter section
	2X: June – October	Grass (if applicable)	• Grass becomes excessively tall (greater than 6 inches) • Nuisance weeds and other vegetation start to take over • Thatch build up occurs	Mow vegetation and/or remove nuisance vegetation
Side Slopes of Pond	A	Rodent holes	• Any evidence of rodent holes if facility is acting as a dam or berm • Any evidence of water piping through dam or berm via rodent holes	Rodents removed or destroyed Dam or berm repaired
	A	Tree growth	Tree growth threatens integrity of dams, berms or slopes, does not allow maintenance access, or interferes with maintenance activity. If trees are not a threat to dam, berm, or embankment integrity or not interfering with access or maintenance, they do not need to be removed.	Trees do not hinder facility performance or maintenance activities

No. 15 – Sand Filter Basins				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Side Slopes of Pond (continued)	A	Erosion	• Eroded damage over 2 inches deep where cause of damage is still present • Where there is potential for continued erosion • Any erosion observed on a compacted slope	Slopes stabilized using appropriate erosion control measures If erosion is occurring on compacted slope, a licensed engineer should be consulted to resolve source of erosion.
Sand Filter Media	A, E	Plugging	• Drawdown of water through the sand filter media, takes longer than 24 hours • Flow through the overflow pipes occurs frequently	• Sand filter media surface is aerated • Drawdown rate is normal
	A	Prolonged flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities	Excess flows bypassed or confined to small portion of filter media surface
	A	Short circuiting	• Flows become concentrated over one section of the sand filter rather than dispersed • Drawdown rate of pool exceeds 12 inches per hour	• Flow and percolation of water through the sand filter is uniform and dispersed across the entire filter area • Drawdown rate is normal
	A	Media thickness	Sand thickness is less than 6 inches	Rebuild sand thickness to a minimum of 6 inches and preferably to 18 inches

No. 15 – Sand Filter Basins				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance Is Performed**
Underdrains and Clean-Outs	A	Sediment/debris	• Underdrains or clean-outs partially plugged or filled with sediment and/or debris • Junction box/cleanout wyes not watertight	Underdrains and clean-outs free of sediment and debris and are watertight
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Rock Pad	A	Missing or out of place	• Only one layer of rock exists above native soil in area 5 square feet or larger • Any exposure of native soil	Rock pad restored to design standards
Flow Spreader	A	Concentrated flow	Flow from spreader not uniformly distributed across sand filter	Flows spread evenly over sand filter

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No. 16 – Sand Filter Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	A, E	Trash and debris	Trash and debris accumulation	Trash and debris removed from facility
	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	A	Grass/groundcover	Grass or groundcover exceeds 18 inches in height	Grass or groundcover mowed to a height no greater than 6 inches
Pre-Treatment Chamber	A	Sediment accumulation	Sediment accumulation exceeds the depth of the sediment zone plus 6 inches	Sediment storage contains no sediment
Sand Filter Media	A	Sediment accumulation	Sediment depth exceeds ½ inch on sand filter media	Sand filter freely drains at normal rate
	A	Trash and debris	Trash and debris accumulated in vault (floatables and non-floatables)	No trash or debris in vault

No. 16 – Sand Filter Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Sand Filter Media (continued)	A, E	Plugging	• Drawdown of water through the sand filter media, takes longer than 24 hours • Flow through the overflow pipes occurs frequently	Sand filter media drawdown rate is normal
	A	Short circuiting	• Seepage or flow occurs along the vault walls and corners • Sand eroding near inflow area • Cleanout wyes are not watertight	• Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal • Erosion protection added to dissipate force of incoming flow and curtail erosion
Vault Structure	A	Damaged to walls, frame, bottom and/or top slab.	• Cracks wider than ½ inch • Any evidence of soil entering the structure through cracks • Qualified inspection personnel determines that the vault is not structurally sound	Vault replaced or repaired to provide complete sealing of the structure
	A	Ventilation	Ventilation area blocked or plugged	No reduction of ventilation area exists
Underdrains and Cleanouts	A	Sediment/debris	Underdrains or clean-outs partially plugged, filled with sediment and/or debris or not watertight	Underdrains and clean-outs free of sediment and debris and sealed
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes

No. 16 – Sand Filter Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Inlet/Outlet Pipe (continued)	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe
Access Maintenance Hole	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open maintenance hole requires immediate maintenance**	Maintenance hole access cover/lid in place and secure
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment	Replace or repair access door so it can opened as designed
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered	Doors close flat and covers access opening completely

No. 16 – Sand Filter Vaults				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Large Access Doors/Plate (continued)	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate	Lifting rings sufficient to lift or remove door or plate

1 Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.				
Facility – General Requirements	A, E	Trash and debris	Any trash or debris or organic material which impairs the function of the facility	• Trash and debris removed from facility • Flow receives treatment instead of bypassing
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	A	Life cycle	Once per year	Facility is re-inspected and any needed maintenance performed
Vault Treatment Area	Varies – Refer to Manufacturer's requirements.	Sediment on vault floor	Varies – Refer to Manufacturer's requirements.	Vault is free of sediment
	Varies – Refer to Manufacturer's requirements.	Sediment on top of cartridges	Varies – Refer to Manufacturer's requirements.	Vault is free of sediment
	Varies – Refer to Manufacturer's requirements.	Multiple scum lines above top of cartridges	Thick or multiple scum lines above top of cartridges	Cause of plugging corrected and canisters replaced if necessary

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil particles entering the structure through the cracks • Qualified inspection personnel determines the vault is not structurally sound	Vault replaced or repaired to design specifications
	A	Baffles damaged	Baffles corroding, cracking warping, and/or showing signs of failure	Repair or replace baffles to specification
Filter Media	A, E	Standing water in vault	Varies – Refer to Manufacturer's requirements.	No standing water in vault 24 hours after a rain event
	A	Short circuiting	Flows do not properly enter filter cartridges	Flows go through filter media
Underdrains and Clean-Outs	A	Sediment/debris	Underdrains or clean-outs partially plugged or filled with sediment and/or debris	Underdrains and clean-outs free of sediment and debris
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	• Cracks wider than ½ inch at the joint of the inlet/outlet pipes • Any evidence of soil entering at the joints of the inlet/outlet pipes	Cracks repaired, and no evidence of soil entering

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Access Maintenance Hole	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open maintenance hole requires immediate maintenance**	Maintenance hole access cover/lid in place and secure
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person
	A	Cover/lid rocking or noisy	Lid rocking when driven over	Cover/lid not rocking
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access
Large Access Doors/Plate	A	Difficult to open	Large access doors or plates cannot be opened/removed using normal equipment	Replace or repair access door so it can opened as designed.
	A	Damaged	Hatch doors show major dents and stress	Replace to support surface loading and uses
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered.	Doors close flat and cover access opening completely.

No. 17 – Proprietary Technology Filter Cartridge Systems (example: BayFilter, FloGard PerkFilter, StormFilter)				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Large Access Doors/Plate (continued)	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate.	Lifting rings sufficient to lift or remove door or plate.

1 Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

2 Inspection frequencies provided are recommendations only. Proprietary technologies shall be inspected on a frequency as recommended by the manufacturer.

No. 18 – API Oil/Water Separators				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	A, E	Trash and debris	Any trash or debris which impairs the function of the facility	Trash and debris removed from facility
	A, E	Contaminants and pollution	Floating oil in excess of 1 inch in first chamber, any oil in other chambers or other contaminants of any type in any chamber	No contaminants present other than a surface oil film
Vault Treatment Area	A, E	Sediment accumulation	Sediment accumulates exceeds 6 inches in the vault	No sediment in the vault.
	A, E	Discharge water not clear	Inspection of discharge water shows obvious signs of poor water quality-effluent discharge from vault shows thick visible sheen	Effluent discharge is clear
	A, E	Trash or debris accumulation	Any trash and debris accumulation in vault (floatables and non-floatables)	Vault is clear of trash and debris
	A, E	Oil accumulation	Oil accumulations that exceed 1 inch, at the surface of the water in the oil/water separator chamber	No visible oil depth on water
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil particles entering the structure through the cracks • Maintenance/inspection personnel determines that the vault is not structurally sound	Vault replaced or repaired to design specifications
	A	Baffles damaged	Baffles corroding, cracking, warping and/or showing signs of failure	Repair or replace baffles to specifications

No. 18 – API Oil/Water Separators				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Gravity Drain	A	Inoperable valve	Valve will not open and close	Valve opens and closes normally
	A	Valve will not seal	Valve does not seal completely	Valve completely seals closed
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	Cracks, broken welds, seams or any other conditions that allows water to be discharged from other than the submerged portion of the tee	Water will be discharged from the submerged portion of the tee
	A	Missing	When the required inlet or outlet tee is not installed	Tees installed
	A	Permanently installed	When the tee is grouted to the inlet or outlet pipe and is not removable to allow for maintenance and inspection	Tee removable for maintenance and inspection
Access Maintenance Hole	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open maintenance hole requires immediate maintenance**	Maintenance hole access cover/lid in place and secure
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person

No. 18 – API Oil/Water Separators				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Access Maintenance Hole (continued)	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment	Replace or repair access door so it can opened as designed
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered	Doors close flat and cover access opening completely
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or cover/lid	Lifting rings sufficient to lift or remove cover/lid

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 19 – Coalescing Plate Oil/Water Separators				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	A, E	Trash and debris	Any trash or debris which impairs the function of the facility	Trash and debris removed from facility
	A, E	Contaminants and pollution	Floating oil in excess of 1 inch in first chamber, any oil in other chambers or other contaminants of any type in any chamber	No contaminants present other than a surface oil film
Vault Treatment Area	A, E	Sediment accumulation in the forebay	Sediment accumulation of 6 inches or greater in the forebay	No sediment in the forebay
	A, E	Discharge water not clear	Inspection of discharge water shows obvious signs of poor water quality – effluent discharge from vault shows thick visible sheen	Repair function of plates so effluent is clear
	A, E	Trash or debris accumulation	Trash and debris accumulation in vault (floatables and non-floatables)	Trash and debris removed from vault
	A, E	Oil accumulation	Oil accumulation that exceeds 1 inch at the water surface in the in the coalescing plate chamber	No visible oil depth on water and coalescing plates clear of oil
Coalescing Plates	A	Damaged	Plate media broken, deformed, cracked and/or showing signs of failure	Replace that portion of media pack or entire plate pack depending on severity of failure
	A, E	Sediment accumulation	Any sediment accumulation which interferes with the operation of the coalescing plates	No sediment accumulation interfering with the coalescing plates

No. 19 – Coalescing Plate Oil/Water Separators				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Vault Structure	A	Damage to wall, frame, bottom, and/or top slab	• Cracks wider than ½ inch • Any evidence of soil particles entering the structure through the cracks • Maintenance inspection personnel determines that the vault is not structurally sound	Vault replaced or repaired to design specifications
	A	Baffles damaged	Baffles corroding, cracking, warping and/or showing signs of failure	Repair or replace baffles to specifications
Ventilation Pipes	A	Plugged	Any obstruction to the ventilation pipes	Ventilation pipes are clear
Shutoff Valve	A	Damaged or inoperable	Shutoff valve cannot be opened or closed	Shutoff valve operates normally
Inlet/Outlet Pipe	A	Sediment accumulation	Sediment filling 1/3 or more of the pipe	Inlet/outlet pipes clear of sediment
	B, W, E	Trash and debris	Trash and debris accumulated in inlet/outlet pipes (includes floatables and non-floatables)	No trash or debris in pipes
	A	Damaged	Cracks, broken welds, seams or any other conditions that allows water to be discharged from other than the submerged portion of the tee	Water will be discharged from the submerged portion of the tee
	A	Missing	When the required inlet or outlet tee is not installed	Tees installed
	A	Permanently installed	When the tee is grouted to the inlet or outlet pipe and is not removable to allow for maintenance and inspection	Tee removable for maintenance and inspection

No. 19 – Coalescing Plate Oil/Water Separators				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Access Maintenance Hole	A	Cover/lid not in place	• Cover/lid is missing or only partially in place • **Any open maintenance hole requires immediate maintenance**	Maintenance hole access cover/lid in place and secure
	A	Locking mechanism not working	• Mechanism cannot be opened by one maintenance person with proper tools • Bolts cannot be seated • Self-locking cover/lid does not work	Mechanism opens with proper tools
	A	Cover/lid difficult to remove	One maintenance person cannot remove cover/lid after applying 80 lbs of lift	Cover/lid can be removed and reinstalled by one maintenance person
	A	Ladder rungs unsafe	Missing rungs, misalignment, rust, or cracks	Ladder meets design standards and allows maintenance person safe access
Large Access Doors/Plate	A	Damaged or difficult to open	Large access doors or plates cannot be opened/removed using normal equipment.	Replace or repair access door so it can opened as designed
	A	Gaps, does not cover completely	Large access doors not flat and/or access opening not completely covered	Doors close flat and cover access opening completely
	A	Lifting rings missing, rusted	Lifting rings not capable of lifting weight of door or plate	Lifting rings sufficient to lift or remove door or plate

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 20 – Catch Basin Filter Socks				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Media Insert[2]	M	Visible oil	Visible oil sheen passing through media	Media insert replaced
	M	Insert does not fit catch basin properly	Flow gets into catch basin without going through media	All flow goes through media
	M	Filter media plugged	Filter media plugged	Flow through filter media is normal
	M	Oil absorbent media saturated	Media oil saturated	Oil absorbent media replaced
	M	Water saturated	Catch basin insert is saturated with water, which no longer has the capacity to absorb	Insert replaced
	M	Service life exceeded	Regular interval replacement due to typical average life of product	Media replaced at manufacturer's recommended interval

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[2] Inspection frequencies provided are recommendations only. Catch basin filter socks shall be inspected on a frequency as recommended by the manufacturer.

No. 21 - Proprietary Technology Filterra System				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.				
Facility – General Requirements	A	Life cycle	Once per year, except mulch and trash removal twice per year	Facility is re-inspected and any needed maintenance performed
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Inlet	B, E	Excessive sediment or trash accumulation	Accumulated sediments or trash impair free flow of water into system	Inlet should be free of obstructions allowing free distributed flow of water into system
Mulch Cover	B, E	Trash and floatable debris accumulation	Excessive trash and/or debris accumulation	• Minimal trash or other debris on mulch cover • Mulch cover raked level
	B, E	"Ponding" of water on mulch cover	"Ponding" in unit could be indicative of clogging due to excessive fine sediment accumulation or spill of petroleum oils	Stormwater should drain freely and evenly through mulch cover
Proprietary Filter Media/ Vegetation Substrate	B, E	"Ponding" of water on mulch cover after mulch cover has been maintained	Excessive fine sediment passes the mulch cover and clogs the filter media/vegetative substrate	• Stormwater should drain freely and evenly through mulch cover • Replace substrate and vegetation when needed

No. 21 – Proprietary Technology Filterra System				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Vegetation	B, E	Plants not growing or in poor condition	• Soil/mulch too wet • Evidence of spill • Incorrect plant selection • Pest infestation • Vandalism to plants	Plants should be healthy and pest free
			Media/mulch too dry	Irrigation is required
	B, E	Plants absent	Plants absent	Appropriate plants are present
	B, E	Excessive plant growth	Excessive plant growth inhibits facility function or becomes a hazard for pedestrian and vehicular circulation and safety	• Pruning and/or thinning vegetation maintains proper plant density • Appropriate plants are present
Structure, if used	B	Structure has visible cracks	• Cracks wider than ½ inch • Evidence of soil particles entering the structure through the cracks	Structure is sealed and structurally sound

1 Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

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No. 22 - Proprietary Technology Modular Wetland System				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
In addition to the specific maintenance criteria provided below, all manufacturers' requirements shall be followed.				
Facility – General Requirements	B	Trash and debris	Any trash or debris which impairs the function of the facility	Trash and debris removed from facility
	B	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
	B	Odor	Septic or foul odor coming from inside the system	Odors are eliminated
	B	Standing water	Standing water observed after a prolonged dry period	No standing water
Inlet/Outlet Pipe	B	Excessive sediment or trash accumulation	Accumulated sediments or trash impair free flow of water into system	Inlet should be free of obstructions allowing free distributed flow of water into system
	B	Pipe damage or blockage	Pipe damaged or otherwise not functioning properly	Pipe is repaired and allowing free flow of water into system
Pre-Treatment Chamber	B	Sediment accumulation	Sediment accumulation in the pre-treatment chamber	Sediment removed from the pre-treatment chamber
	B	Access cover damage or difficulty opening	Access cover (manhole cover/grate) is damaged or cannot be opened using normal lifting pressure	Access cover is repaired and can be opened using normal lifting pressure.

No. 22 - Proprietary Technology Modular Wetland System				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Pre-Treatment Chamber (continued)	B	Obstruction or clogging of screening device	Contaminants and pollutants collected by screen are obstructing flow of water into the system	• All pollutants removed and disposed of according to applicable regulations • Screen is free of obstructions and allows free flow of water into system
	B	Accumulated pollutants or debris in separation chamber	Accumulated pollutants or debris impedes function of unit	All pollutants removed and disposed of according to applicable regulations
Filter Media	A	Life cycle	Regular interval replacement due to typical average life of product or clogging	Old filter media is removed and new filter media is installed
Structure	A	Unit shows signs of structural deterioration	• Visible cracks wider than ½ inch • Evidence of soil particles entering the structure through the cracks • Damage to frame	Structure is sealed and structurally sound
Access Cover	A	Hard to open	Cannot be easily opened	Access lid is repaired or replaced
	A	Buried	Buried	Access lid functions as designed (refer to record drawings for design intent)
	A	Missing cover	Cover missing	Cover replaced
Vegetation	B	Plants not growing or in poor condition	• Soil/mulch too wet • Evidence of spill • Incorrect plant selection • Pest infestation • Vandalism to plants	Plants should be healthy and pest free.

No. 22 - Proprietary Technology Modular Wetland System				
Maintenance Component	**Recommended Inspection Frequency[1,2]**	**Defect or Problem**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Vegetation (continued)	B	Excessive plant growth	Excessive plant growth inhibits facility function or becomes a hazard for pedestrian and vehicular circulation and safety	● Pruning and/or thinning vegetation maintains proper plant density ● Appropriate plants are present

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

[2] Inspection frequencies provided are recommendations only. Proprietary technologies shall be inspected on a frequency as recommended by the manufacturer.

No. 23 - Bioretention Facilities				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Facility – General Requirements	B, E	Pests: Insects/Rodents	Pest of concern is present and impacting facility function	• Pests removed or destroyed and facility returned to original functionality • Do not use pesticides or *Bacillus thuringiensis israelensis* (*Bti*)
	A, E	Trash	Trash and debris present	No trash and debris present
	B, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Earthen Side Slopes and Berms	B, E	Erosion	Erosion (gullies/rills) greater than 2 inches deep around inlets, outlet, and alongside slopes	• Cause of erosion is eliminated • Damaged area is stabilized (regrade, rock, vegetation, erosion control blanket) For deep channels or cuts (over 3 inches in ponding depth), temporary erosion control measures are in place until permanent repairs can be made.
			Erosion of sides causes slope to become a hazard	The hazard is eliminated and slopes are stabilized
	A, E	Settlement	Settlement greater than 3 inches (relative to undisturbed sections of berm)	The design height is restored with additional mulch

No. 23 – Bioretention Facilities				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Earthen Side Slopes and Berms (continued)	A, E	Berm leakage	Downstream face of berm wet, seeps or leaks evident	Holes are plugged and berm is compacted (may require consultation with licensed engineer, particularly for larger berms)
			Any evidence of rodent holes or water piping in berm	• Rodents (refer to "Pests: Insects/Rodents") removed or destroyed • Berm repaired/compacted
Concrete Sidewalls	A	Cracks	Rot, cracks, or failure of concrete sidewalls	Concrete is repaired or replaced
Rockery Sidewalls	A	Instable rockery	Rockery side walls are insecure	Rockery sidewalls are stable (may require consultation with licensed engineer, particularly for walls 4 feet or greater in height)
Facility Bottom Area	B	Sediment accumulation	Accumulated sediment to extent that infiltration rate is reduced (refer to “Bioretention Soil”) or surface storage capacity significantly impacted	• Sediment cleaned out to restore facility shape and depth • Damaged vegetation is replaced and mulched • Source of sediment identified and controlled (if feasible)
	B	Leaf accumulation	Accumulated leaves in facility	No leaves clogging outlet structure or impeding water flow
Check Dams and Weirs	A, E	Sediment, vegetation, or debris accumulation	Sediment, vegetation, or debris accumulated at or blocking (or having the potential to block) check dam, flow control weir, or orifice	Blockage is cleared

No. 23 - Bioretention Facilities				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Check Dams and Weirs (continued)	A, E	Erosion	Erosion and/or undercutting present	• No eroded or undercut areas in bioretention facility • Cause of erosion or undercutting addressed • Check dam or weir is repaired
	A	Unlevel top of weir	Grade board or top of weir damaged or not level	Weir restored to level position
Bioretention Soil	As needed	Ponded water	Water remains in the basin 48 hours or longer after the end of a storm	Cause of ponded water is identified and addressed: 1) Leaf litter/debris is removed 2) Underdrain is clear 3) Other water inputs (e.g., groundwater, illicit connections) investigated 4) Contributing area verified and facility size is evaluated If items #1–4 do not solve the problem, imported bioretention soil is replaced and replanted.
	As needed	Protection of soil	Maintenance will occur requiring entrance into the facility footprint	Maintenance is performed without compacting bioretention soil media
Splash Block Inlet	B	Water not properly directed to facility	Water is not being directed properly to the facility and away from the inlet structure	Blocks are reconfigured to direct water to facility and away from structure
Curb Cut Inlet/Outlet	A, E	Accumulated debris	Accumulated leaves, sediment, debris or vegetation at curb cuts	• Blockage is cleared • Source of the blockage is identified and action is taken to prevent future blockages

No. 23 - Bioretention Facilities				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Inlet/Outlet Pipe	A	Damaged pipe	Pipe is damaged	• Pipe is repaired/replaced • No cracks more than ¼-inch wide at the joint of inlet/outlet pipes exist
	A	Clogged pipe	Pipe is clogged	Pipe is clear
	A, E	Accumulated debris	Accumulated leaves, sediment, debris or vegetation at inlet or outlet pipe	• Pipe is clear of debris • Source of the blockage is identified and action is taken to prevent future blockages
	A, E	Blocked access	Maintain access for inspections	• Vegetation is cleared within 1 foot of inlets and outlets • Access pathways are maintained
	B	Erosion	Water disrupts soil media	• No eroded or scoured areas in bioretention facility • Cause of erosion or scour addressed. • Pipes or splash blocks are reconfigured or repaired • A cover of rock or cobbles or other erosion protection measure maintained (e.g., matting) to protect the ground where concentrated water enters or exits the facility (e.g., a pipe, curb cut or swale)
Overflow	A, E	Blocked overflow	Capacity reduced by sediment or debris	No sediment or debris in overflow

No. 23 - Bioretention Facilities				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Underdrain Pipe	A	Blocked underdrain	• Plant roots, sediment or debris reducing capacity of underdrain • Prolonged surface ponding (refer to “Bioretention Soil”)	Underdrains and orifice are free of sediment and debris
Facility Bottom Area and Upland Slope Vegetation	M	Lack of vegetation	Vegetation survival rate falls below 75 percent within first 2 years of establishment (unless project O&M manual or record drawing stipulates more or less than 75 percent survival rate)	• Plants are healthy and pest free • Cause of poor vegetation growth addressed • Bioretention facility is replanted as necessary to obtain 75 percent survival rate or greater • Plant selection is appropriate for site growing conditions
Trees and Shrubs	A	Causing problems for operation of facility	Large trees and shrubs interfere with operation of the facility or access for maintenance	Trees and shrubs do not hinder facility performance or maintenance activities
	A	Dead trees or shrubs	Standing dead vegetation is present	• Trees and shrubs do not hinder facility performance or maintenance activities • Dead vegetation is removed • Cause of dead vegetation is addressed • Specific plants with high mortality rate are replaced with more appropriate species

No. 23 - Bioretention Facilities				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Trees and Shrubs Adjacent to Vehicle Travel Areas (or areas where visibility needs to be maintained)	A	Safety issues	Vegetation causes some visibility (line of sight) or driver safety issues	• Appropriate height for sight clearance is maintained • Regular pruning maintains visual sight lines for safety or clearance along a walk or drive • Tree or shrub is removed or transplanted if presenting a continual safety hazard
Emergent Vegetation	M	Conveyance blocked	Vegetation compromises conveyance	Sedges and rushes are clear of dead foliage
Noxious Weeds	M (March – October)	Presence of noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
Excessive Vegetation	M	Adjacent facilities compromised	Low-lying vegetation growing beyond facility edge onto sidewalks, paths, or street edge poses pedestrian safety hazard or may clog adjacent permeable pavement surfaces due to associated leaf litter, mulch, and soil	• Vegetation does not impede function of adjacent facilities or pose as safety hazard • Groundcovers and shrubs trimmed at facility edge • Excessive leaf litter is removed.

No. 23 - Bioretention Facilities

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Excessive Vegetation (continued)	M	Causes facility to not function properly	Excessive vegetation density inhibits stormwater flow beyond design ponding or becomes a hazard for pedestrian and vehicular circulation and safety	• Pruning and/or thinning vegetation maintains proper plant density and aesthetics • Plants that are weak, broken, or not true to form are removed or replaced in-kind • Appropriate plants are present
Mulch	A	Lack of mulch	Bare spots (without mulch cover) are present or mulch depth less than 2 inches	• Facility has a minimum 3-inch layer of an appropriate type of mulch • Mulch is kept away from woody stems
Plant Watering	Weekly or as required (May – September)	Plant establishment	Plant establishment period (1–3 years)	Plants are watered as necessary during periods of no rain to ensure plant establishment
Summer Watering (after establishment)	Weekly or as required (May – September)	Drought period	Established vegetation (after 3 years)	• Plants are watered as necessary during drought conditions • Trees are watered up to 5 years after planting

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No. 24 – Cisterns				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Roof	B	Debris accumulation in cistern	Debris has accumulated	No debris in cistern
Gutter	B	Debris accumulation in cistern	Debris has accumulated	No debris in cistern or gutter
Screens at the Top of Downspout and Cistern Inlet	A	Debris accumulation in cistern	Screen has deteriorated or is missing	Screen is in place and functions as designed
	Monthly (October – April), E		Preventative maintenance	No debris in cistern or accumulated on screen
Overflow Pipe	B	Damaged	Pipe is cracked, joints and fittings not sealed	Overflow pipe is watertight and does not leak.
	B	Discharge is sporadic, cistern overtops	Debris has accumulated blocking flow	Overflow pipe can convey overflow to point of discharge.
Cistern	A	Accumulated debris and/or sediment	More than 6 inches of accumulation in bottom of cistern	Accumulation of debris and/or sediment removed
Low Flow Orifice (detention cistern)	M (October – April), E	Cistern overflows are too frequent	Debris or other obstruction of orifice	Orifice is clear
Delivery and Distribution System (harvesting)	Varies	None – ongoing maintenance activity	Ongoing maintenance (e.g., replacing and/or cleaning filters, removing sediment and other pollutants from storage systems)	Manufacturer's, installer's, or designer's instructions for O&M are followed
Access and Safety	Ongoing	None – ongoing maintenance activity	Access to cistern required for maintenance or cleaning	Any cistern opening that could allow the entry of people is marked: "DANGER—CONFINED SPACE"
Pests	B	Mosquito infestation	Standing water remains for more than 3 days following storms	• All inlets, overflows and other openings are protected with mosquito screens • No mosquito infestation present

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No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Splash Block	B	Water directed toward building	Water is being directed towards building structure	Blocks direct water away from building structure
	B	Water causing erosion	Water disrupts soil media	Blocks are reconfigured/repaired and media is restored
Transition Zone	B, E	Erosion	Adjacent soil erosion; uneven surface creating concentrated flow discharge; or less than 2 foot of width	No eroded or scoured areas Cause of erosion or scour is addressed
Dispersion Trench	B	Concentrated flow	Visual evidence of water discharging at concentrated points along trench (normal condition is a "sheet flow" from edge of trench; intent is to prevent erosion damage)	No debris on trench surface Notched grade board or other distributor type is aligned to prevent erosion Trench is rebuilt to standards, if necessary
Surface of Trench	A, E	Accumulated debris	Accumulated trash, debris, or sediment on drain rock surface impedes sheet flow from facility	Trash or debris is removed/disposed in accordance with local solid waste requirements
	A, E	Vegetation impeding flow	Vegetation/moss present on drain rock surface impedes sheet flow from facility	Freely draining drain rock surface
Pipe(s) to Trench	A	Accumulated debris in drains	Accumulation of trash, debris, or sediment in roof drains, gutters, driveway drains, area drains, etc.	No trash or debris in roof drains, gutters, driveway drains, or area drains
	A	Accumulated debris in inlet pipe	Pipe from sump to trench or drywell has accumulated sediment or is plugged	No sediment or debris in inlet/outlet pipe screen or inlet/outlet pipe
	A	Damaged pipes	Cracked, collapsed, broken, or misaligned drain pipes	No cracks more than ¼-inch wide at the joint of the inlet/outlet pipe

No. 25 – Downspout, Sheet Flow, and Concentrated Dispersion Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Rock Pad (concentrated flow dispersion)	A	Inadequate rock cover	Only one layer of rock exists above native soil in area 6 square feet or larger, or any exposure of native soil	Rock pad is repaired/replaced to meet design standards
	A	Erosion	Soil erosion in or adjacent to rock pad	Rock pad is repaired/replaced to meet design standards
Dispersal Area (general)	A	Erosion	Erosion (gullies/rills) greater than 2 inches deep in dispersal area	No eroded or scoured areas Cause of erosion or scour is addressed
	A	Accumulated sediment	Accumulated sediment or debris to extent that blocks or channelizes flow path	No excess sediment or debris in dispersal area. Sediment source is addressed (if feasible)
Ponded Water	As needed	Ponded water	Standing surface water in dispersion area remains for more than 3 days after the end of a storm event	• System freely drains • Standing water in dispersion area does not persist for more than 3 days after a storm event • Cause of the standing water (e.g., grade depressions, compacted soil) addressed
Vegetation	M	Plant survival	Dispersal area vegetation in establishment period (1–2 years, or additional 3rd year) during extreme dry weather)	Vegetation healthy and watered weekly during periods of no rain to ensure plant establishment

No. 25 - Downspout, Sheet Flow, and Concentrated Dispersion Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Vegetation (continued)	M	Lack of vegetation allowing erosion	Poor vegetation cover such that erosion is occurring	• Vegetation healthy and watered. • No eroded or scoured areas present • Cause of erosion or scour addressed • Plant species appropriate for the soil and moisture conditions
	M	Vegetation blocking flow	Vegetation inhibits dispersed flow along flow path	Vegetation is trimmed, weeded, or replanted to restore dispersed flow path
	M (March – October)	Presence of noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
Sump	A	Accumulated sediment	Accumulated sediment in the sump exceeds 30 percent of storage volume	No sediment in sump or inlet/outlet pipes
Access Lid	A	Hard to open	Cannot be easily opened	Access lid is repaired or replaced
	A	Buried	Buried	Access lid functions as designed (refer to record drawings for design intent)
	A	Missing cover	Cover missing	Cover replaced

No. 25 - Downspout, Sheet Flow, and Concentrated Dispersion Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Pest Control	B	Mosquito infestation	Standing surface water in dispersion area remains for more than 3 days after the end of a storm	• System freely drains • Standing water in dispersion area does not persist for more than 3 days after a storm event • Cause of the standing water (e.g., grade depressions, compacted soil) addressed
Rodents	As required	Presence of rodents	Rodent holes or mounds disturb dispersion flow paths	• Rodents removed or destroyed • Holes filled • Flow path revegetated

[1] Inspection frequency:

A = Annually; B = Biannually; M = Monthly; E = Recommend that additional inspections be performed as appropriate after major events (e.g., >1 inch of precipitation in 24 hours or environmental incident that causes contaminant release; Q = Quarterly (four times per year); W = Recommend that at least one inspection occur during the wet season, preferably after trees have lost their leaves

No. 26 - Permeable Pavement[1]				
Maintenance Component	**Recommended Inspection Frequency[2]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	A	Unstable adjacent area	Runoff from adjacent pervious areas deposits soil, mulch or sediment on paving	• No deposited soil or other materials on permeable pavement or other adjacent surfacing • All exposed soils that may erode to pavement surface mulched and/or planted
	A	Wearing course covered by adjacent vegetation	Vegetation growing beyond facility edge onto sidewalks, paths, and street edge	• Vegetation does not impede function of adjacent facilities or pose as safety hazard • Groundcovers and shrubs trimmed to avoid overreaching the sidewalks, paths and street edge
	A, E	Contaminants and pollution	Any evidence of contaminants or pollution such as oil, gasoline, concrete slurries, or paint	• Materials removed and disposed of according to applicable regulations • Source control BMPs implemented if appropriate • No contaminants present other than a surface oil film
Pavement Wearing Course (all types)	A	Accumulated sediment on surface	Sediment present at the surface of the pavement	Sediment at surface does not inhibit infiltration
	A	Surface clogged by moss	Moss growth inhibits infiltration or poses slip safety hazard	Moss growth on surface does not inhibit infiltration or present a slip safety hazard

No. 26 – Permeable Pavement[1]				
Maintenance Component	**Recommended Inspection Frequency[2]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Pavement Wearing Course (all types)	A	Surface is clogged	Ponding on surface or water flows off the permeable pavement surface during a rain event (does not infiltrate)	• System drains freely • No standing water on surface between storms
	A	Settlement	When deviation from original grade impedes function.	Original grade re-established
Permeable Asphalt or Cement Concrete	A	Cracks	Major cracks or trip hazards and concrete spalling and raveling	• Potholes or small cracks filled with patching mixes • Large cracks and settlement addressed by cutting and replacing the pavement section
Permeable Paver or Open-Celled Paving Grid	A	Paver block missing or damaged	Paver block missing or damaged	Individual damaged paver blocks removed and replaced or repaired per manufacturer's recommendations
	A	Loss of aggregate material between paver blocks	Loss of aggregate material between paver blocks	Aggregate replaced per manufacturer's recommendations
Open-Celled Paving Grid	A	Paving grid missing or damaged	Three or more adjacent rings in paving grid missing or damaged	Grid segment replaced or repaired per manufacturer's recommendations
	A	Loss of aggregate material in paving grid	Loss of aggregate material in paving grid	Aggregate gravel level maintained at the same level as the plastic rings or no more than ¼ inch above the top of rings
	A	Lack of grass coverage	Poor grass coverage in paving grid	• Growing medium restored • Facility reseeded or planted • Aerated • Vegetated area amended as needed

No. 26 – Permeable Pavement[1]				
Maintenance Component	**Recommended Inspection Frequency[2]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Open-Celled Paving Grid (continued)	A	Weeds present	Weeds present	Weeds are removed if infiltration is hindered. Noxious weeds are removed.
Inlet/Outlet Pipe	A	Pipe is damaged	Pipe is damaged	Pipe is repaired/replaced
	A	Pipe is clogged	Pipe is clogged	Roots or debris is removed
	A, E	Erosion	Native soil exposed or other signs of erosion damage present	• No eroded or scoured areas • Cause of erosion or scour is addressed
Underdrain Pipe	B	Blocked underdrain	Plant roots, sediment or debris reducing capacity of underdrain (may cause prolonged drawdown period)	Underdrains and orifice free of sediment and debris

1 Fog seal, chip seal and other impervious overlays are not permitted on top of permeable pavement.[2] Inspection frequency:

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No. 27 - Trees				
Maintenance Component	**Recommended Inspection Frequency**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Tree	As needed	Dead or declining	Dead, damaged, or declining	Tree replaced per planting plan or acceptable substitute

No. 28 – Vegetated Roof Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Facility – General Requirements	A	Improper access and safety for maintenance	Insufficient egress/ingress routes and fall protection	• Egress and ingress routes maintained to design standards and fire codes • Fall protection is appropriate
	A	Border zone not defined	Vegetation is encroaching into border zone aggregate	• No weeds and undesirable vegetation present • Desirable vegetation transplanted
	A	Flashing, gravel stops, utilities, or other structures on roof	Flashing, utilities or other structures on roof are deteriorating (can serve as source of metal pollution in vegetated roof runoff)	Potential pollutant sources replaced or eliminated
	B	Mosquitoes	Standing water remains for more than 3 days after the end of a storm	• System freely drains • Standing water on roof does not persist for more than 3 days after a storm event
	As required	Nuisance animals	Nuisance animals causing erosion, damaging plants, or depositing large volumes of feces	Measures in place to deter nuisance species
Growth Medium	A	Water is not infiltrating properly	Water does not permeate growth media (runs off soil surface) or crusting is observed	Stormwater infiltrates freely through growth media
	A	Insufficient growth medium	Growth medium thickness is less than design thickness (due to erosion and plant uptake)	Growth medium is present at design thickness
	B, W	Fallen leaves/debris	Fallen leaves or debris are present	No leaves or debris present

No. 28 – Vegetated Roof Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Growth Medium (continued)	A	Erosion	Growth media erosion/scour is visible (e.g., gullies)	• No eroded or scoured areas • Cause of erosion or scour addressed
Roof Drain	B, E	Not draining	Sediment, vegetation, or debris reducing capacity of inlet structure	• Inlet clear • Cause of blockage addressed
	A	Pipe is clogged	Pipe is clogged	Debris, roots, or other obstruction removed and pipe is free draining
Vegetation	B	Plant coverage	Vegetative coverage falls below 80 percent (unless design specifications stipulate less than 80 percent coverage)	• Bare areas planted with vegetation • Erosion control measures installed until percent coverage goal attained
			Summer watering – extensive vegetated roof system	Vegetation watered weekly during periods of no rain during vegetation establishment period (1–2 years)
				Vegetation watered during drought conditions or more often if necessary to maintain plant cover during post-establishment period (after 2 years)
			Summer watering – intensive vegetated roof system	Vegetation watered deeply, but infrequently, and the top 6 to 12 inches of the root zone is moist during vegetation establishment period (1–2 years)

No. 28 – Vegetated Roof Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Vegetation (continued)	B	Plant coverage (continued)	Summer watering – intensive vegetated roof system (continued)	Vegetation watered during drought conditions or more often if necessary to maintain plant cover during post-establishment period (after 2 years)
			Extensive roof with low density sedum population	Sedums are mulch mowed
	A	Poor plant establishment and possible nutrient deficiency in growth medium	Fertilization–extensive vegetated roof system	• Organic debris replenished • Annual soil test conducted to assess need for fertilizer • Minimal amounts of slow-release fertilizer applied
			Fertilization–intensive vegetated roof system	• Annual soil test conducted to assess need for fertilizer • Minimal amounts of slow-release fertilizer applied
			Dead vegetation is present	Dead plant material recycled on the roof or removed and replaced (see manufacturer's recommendations)
	Q	Weeds	Weeds are present	• Weeds removed (manual methods preferred) • IPM protocols followed

No. 28 – Vegetated Roof Systems				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance Is Needed**	**Results Expected When Maintenance Is Performed**
Vegetation (continued)	M (March – October)	Noxious weeds	Any noxious or nuisance vegetation which may constitute a hazard to City personnel or the public	• Noxious and nuisance vegetation removed according to applicable regulations • No danger of noxious vegetation where City personnel or the public might normally be
Irrigation System (if any)	Based on manufacturer's instructions	Not applicable	Irrigation system is not working or routine maintenance needed	Manufacturer's/installer's instructions are followed for operation and maintenance

1 Inspection frequency:

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No. 29 – Rain Gardens

Maintenance Component	Recommended Inspection Frequency[1]	Defect or Problem	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Facility – General Requirements	B, E	Mosquitoes	Standing water remains for more than 3 days after the end of a storm	• Rain garden drains freely • Standing water in rain garden does not persist for more than 3 days after a storm event • Cause of the standing water addressed (see "Ponded water")
	A, E	Trash	Trash and debris present	No trash or debris present
Earthen Side Slopes and Berms	B, E	Erosion	Persistent soil erosion on slopes	• No eroded or scoured areas • Cause of erosion or scour addressed
Rockery Sidewalls	A	Unstable rockery	Rockery side walls are insecure	Stable rockery sidewalls (may require consultation with licensed engineer, particularly for walls 4 feet or greater in height)
Rain Garden Bottom Area	B	Sediment accumulation	Visible sediment deposition in the rain garden that reduces drawdown time of water in the rain garden	• No sediment accumulation in rain garden • Source of sediment addressed
	B	Debris accumulation	Accumulated leaves in facility	No leaves clogging outlet structure or impeding water flow
Mulch	A	Lack of mulch	Bare spots (without mulch cover) are present or mulch depth less than 2 inches	• Facility has a minimum 2- to 3-inch layer of an appropriate type of mulch • Mulch kept away from woody stems
Splash Block Inlet	B	Water not properly directed to rain garden	Water is being directed towards building structure	Blocks are reconfigured to direct water to rain garden and away from structure

No. 29 – Rain Gardens				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Pipe Inlet/Outlet	B	Erosion	Rock or cobble removed or missing and concentrated flows contacting soil	• No eroded or scoured areas • Cause of erosion or scour addressed • Cover of rock or cobbles protects the ground where concentrated water flows into the rain garden
	A	Accumulated debris	Accumulated leaves, sediment, debris or vegetation at curb cuts, inlet or outlet pipe	Blockage cleared
	A	Damaged pipe	Pipe is damaged	Pipe repaired/replaced
	A	Clogged pipe	Pipe is clogged	Pipe clear of roots and debris
	A	Blocked access	Maintain access for inspections	Vegetation cleared or transplanted within 1 foot of inlets and outlets
Ponded Water	As needed	Ponded water	Excessive ponding water: Ponded water remains in the rain garden more than 48 hours after the end of a storm	• Rain garden drains freely • Standing water in rain garden does not persist for more than 48 hours after a storm event • Leaf litter/debris/sediment removed
Overflow	A, E	Blocked overflow	Capacity reduced by sediment or debris	No sediment or debris in overflow
Vegetation	A	Blocked site distances and sidewalks	Vegetation inhibits sight distances and sidewalks	Sidewalks and sight distances along roadways and sidewalks are kept clear
	A	Blocked pipes	Vegetation is crowding inlets and outlets	Inlets and outlets in rain garden clear of vegetation

No. 29 - Rain Gardens				
Maintenance Component	**Recommended Inspection Frequency[1]**	**Defect or Problem**	**Conditions When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
Vegetation (continued)	M	Unhealthy vegetation	• Yellowing: possible Nitrogen (N) deficiency • Poor growth: possible Phosphorous (P) deficiency • Poor flowering, spotting or curled leaves, or weak roots or stems: possible Potassium (K) deficiency	Plants are healthy and appropriate for site conditions
	M	Weeds	Presence of weeds	Weeds removed (manual methods preferred) and mulch applied
Summer Watering (years 1–3)	Weekly or as required (May – September)	Plant establishment	Tree, shrubs and groundcovers in first 3 years of establishment period	Plants are watered during plant establishment period (years 1–3)
Summer Watering (after establishment)	As needed	Drought conditions	Vegetation requires supplemental water	Plants are watered during drought conditions or more often if necessary during post-establishment period (after 2 years)

[1] Inspection frequency:

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City of Seattle

Appendix H - Financial Infeasibility Documentation for Vegetated Roofs and Rainwater Harvesting

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

Vegetated roofs and rainwater harvesting may not be financially feasible in all project situations. If the applicant determines that including a vegetated roof or rainwater harvesting to meet the on-site stormwater management requirement is not economically feasible using reasonable consideration of financial costs, even when engineering design limitations and physical limitations of the site would allow greater use of these best management practices (BMPs), then the applicant shall provide the following additional submittal documentation:

1. A narrative description and rationale with substantial evidence sufficient to explain and justify the applicant's conclusion that installation of a vegetated roof or rainwater harvesting is economically infeasible.
2. A detailed cost estimate of constructing the project as proposed (i.e., including the level of on-site stormwater management that is considered cost feasible for the project). The detailed cost estimate must include the following:
    - Breakdown of project costs into subtotals for demolition, site preparation, building construction, site paving, landscaping, and utilities, as applicable.
    - Itemization of the proposed stormwater control measures.
    - If a vegetated roof or rainwater harvesting would be feasible but for cost considerations, documentation of the difference in unit and total cost between the conventional surface and rainwater harvesting and/or alternative surface approach (e.g., the difference in cost between a standard roof and associated stormwater control BMPs compared to a vegetated roof and associated stormwater control BMPs).
3. A detailed cost estimate of constructing the project with additional stormwater control BMPs beyond what the applicant considers a feasible cost (i.e., beyond the proposed design itemized in item 2 above). That is, provide the additional cost the project would incur if the project were to use a vegetated roof or rainwater harvesting to meet the on-site stormwater management requirements.
4. Building/project valuation construction cost as determined by the Seattle Department of Construction and Inspection (SDCI).
5. If applicable, Street Improvement Plan or Utility Plan construction cost as determined by the Seattle Department of Transportation (SDOT) or capital improvement project cost as determined by applicable City department.
6. If the project does not achieve the on-site stormwater management requirements and the project application is not signed and stamped by a professional engineer, a signed statement by the applicant certifying that the project design implements the on-site stormwater management requirements is required.

Alternatively, the applicant may establish financial infeasibility of rainwater harvesting based on one of the following simplified criteria:

- The non-pollution generating roof area is less than 20,000 square feet
- The ratio of roof area to average daily rainwater demand is less than 10,000 square feet/gallons per minute (gpm) (refer to *Volume 3*, *Section 5.5.1.6* for rainwater demand calculations)

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City of Seattle

Appendix I - Landscape Management Plans and Integrated Pest Management Plans

City of Seattle
Stormwater Manual
July 2021

Note:

Some pages in this document have been purposely skipped or blank pages inserted so that this document will copy correctly when duplexed.

I-1. Landscape Management Plans

A landscape management plan (LMP) is a plan for defining the layout and long-term maintenance of landscaping features to minimize the use of pesticides (including herbicides and fungicides) and fertilizers and reduce the discharge of suspended solids and other pollutants. Use of an LMP that has been approved by the City of Seattle (City) is allowed as an alternative to the requirement to formally treat (with a water quality treatment BMP) the runoff from pollution-generating pervious surfaces (PGPS) that are subject to water quality treatment. LMPs have the potential to significantly reduce the pollutant load washing off managed green spaces. The requirements for obtaining City approval of an LMP are summarized in this section.

LMPs must address the basic principles provided in *Volume 1, Section 7.8*, tailoring them to fit the specific site. Every LMP will not necessarily be able to apply each of the listed recommendations related to the basic principles. In addition, landscapes are managed for different purposes, some more formal than others. Some recommendations may not be appropriate for very formal sites; therefore, they will not be adopted, in favor of other management practices that better fit the intended uses of the site. In the end, the extent to which an LMP is successful depends on the ability of the applied practices to retain soil, fertilizers, and pesticides on the site and away from receiving waters throughout the entire year.

If an LMP is proposed, it must be submitted with the engineering plans for the proposed project. The following documentation is required for the evaluation of an LMP submittal:

- Site vicinity map showing topography.
- Site plan including topography, areas with saturated soils (if applicable), and high water tables (if applicable).
- Narrative describing how the basic principles in *Volume 1, Section 7.8,* will be achieved.
- Plant list (with both common and scientific names) that includes the following:
  - Drought-tolerant plants, disease-resistant varieties, species for attracting beneficial insects (if any), and native plants.
  - Proposed spacing for shrubs and groundcovers.
  - Grass mix or mixes planned for turf areas including their sun/shade tolerance, disease susceptibility, drought tolerance, and tolerance of wet soil conditions.
- Landscape plan indicating placement of landscape features, lawn areas, trees, and planting groups (e.g., forbs, herbs, and groundcovers) on the site.
- Signage plan including proposed locations of signs and content of signs.
  - Signage must be located to identify which areas are included in the LMP.
  - Signage must indicate how a copy of the approved LMP can be obtained.
  - Inclusion of the following information in the signage is also encouraged: basic educational information about the LMP for maintenance workers and the public.

- Information on soil preparation and fertility requirements.
- Information on the design of the irrigation method (e.g., installed sprinkler system, drip irrigation system, or manual watering).
- Landscape maintenance plan, including the following:
  - Physical care methods, such as thatch removal or aeration, and mowing height and frequency.
  - Type of fertilizer (including percentages of nitrogen, phosphorus, and potassium [N-P-K]) and fertilization schedule or criteria.
- Integrated Pest Management (IPM) plan (refer to *Section I-2*), including the following:
  - Type of chemicals to be used for common pests such as crane fly larvae and the criteria or schedule for application.
  - Any biocontrol methods to be used.
- Information about the storage of pesticides or other chemicals, and the measures that will be used to dispose of them, including the following:
  - How the chemicals will be stored on the site between applications to prevent contact with stormwater or spills into the drainage system (if applicable).
  - How excess quantities of fertilizers or chemicals will be handled for individual applications.
- Implementation plan, including the following:
  - The responsible party for ensuring that the LMP is implemented.
  - How the applicant will ensure that grounds crews have the training and/or resources required to implement the LMP and make adjustments based on advances in landscape care practices and products.
  - A fertilizer and pesticide application log, including rate of application, area treated, and disposal or storage of residue.

I-2. Integrated Pest Management Plans

An IPM plan is a natural, long-term, ecologically based systems approach to controlling pest populations. IPM uses techniques either to reduce pest populations or maintain them at levels below those causing economic injury, or to so manipulate the populations that they are prevented from causing injury.

The goals of IPM are the encouragement of optimal selective pesticide use (away from prophylactic, broad-spectrum use) and the maximization of natural controls to minimize environmental side effects by creating and maintaining healthy landscapes:

- **Design for a healthy landscape**. A landscape should be designed to maximize the intended uses of the land and minimize potential pest problems. Design considers such plant health factors as site usage, soils, topography, hydrology and drainage, proximity to sensitive or critical areas and existing vegetation as well as known pest sensitivity. Take drainage pathways into consideration when considering landscape management and the potential need for pest control.
- **Awareness of potential pest problems**. Certain plants have known pest problems. Likewise, certain cultural conditions or landscape situations can encourage the infestation of pests.
- **Maintenance for maximum landscape health**. A well-designed and maintained landscape dramatically reduces the need for pest control. Appropriate selection of plants, pruning, proper irrigation, applications of mulch and fertilizer, appropriate mowing techniques, and other practices all promote landscapes that resist pest pressures and support natural predators.
- **Minimize disturbance of naturally occurring biological controls**. Pests have natural predators and controls operating on them at all times. Disruption of these systems due to poor maintenance practices can result in the development of new pest problems.

The following step-by-step comprehensive IPM plan process is provided as a guide.

Step 1: Correctly Identify the Pest and Understand Its Life Cycle

Identify the pest (e.g., weed, insect, or disease). Learn more about the pest. Observe it and pay attention to any damage that may be occurring. Learn about the life cycle. Many pests are a problem only during certain seasons or can be treated effectively only during certain phases of the life cycle. Repeat this step if more than one pest is identified.

Step 2: Establish Tolerance/Action Thresholds

Every landscape has a population of some pest (insect, weed, or disease), which is good because it supports a population of beneficial species that keep pest numbers in check. Beneficial organisms may compete with, eat, or parasitize disease or pest organisms. Decide on the level of infestation that must be exceeded before treatment needs to be considered. Pest populations under this threshold should be monitored but do not need treatment. For instance, European crane flies usually do not cause serious damage to a lawn unless there are between 25 and 40 larvae per square foot feeding on the turf in February (in normal weather years). Also, most people consider a lawn healthy and well maintained even with up to

20 percent weed cover; therefore, treatment, other than continuing good maintenance practices, is generally unnecessary.

Step 3: Monitor Regularly to Detect Pest Problems

Regular monitoring is a key practice for anticipating and preventing major pest outbreaks. It begins with a visual evaluation of the lawn or landscape condition. Take a few minutes before mowing to walk around and look for problems. Keep a notebook, record when and where a problem occurs, then monitor for it at about the same time in future years. Specific monitoring techniques can be used in the appropriate season for some potential problem pests, such as the European crane fly.

Step 4: Modify Maintenance Program to Promote Plant Health and Discourage Pests

A healthy landscape is resistant to most pest problems. Lawn aeration and overseeding along with proper mowing height, fertilization, and irrigation will help the grass out-compete weeds. Correcting drainage problems and letting soil dry out between watering in the summer may reduce the number of surviving crane-fly larvae. Gradually replace pest-prone plants.

Step 5: If Pests Exceed the Tolerance Thresholds, Use Cultural, Physical, Mechanical, or Biological Controls Prior to Implementing Chemical Controls

When a pest outbreak occurs (or monitoring indicates that one is imminent), implement cultural, physical, mechanical, or biological controls. If these types of controls prove insufficient, then consider chemical control options that are the least toxic or have the least non-target impact.

Here are two examples of an IPM approach for damaged lawns:

- **Red thread disease** is most likely under low-nitrogen fertility conditions and most severe during slow growth conditions. Mow the lawn and bag the clippings to remove diseased blades. Fertilize lightly to help the grass recover, then begin grasscycling (e.g., leaving grass clippings on a mowed lawn) and change to fall fertilization with a slow release or natural organic fertilizer to provide an even supply of nutrients. Chemical fungicides are not recommended because red thread cannot kill the lawn.
- **Crane fly damage** is most prevalent on lawns that stay wet in the winter and are irrigated in the summer. Correct the winter drainage and/or allow the soil to dry between irrigation cycles; larvae are susceptible to drying out so these changes can reduce their numbers. It may also be possible to reduce the number of crane fly larvae by using a power dethatcher on a cool, cloudy day when they are feeding close to the surface. Current studies are investigating the use of beneficial nematodes that parasitize the crane fly larvae; this type of treatment may eventually be a reasonable alternative.

Only after trying suitable non-chemical control methods or determining that the pest outbreak is causing too much serious damage, should chemical controls be considered. Determine the available products and choose the one that is the least toxic and has the least non-target impact.

Step 6: Evaluate and Record Effectiveness of Control and Modify Maintenance or Plant Choices to Support Recovery and Prevent Recurrence

Keep records. Note when, where, and what symptoms occurred, or when monitoring revealed a potential pest problem. Note what controls were applied and when, and the effectiveness of the control. Monitor the following year for the same problems. Review your landscape maintenance and cultural practices to see if they can be modified to prevent or reduce the severity of the problem.

A comprehensive IPM program should also include the proper use of pesticides as a last resort and vegetation/fertilizer management to eliminate or minimize the contamination of stormwater.

I-3. References

Refer to the Seattle Public Utilities IPM web page for additional resources for developing an LMP or IPM plan: www.seattle.gov/utilities/protecting-our-environment/sustainability-tips/landscaping/for-professionals/integrated-pest-management.