Kitsap County
Stormwater Design Manual

Appendices
2nd Draft
June 2020

March 2020 1st Draft Revisions are in RED

June 2020 2nd Draft Revisions are highlighted in aqua

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Appendix A – Glossary

Appendix A: Glossary

Note: The definitions in Chapter 12.08 Kitsap County Code (KCC) shall be reviewed and used where applicable. This appendix provides supplemental definitions only.

Arterial – A road or street primarily for through traffic. The term generally includes roads or streets considered collectors. It does not include local access roads which are generally limited to providing access to abutting property. See also RCW 35.78.010, RCW 36.86.070, and RCW 47.05.021.

Bioengineering – The combination of biological, mechanical, and ecological concepts (and methods) to control erosion and stabilize soil through the use of vegetation or in combination with construction materials.

BMPs – Best Management Practices. See Chapter 12.08 KCC for definition.

CESCL – Certified Erosion and Sediment Control Lead. See Chapter 12.08 KCC for definition.

CMP – Corrugated metal pipe

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

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

CPEP – Corrugated polyethylene pipe

Discharge point – The location where a discharge leaves the Permittee's MS4 through the Permittee's MS4 facilities/BMPs designed to infiltrate.

Erodible or leachable materials – Wastes, chemicals, or other substances that measurably alter the physical or chemical characteristics of runoff when exposed to rainfall. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage dumpster leakage.

GSS – Green Stormwater Solutions. ~~***(GSS) –***~~ See definition for Low Impact Development (LID).

HDPE – High-density polyethylene

HDPP – High-density polyethylene pipe

Highway – A main public road connecting towns and cities.

KCC – Kitsap County Code.

LID – Low Impact Development. See Chapter 12.08 KCC for definition.

LID principles – Land use management strategies that emphasize conservation, use of onsite natural features, and site planning to minimize impervious surfaces, native vegetation loss, and stormwater runoff.

Outfall – A point source as defined by 40 CFR 122.2 at the point where a discharge leaves the permittee's MS4 and enters a surface receiving waterbody or surface receiving waters. Outfall does not include pipes, tunnels, or other conveyances which connect segments of the same stream or other surface waters and are used to convey primarily surface waters (i.e., culverts).

Onsite stormwater management BMPs – As used in this manual~~appendix~~, a synonym for Low Impact Development BMPs. See Chapter 12.08 KCC for definition.

Permeable pavement – Pervious concrete, porous asphalt, permeable pavers or other forms of pervious or porous paving material intended to allow passage of water through the pavement section. It often includes an aggregate base that provides structural support and acts as a stormwater reservoir.

Pervious surface – Any surface material that allows stormwater to infiltrate into the ground. Examples include lawn, landscape, pasture, native vegetation areas, and permeable pavements.

PVC – Polyvinyl chloride

Rain garden – A non-engineered shallow landscaped depression, with compost-amended native soils and adapted plants. The depression is designed to pond and temporarily store stormwater runoff from adjacent areas, and to allow stormwater to pass through the amended soil profile.

SDAP – Site Development Activity Permit

Steep slopes – Slopes of 30 percent gradient or steeper within a vertical elevation change of at least 10 feet. A slope is delineated by establishing its toe and top, and it is measured by averaging the inclination over at least 10 feet of vertical relief. For the purpose of this definition:

The toe of a slope is a distinct topographic break in slope that separates slopes inclined at less than 30 percent from slopes 30 percent or steeper. Where no distinct break exists, the toe of a steep slope is the lower-most limit of the area where the ground surface drops 10 feet or more vertically within a horizontal distance of 25 feet; AND

The top of a slope is a distinct topographic break in slope that separates slopes inclined at less than 30 percent from slopes 30 percent or steeper. Where no distinct break exists, the top of a steep slope is the upper-most limit of the area where the ground surface drops 10 feet or more vertically within a horizontal distance of 25 feet.

Strahler order – The number is assigned to a stream to define the stream size based on a hierarchy of tributaries. The headwaters are the 1st order and downstream segments are defined at confluences (two streams running into each other). At a confluence, if the two streams are not of the same order, then the highest numbered order is maintained on the downstream segment. At a confluence of two streams with the same order, the downstream segment gets the next highest numbered order (e.g., two 1st order streams would be numbered 2nd order downstream). Divergences such as braided streams maintain the same order all the way through the braid, just like it was a single stream; however, divergences that are not braided streams keep the upstream order number and follow the normal hierarchy further downstream.

SWPE – Solid-wall polyethylene

TDA – Threshold discharge area

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

Underground Injection Control well – A structure built to discharge fluids from the ground surface into the subsurface; a bored, drilled, or driven shaft whose depth is greater than the largest surface dimension; or a dug hole whose depth is greater than the largest surface dimension; or an improved sinkhole, which is a natural crevice that has been modified; or a subsurface fluid distribution system that includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of UIC wells or subsurface infiltration systems include drywells, drain fields, infiltration trenches with perforated pipe, storm chamber systems with the intent to infiltrate, french drains, bioretention systems intended to distribute water to the subsurface by means of perforated pipe installed below the treatment soil, and other similar devices that discharge to the ground.

Vegetated flow path – A vegetated flow path consists of well-established lawn or pasture, landscaping with well-established groundcover, native vegetation with natural groundcover, or an area that meets Post-Construction Soil Quality and Depth. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.

Appendix B – Standard Plan Notes

Appendix B: Standard Plan Notes

The following is a listing of standard plan notes that shall be incorporated in the site improvement plan. All the notes on the list may not pertain to every project. The project engineer may omit non-relevant notes as determined by the director. However, do not renumber the remaining notes. If additional notes are needed for specific aspects, they should be added after the standard plan notes.

Construction Sequence

1. Apply for and pick up any ~~right-of-way~~right of way permits from Kitsap County Department of Public Works (KCPW).
2. Construct stabilized construction entrance(s).
3. Construct silt~~filter~~ fence barriers.
4. Construct sedimentation basins.
5. Construct runoff interception and diversion ditches.
6. Clear and grade the minimum site area required for construction of the various phases of work.
7. Provide temporary hydroseeding or other source control stabilization measures on all disturbed soils.
8. Maintain all erosion and sedimentation control best management practices (BMPs)~~facilities~~ to provide the required protection of downstream water quality.
9. All catch basins and conveyance lines shall be cleaned prior to paving. The cleaning operation shall not flush sediment laden water into the downstream system.
10. Provide permanent site stabilization.
11. Erosion and sedimentation control BMPs~~facilities~~ shall not be removed until construction is complete and accepted by Kitsap County.

Drainage Notes

1. The contractor shall ensure that the drainage is installed and operational prior to commencement of paving work.
2. All steel pipe and parts shall be galvanized. All submerged steel pipes and parts shall be galvanized and have asphalt treatment #1 or better.
3. Drainage stub-outs on individual lots shall be located with a 5-foot-high 2" x 4" stake marked "STORM." The stub out shall extend above surface level and be secured to the stake.
4. Video documentation of pipe interior for alignment and joint connection adequacy shall be provided if not inspected prior to cover.

Temporary Erosion and Sedimentation Control Maintenance Requirements

1. Erosion and sedimentation control ~~facilities~~ BMPs shall be inspected after each storm event and daily during prolonged rainfall.
2. Necessary repairs or replacement of ~~facilities~~ BMPs shall be accomplished promptly.
3. Sediment deposits shall be removed after each storm event or when the level of deposition reaches approximately one-half the maximum potential depth.
4. Sediment deposits remaining in place after the ESC ~~facilities~~ BMPs are no longer required shall be dressed to conform to the existing grade, prepared and seeded.
5. Temporary ~~Erosion and Sedimentation Control~~ESC ~~facilities~~ BMPs shall be maintained by:

Grading Notes

The contractor shall notify the engineer in the event or discovery of poor soils, groundwater or discrepancies in the existing conditions as noted on the plans.

1. Maximum slope steepness shall be 2:1 (Horizontal to Vertical) for cut and fill slopes.
2. Unless otherwise specified, all embankments in the Plan Set shall be constructed in accordance with Section 2-03.3(14)B of the WSDOT Standard Specifications for Road, Bridge and Municipal Construction (WSDOT 2020). Embankment compactions shall conform to Section 2-03.3(14)C, Method B of said Standard Specifications.
3. Embankments designed to impound water shall be compacted to 95 percent maximum density per Section 2-03.3(14)C, Method C of WSDOT Standard Specifications.
4. All areas receiving fill material shall be prepared by removing vegetation, non-complying fill, topsoil and other unsuitable material, by scarifying the surface to provide a bond with the new fill, and where slopes are steeper than 3 horizontal to 1 vertical and the height is greater than 5 feet., by benching into sound competent material as determined by a ~~soils~~ geotechnical engineer.

General Notes

1. All workmanship and materials shall conform to the MOST CURRENT Standard Specifications for Road, Bridge and Municipal Construction prepared by WSDOT and APWA as adopted by the ~~Kitsap County Department of Public Works (~~KCPW~~)~~.
2. Any revisions to the accepted construction plans shall be reviewed and approved by ~~the~~Kitsap County prior to implementation in the field.
3. The contractor shall maintain a set of the accepted construction drawings onsite at all times while construction is in progress.

4. It shall be the responsibility of the contractor to obtain all necessary permits from the KCPW prior to commencing any work within County ~~right-of-way~~right of way.
5. The contractor shall be responsible for providing adequate traffic control at all times during construction alongside or within all public roadways. Traffic flow on existing public roadways shall be maintained at all times, unless permission is obtained from the KCPW for road closure and/or detours.
6. The location of existing utilities on this plan is approximate only. The contractor shall ~~contract~~ contact the "Underground Locate" center at 811, and non-subscribing individual utility companies 48 hours in advance of the commencement of any construction activity. The contractor shall provide for protection of existing utilities from damage caused by the contractor's operations.
7. Rockeries or other retaining facilities that sustain a surcharge or exceed~~exceeding~~ 4 feet~~.~~ in height as measured from the foundation require a separate permit prior to construction.
8. A ~~"Forestry Practices"~~Timber Harvest permit may be required prior to clearing of the site.

Inspection Schedule

1. The Contractor shall notify the department of community development to arrange for inspection of the various work activities listed below. All inspections shall be completed prior to proceeding with the next phase of work.
    a. Establishment of clearing limits.
    b. Implementation of the various phases of the Erosion and Sedimentation Control Plan.
    c. Installation of conveyance, Onsite Stormwater Management BMPs, Flow Control BMPs, and Water Quality ~~Treatment~~ BMPs, prior to backfill.
    d. Protection of Onsite Stormwater Management BMPs.
    e. Prior to placement of the outlet control structures (orifice size verified prior to installation).
    f. For public road projects:
        i. Inspection of prepared sub-grade.
        ii. Inspection of gravel base placement.
        iii. Inspection of fine grading prior to paving.
        iv. Inspection of paving operations.
        v. Final inspection.
2. The Contractor shall be responsible for all work performed and shall ensure that construction is acceptable to Kitsap County.

3. If inspection is not called for prior to completion of any item of work so designated, special destructive and/or non-destructive testing procedures may be required to ensure the acceptability of the work. If such procedures are required, the Contractor shall be responsible for all costs associated with the testing and/or restoration of the work.

General Erosion and Sedimentation Control Notes

1. The following erosion and sedimentation control notes apply to all construction site activities at all times, unless otherwise specified on these plans:
2. Approval of this erosion and sedimentation control plan does not constitute an acceptance of the permanent road or drainage design.
3. The owner and his/her contractor shall be responsible at all times for preventing silt-laden runoff from discharging from the project site. Failure by the owner and/or contractor can result in a fine. The designated temporary contact person noted on this plan shall be available for contact by telephone on a 24-hour basis throughout construction and until the project has been completed and accepted by ~~the~~ Kitsap C~~c~~ounty.
4. The implementation of these ESC plans and the construction, maintenance, replacement and upgrading of these ~~facilities~~ BMPs is the responsibility of the owner and/or contractor from the beginning of construction until all construction is completed and accepted by Kitsap~~the~~ C~~c~~ounty and the site is stabilized.
5. Prior to beginning any work on the project site, a pre-construction conference shall be held, and shall be attended by the owner or owner's representative, the general contractor, the project engineer, representatives from affected utilities, and a representative of Kitsap County.
6. The ~~erosion and sedimentation control~~ESC ~~facilities~~ BMPs shown on this plan are ~~to be~~ considered adequate basic requirements for the anticipated site conditions. During construction, deviations from this plan may be necessary in order to maintain water quality. Minor departures from this plan are permitted subject to the approval of the C~~c~~ounty inspector. However, except for emergency situations, all other deviations from this plan shall be designed by the project engineer and approved by Kitsap County prior to installation.
7. All erosion and sedimentation control measures shall be inspected by the owner and/or contractor on a frequent basis and immediately after each rainfall and maintained as necessary to insure their continued functioning. All sediment shall be removed from silt fences, straw bales, sediment ponds, etc. prior to the sediment reaching 1/3 its maximum potential depth.
8. At no time shall concrete, concrete byproducts~~by-products~~, vehicle fluids, paint, chemicals, or other polluting matter be permitted to discharge to the temporary or permanent drainage system, or to discharge from the project site.

9. Permanent detention/retention ponds, pipes, tanks or vaults may only be used for sediment containment when specifically indicated on these plans.
10. Redirect sheet flow, block drain inlets and/or curb openings in pavement and install flow diversion measures to prevent construction silt laden runoff and debris from entering excavations and finish surfaces for bioretention facilities and permeable pavements.
11. Where amended soils, bioretention facilities, and permeable pavements are installed, these areas shall be protected at all times from being over-compacted. If areas become compacted, remediate and till soil in accordance with ~~the~~ Kitsap County requirements at no additional cost in order to restore the system's ability to infiltrate.
12. Install flow diversion measures outside of the Critical Root Zone of trees to be protected. At no time shall construction stormwater be directed towards trees to be protected. Construction stormwater shall not pond within a tree's critical root zone.

Minimum Erosion and Sedimentation Control Requirements

1. All exposed and unworked soils, including soil stockpiles, shall be stabilized by suitable application of BMPs that protect soil from the erosive forces of raindrop impact and flowing water. Applicable practices include, but are not limited to vegetative establishment, mulching, plastic covering, and the early application of gravel base on areas to be paved. From October 1 to April 30, no soils shall remain unstabilized for more than 2 days. From May 1 to September 30, no soils shall remain unstabilized for more than 7 days.
2. At all times of the year, the contractor shall have sufficient materials, equipment and labor onsite to stabilize and prevent erosion from all denuded areas within 12 hours as site and weather conditions dictate.
3. From October 1 to April 30, the project engineer shall visit the development site a minimum of once per week for the purpose of inspecting the ~~erosion and sedimentation control~~ESC ~~facilities~~BMPs, reviewing the progress of construction, and verifying the effectiveness of the erosion control measures being undertaken. The project engineer shall immediately inform ~~the~~Kitsap County of any problems or potential problems observed during said site visits, as well as of any recommended changes in the erosion control measures to be undertaken. When requested by ~~the~~ Kitsap County, the project engineer shall provide ~~the~~ Kitsap County with written records of said weekly site visits, including dates of visits and noted site observations.
4. In the event that ground on a project site is left bare after September 30, ~~the~~ Kitsap County may issue a Stop Work Order for the entire project until satisfactory controls are provided. In addition, the Owner will be subject to the penalties provided in Chapter~~Section~~ 12.32 of the Kitsap County Code.

5. In the event that ground on a project site is left bare after September 30, and ~~the~~ Kitsap County is unsuccessful in contacting the Owner or his/her designated emergency contact person, ~~the~~Kitsap County may enter the project site and install temporary ground cover measures and bill the Owner for all expenses incurred by ~~the~~Kitsap County. These costs will be in addition to any monetary penalties levied against the Owner.
6. Clearing limits, setbacks, buffers, and sensitive or critical areas such as steep slopes, wetlands and riparian corridors shall be clearly marked in the field and inspected by Kitsap County Department of Community Development prior to commencement of land clearing activities. During the construction period, no disturbance beyond the flagged clearing limits shall be permitted. The flagging shall be maintained by the applicant/contractor for the duration of construction.
7. Adjacent properties shall be protected from sediment deposition by appropriate use of vegetative buffer strips, sediment barriers or filters, dikes or mulching, or by a combination of these measures and other appropriate BMPs.
8. Sediment ponds and traps, perimeter dikes, sediment barriers and other BMPs intended to trap sediment onsite shall be constructed as a first step in grading. These BMPs shall be functional before land disturbing activities take place. Earthen structures such as dams, dikes, and diversions shall be stabilized according to the timing indicated in item (1) above.
9. Cut and fill slopes shall be constructed in a manner that will minimize erosion. Roughened soil surfaces are preferred to smooth surfaces. Interceptors should be constructed at the top of long, steep slopes which have significant areas above that contribute runoff. Concentrated runoff should not be allowed to flow down the face of a cut or fill slope unless contained within an adequate channel or pipe slope drain. Wherever a slope face crosses a water seepage plane, adequate drainage or other protection should be provided. In addition, slopes should be stabilized in accordance with item (1) above.
10. Properties and waterways downstream from development sites shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the development site by the implementation of appropriate BMPs to minimize adverse downstream impacts.
11. All temporary onsite conveyance channels shall be designed, constructed and stabilized to prevent erosion from the expected flow velocity from a 2-year frequency, 24-hour duration storm for the post-development condition. Stabilization adequate to prevent erosion of outlets, adjacent streambanks, slopes and downstream reaches shall be provided at the outlets of all conveyance systems.

12. All storm drain inlets made operable during construction shall be protected so that stormwater runoff shall not enter the conveyance system without first being filtered or otherwise treated to remove sediment. After proper written application, the requirement for inlet protection may be waived by ~~the~~ Kitsap County on a site-specific basis when the conveyance system downstream of the inlet discharges to an appropriate sediment containment BMP and the conveyance system can be adequately cleaned following site stabilization.
13. The construction of underground utility lines shall be limited, where feasible, to no more than 500 feet of open trench at any one time. Where consistent with safety and space considerations, excavated material shall be placed on the uphill side of the trench. Dewatering devices shall discharge to an appropriate sediment trap or pond, preceded by adequate energy dissipation, prior to runoff leaving the site.
14. Wherever construction vehicle access routes intersect paved roads, provisions shall be made to minimize the transport of sediment (mud) onto the paved road by use of appropriate BMPs such as a Stabilized Construction Entrance. If sediment is transported onto a road surface, the roads shall be cleaned thoroughly, as a minimum, at the end of each day. Sediment shall be removed from roads by shoveling or sweeping and be transported to a controlled sediment disposal area. Street washing shall be allowed only after sediment is removed in this manner.
15. All temporary erosion and sediment control BMPs shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized onsite. Disturbed soil areas resulting from removal of temporary BMPs shall be permanently stabilized. The removal of temporary erosion and sediment control BMPs may not be required for those projects, such as single family plats, that will be followed by additional construction under a different permit. In these circumstances, the need for removing or retaining the measures will be evaluated on a site-specific basis.
16. Dewatering devices shall discharge into an appropriate sediment trap or pond, designed to accept such a discharge, preceded by adequate energy dissipation, prior to runoff leaving the site.
17. All pollutants other than sediment that occur onsite during construction shall be handled and legally disposed of in a manner that does not cause contamination of storm or surface waters. Pollutants of concern include, but are not limited to, fuels, lubricants, solvents, concrete ~~bi-products~~byproducts and construction materials

18. Protect all LID BMPs, including but not limited to bioretention, rain garden, and permeable pavement, from sedimentation through installation and maintenance of erosion and sediment control BMPs on portions of the site that drain into such BMPs. Restore the BMPs to their fully functioning condition if they accumulate sediment during construction. Prevent compaction in bioretention and rain garden BMPs by excluding construction equipment and foot traffic. Protect lawn and landscaped areas from compaction by construction equipment. Keep all heavy equipment off existing soils under LID ~~facilities~~ BMPs that have been excavated to final grade to retain infiltration rate of the soils.
19. All temporary and permanent erosion and sediment control BMPs shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with the manual. The Applicant shall be responsible for assuring that any such facilities damaged during floods, storms or other adverse weather conditions are immediately returned to normal operating condition.
20. A performance covenant or performance surety shall be required for all projects to ensure compliance with the approved erosion and sediment control plan, as outlined in Chapter~~Section~~ 12.12 of the Kitsap County Code.

Appendix C – Site Assessment and Planning Packet

Appendix C: Site Assessment and Planning Packet

Appendix D – Determining Construction Site Sediment Damage Potential

Appendix D: Determining Construction Site Sediment Damage Potential

The following rating system allows objective evaluation of a particular development site's potential to discharge sediment. Permittees may use the rating system below or develop an alternative process designed to identify site-specific features, which indicate that the site must be inspected prior to clearing and construction. Any alternative evaluation process must be documented and provide for equivalent environmental review.

Step 1 is to determine if there is a sediment/erosion sensitive feature downstream of the development site. If there is such a site downstream complete Step 2~~step two~~, assessment of hydraulic nearness. If there is a sediment/erosion sensitive feature and it is hydraulically near the site, then go to Step 3~~step three~~ to determine the construction site sediment transport potential.

Step 1 – Sediment / Erosion Sensitive Feature Identification

Sediment/erosion sensitive features are areas subject to significant degradation due to the effect of sediment deposition or erosion. Special protection ~~must be provided to protect them~~measures for these areas must be provided.

Sediment/erosion sensitive features include but are not limited to:

A. Salmonid bearing freshwater streams and their tributaries or freshwater streams that would be Salmonid bearing if not for anthropogenic barriers;

B. Lakes;

C. Category I, II, and III wetlands;

D. Marine near-shore habitat;

E. Sites containing contaminated soils where erosion could cause dispersal of contaminants;

F. Steep slopes (25 percent or greater) associated with one of the above features.

Identify any sediment/erosion sensitive features and proceed to Step 2~~step two~~. If there are none, the assessment is complete.

Step 2 – Hydraulic Nearness Assessment

Sites are hydraulically near a feature if the pollutant load and peak quantity of runoff from the site will not be naturally attenuated before entering the feature. The conditions that render a site hydraulically near to a feature include, but are not limited to, the following:

A. The feature or a buffer to protect the feature is within 200 ~~feed~~ feet downstream of the site.

B. Runoff from the site is tight-lined to the feature or flows to the feature through a channel or ditch.

A site is not hydraulically near a feature if one of the following takes place to provide attenuation before runoff from the site enters the feature:

1. Sheet flow through a vegetated area with dense ground cover. ~~(Western Washington Phase II Municipal Stormwater Permit, January 17, 2007 Appendix 7- Determining Sediment Damage Potential, Page 2 of 3)~~
2. Flow through a wetland not included as a sensitive feature.
3. Flow through a significant shallow or adverse slope, not in a conveyance channel, between the site and the sensitive feature.

Identify any of the sediment/erosion sensitive features from Step 1~~step one~~ that are hydraulically near the site and proceed to Step 3~~step three~~. If none of the sediment/erosion sensitive features are hydraulically near the site, the assessment is complete.

Step 3 – Construction Site Sediment Transport Potential

Using the Appendix E worksheet~~ below~~, determine the total points for each development site. Assign points based on the most critical condition that affects 10 percent or more of the site. If soil testing has been performed on site, the results should be used to determine the predominant soil type on the site. Otherwise, soil information should be obtained from the county soil survey to determine Hydrologic Soil Group (Table of Engineering Index Properties for part D in Appendix E~~step 1.D~~) and Erosion Potential (Table of Water Features for part E in Appendix E~~step 1.E~~).

When using the county soil survey, the dominant soil type may be in question, particularly when the site falls on a boundary between two soil types or when one of two soil types may be present on a site. In this case, the soil type resulting in the most points on the rating system will be assumed unless site soil tests indicate that another soil type dominates the site. Use the point score from Step 3 to determine whether the development site has a high potential for sediment transport off of the site.

Total Score	Transport Rating
<100	Low
≥100	High

A high transport rating indicates a higher risk that the site will generate sediment contaminated runoff.

Appendix E – Construction Site Sediment Transport Potential Worksheet

Appendix E: Construction Site Sediment Transport Potential Worksheet

Table E.1 – Construction Site Sediment Transport Potential Worksheet.

A. Existing slope of site (average, weighted by aerial extent)	Points
2% or less	0
>2–5%	5
>5–10%	15
>10–15%	30
>15%	50
B. Site area to be cleared and/or graded	
<5,000 square feet (sf)	0
5,000 sf–1 acre	30
>1 acre	50
C. Quantity of cut and/or fill on site	
<500 cubic yards	0
500–5,000 cubic yards	5
>5,000–10,000 cubic yards	10
>10,000–20,000 cubic yards	25
>20,000 cubic yards	40
D. Runoff potential of predominant soils (Natural Resources Conservation Service)	
Hydrologic soil group A	0
Hydrologic soil group B	10
Hydrologic soil group C	20
Hydrologic soil group D	40
E. Erosion potential of predominant soils (Unified Classification System)	
GW, GP, SW, SP soils	0
Dual classifications (GW-GM, GP-GM, GW-GC, GP-GC, SW-SM, SW-SC, SP-SM, SP-SC)	10
GM, GC, SM, SC soils	20
ML, CL, MH, CH soils	40

Table E.1 (continued) – Construction Site Sediment Transport Potential Worksheet.	
F. Surface or groundwater entering site identified and intercepted[1]	
Yes	0
No	25
G. Depth of cut or height of fill>10 feet	
Yes	25
No	0
H. Clearing and grading will occur in the wet season (October 1 – May 1)	
Yes	50
No	0
Total Points	

[1] If no surface or groundwater enters the site, assign~~give~~ 0 points

~~A. Existing slope of site (average, weighted by aerial extent): Points~~

~~2% or less .... 0~~

~~>2-5% .... 5~~

~~>5-10% .... 15~~

~~>10-15% .... 30~~

~~>15% .... 50~~

~~B. Site Area to be cleared and/or graded:~~

~~<5,000 sq. ft .... 0~~

~~5,000 sq. ft. – 1 acre .... 30~~

~~>1 acres .... 50~~

~~C. Quantity of cut and/or fill on site:~~

~~<500 cubic yards .... 0~~

~~500 – 5,000 cubic yards .... 5~~

~~>5,000 – 10,000 cubic yards .... 10~~

~~>10,000 – 20,000 cubic yards .... 25~~

~~>20,000 cubic yards .... 40~~

~~D. Runoff potential of predominant soils (Natural Resources Conservation Service):~~

~~Hydrologic soil group A .... 0~~

~~Hydrologic soil group B .... 10~~

~~Hydrologic soil group C .... 20~~

~~Hydrologic soil group D .... 40~~

~~E. Erosion Potential of predominant soils (Unified Classification System):~~

~~GW, GP, SW, SP soils .... 0~~

~~Dual classifications (GW-GM, GP-GM, GW-GC,~~

~~GP-GC, SW-SM, SW-SC, SP-SM, SP-SC)................................ 10~~

~~GM, GC, SM, SC soils.. 20~~

~~ML, CL, MH, CH soils.. 40~~

~~F. Surface or Groundwater entering site identified and intercepted[1]:~~

~~Yes 0~~

~~No .... 25~~

~~G. .... Depth of cut or height of fill >10 feet:~~

~~Yes.. 25~~

~~No .... 0~~

~~H. Clearing and grading will occur in the wet season (October 1 – May 1):~~

~~Yes 50~~

~~No 0~~

~~TOTAL POINTS~~ ________

Appendix F – Hydrologic/Hydraulic Modeling Methods

Appendix F: Hydrologic / Hydraulic Modeling Methods

This appendix presents detailed discussion on Kitsap County approved methods for the hydrologic/hydraulic analysis and design of pipe conveyance, culverts, and open channel systems. For public road projects, the WSDOT *Highway Runoff Manual* hydrologic/hydraulic methods may be used if preferred over these methods.

F.1 Design Flow Rate

As discussed in Volume II, Section 4.2~~ of Volume II of this manual~~, the Rational Method, the Santa Barbara Unit Hydrograph (SBUH) Method, the Western Washington Hydrology Model (WWHM), and ~~the ~~MGS~~-~~Flood~~ Model~~ may all be used to determine the conveyance design flow rates provided that the basin limitations for each option are met. The Rational Method is preferred by Kitsap County for design of systems serving smaller contributing basins primarily because it tends to provide higher conveyance design flow rates than hydrograph methods, resulting in a more conservative design with a built-in safety factor.

Only the Rational Method equation~~formula~~ is provided below; refer to Volume III, Chapter 2 of the Ecology Manual for instructions on using the SBUH Method and WWHM, and consult with the model user manual for a complete description on how to use ~~the ~~MGSFlood~~ Model~~. With the Rational Method, peak runoff rates can be determined using Equation F-1~~ below~~:

Equation F-1: Rational Method

$$Q = C * I * A \qquad \cancel{(F\text{-}1)}$$

where:

Q	=	r~~R~~unoff ~~in ~~(cubic feet per second [~~(~~cfs]
C	=	r~~R~~unoff coefficient (dimensionless units); see Table F.1
I	=	r~~R~~ainfall intensity ~~in ~~(inches per hour [in/hr]); see Figure F.1
A	=	c~~C~~ontributing area ~~in ~~(acres)

~~The runoff coefficient (C) should be based on Table F.1, Runoff Coefficients - 'C' Values for the Rational Method.~~

~~The rainfall intensity (I) should be based on Figure F.1, Rainfall Intensity-Duration Curves, prepared by the U.S. Weather Bureau for the Mayfield - Bremerton - Kitsap County - Sumner areas~~.

(See separate file for Public Review Draft figures.)

Figure F.1 – Rainfall Intensity-Duration Curves.

Table F.1 – Runoff Coefficients – "c" Values for the Rational Method.		
Undeveloped Land	***"C" Flat (0–5%)***	**"C" Rolling (>5%)**
Wood and forest Sparse trees and ground cover Light grass to bare ground	0.05 0.10 0.15	0.10 0.15 0.20
Developed Area	*"C" Flat (0–5%)*	**"C" Rolling (>5%)**
Pavement and roofs Gravel roads and parking lots City business Apartment dwelling areas Industrial areas (heavy) Industrial areas (light) Earth shoulder Playground Lawns, meadows and pastures Parks and cemeteries	0.90 0.75 0.85 0.80 0.70 0.60 0.50 NA 0.20 0.15	0.90 0.80 0.90 0.85 0.80 0.70 0.50 NA 0.25 0.20
Single Family Residential Areas	**"C"**	
1.0 DU/GA 2.0 DU/GA 3.0 DU/GA 4.0 DU/GA 5.0 DU/GA 9.0 – 15.0 DU/GA	0.30 0.36 0.42 0.48 0.60 0.70	

F.2 Conveyance Capacity

This section details modeling methods for determining the conveyance capacity of pipe, culvert, and open channel conveyance systems.

F.2.1 Pipe Conveyance Systems

Two methods of hydraulic analysis of conveyance capacity are used sequentially for the design and analysis of pipe systems. First, the Uniform Flow Analysis method is used for the preliminary design of new pipe systems. Second, the Backwater Analysis method is used to analyze both proposed and existing pipe systems to verify adequate capacity.

Note: Use of the Uniform Flow Analysis method to determine preliminary pipe sizes is only suggested as a first step in the design process and is not required. Results of the Backwater Analysis method determine final pipe sizes in all cases. The director has the authority to waive the requirement for Backwater Analysis as verification.

F.2.1.1 Uniform Flow Analysis Method

This method is used for preliminary sizing of new pipe systems to convey the design flow. It assumes the following:

- Flow is uniform in each pipe (i.e., depth and velocity remain constant throughout the pipe for a given flow).
- Friction head loss in the pipe barrel alone controls capacity. Other head losses (e.g., entrance, exit, junction, etc.) and any backwater effects or inlet control conditions are not specifically addressed.

Each pipe within the system is sized and sloped such that its barrel capacity at normal full flow computed by Manning's equation is equal to or greater than the design flow. The nomograph in Figure F.2 may be used for an approximate solution of Manning's equation (Equation F-2 ~~below~~). For more precise results, or for partial pipe full conditions, solve Manning's equation directly (Equation F-2) or use the discharge formula (Q = A * V) to solve for the volumetric flow rate (Equation F-3)~~:~~.

Equation F-2: Manning's equation

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$ ~~(F-2)~~

where:	V	=	velocity (feet per second [fps])
	n	=	Manning's roughness coefficient; see Table F.2
	R	=	hydraulic radius = area/wetted perimeter (ft)
	S	=	slope of the energy grade line (ft/ft)

~~or use Equation F-3, the continuity equation, $Q = AV$, such that:~~

Equation F-3: Volumetric flow rate equation

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$ ~~(F-3)~~

where:~~,~~	Q	=	discharge (cfs)
	V	=	velocity (fps)
	A	=	area (sf)
	n	=	Manning's roughness coefficient; see Table F.2 ~~below~~
	R	=	hydraulic radius = area/wetted perimeter (ft)
	S	=	slope of the energy grade line (ft/ft)

Figure F.2 – Nomograph for Sizing Circular Drains Flowing Full.

For pipes flowing partially full, the actual velocity may be estimated from the hydraulic properties shown in Figure F.3 by calculating Q_{full} and V_{full} and using the ratio Q_{design}/Q_{full} to find V and d (depth of flow).

Figure F.3 – Circular Channel Ratios.

Table F.2 provides the recommended Manning's "n" values for preliminary design using the Uniform Flow Analysis method for pipe systems. *Note*: The "*n*" values for this method are 15 percent higher in order to account for entrance, exit, junction, and bend head losses.

Table F.2 – Manning's "n" Values for Pipes.

Type of Pipe Material	Analysis Method	
	Uniform Flow (Preliminary Design)	Backwater Flow (Capacity Verification)
A. Concrete pipe and ~~LCPE~~CPEP ~~pipe~~	0.014	0.012
B. Annular Corrugated Metal Pipe or Pipe Arch		
1. 2-$^2/_3$″ x $^1/_2$″ corrugation (riveted)		
a. plain or fully coated	0.028	0.024
b. paved invert (40% of circumference paved)		
1) flow at full depth	0.021	0.018
2) flow at 80% full depth	0.018	0.016
3) flow at 60% full depth	0.015	0.013
c. treatment 5	0.015	0.013
2. 3″ x 1″ corrugation	0.031	0.027
3. 6″ x 2″ corrugation (field bolted)	0.035	0.030
C. Helical 2-$^2/_3$″ x $^1/_2$″ corrugation and CPE~~ pipe~~P	0.028	0.024
D. Spiral rib metal pipe and PVC pipe	0.013	0.011
E. Ductile iron pipe (cement lined)	0.014	0.012
F. SWPE pipe (butt fused only)	0.009	0.009

F.2.1.2 Backwater Analysis Method

The Backwater Analysis Method is used to analyze the capacity of both new and existing pipe systems to convey the required design flow. For both new and existing systems, structures shall be demonstrated to contain the headwater surface (hydraulic grade line) for the specified peak flow rate.

This method incorporates a re-arranged form of Manning's equation expressed in terms of friction slope (i.e., the slope of the energy grade line, in units of ft/ft). The friction slope is used to determine the head loss in each pipe segment due to barrel friction, which can then be combined with other head losses to obtain water surface elevations at all structures along the pipe system.

The backwater analysis begins at the downstream end of the pipe system and is computed back through each pipe segment and structure upstream. The friction, entrance, and exit head losses computed for each pipe segment are added to that segment's tailwater elevation (the water surface elevation at the pipe's outlet) to obtain its outlet control headwater elevation. This elevation is then compared with the inlet control headwater elevation, computed assuming the pipe's inlet alone is controlling capacity using the methods for inlet control presented in Volume II, Section 4.5 and Appendix F, Section F.2.2. The condition that creates the highest headwater elevation determines the pipe's capacity. The approach velocity head is then subtracted from the controlling headwater elevation, and the junction and bend head losses are added to compute the total headwater elevation, which is then used as the tailwater elevation for the upstream pipe segment.

The Backwater Calculation Sheet in Figure F.4 may be used to compile the head losses and headwater elevations for each pipe segment. The numbered columns on this sheet are described in Figure F.5. An example calculation is performed in Figure F.6. Refer to Figure F.7 and Figure F.8 regarding bend head losses and junction head losses, respectively.

Note: This method should not be used to compute stage/discharge curves for level pool routing purposes. Instead, a more sophisticated backwater analysis using a computer software program is recommended for that purpose.

Figure F.4 – Backwater Calculation Sheet.

Figure F.5 – Backwater Calculation Sheet Notes.

Figure F.6 – Backwater Pipe Calculation Example.

Figure F.7 – Bend Head Losses in Structure.

Figure F.8 – Junction Head Loss in Structure.

Computer Applications

There are a number of commercial software programs for use on personal computers that use variations of the Standard Step backwater method for determining water surface profiles. The most common and widely accepted programs include HEC-RAS, published and supported by the United States (US) Army Corps of Engineers Hydraulic Engineering Center, and Stormwater Management Model (SWMM), originally published by US Environmental Protection Agency.

F.2.2 Culverts

Culverts are classified according to which end controls the discharge capacity; the inlet or the outlet end. If water can flow through and out of the culvert faster than it can enter into the culvert, then then culvert is under inlet control. If water can flow into the culvert faster than it can flow through and out, then it is under outlet control (see Figure F.9). This section details methods for analyzing conveyance capacity for culverts under inlet and outlet control.

F.2.2.1 Inlet Control Analysis

Nomographs such as those provided in Figure F.10 and Figure F.11 may be used to determine the inlet control headwater depth at design flow for various types of culverts and inlet configurations. These nomographs were originally developed by the Bureau of Public Roads—now the Federal Highway Administration (FHWA)—based on their studies of culvert hydraulics. These and other nomographs can be found in the ~~FHWA publication~~ *Hydraulic Design of Highway Culverts, HDS No. #5* (~~Report No.~~ FHWA 2012~~-IP-85-15~~)~~, September 1985;~~ or the *WSDOT Hydraulic Manual* (WSDOT 2019).

Figure F.9 – Inlet/Outlet Control Conditions

Figure F.10 – Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control.

Figure F.11 – Headwater Depth for Corrugated Pipe Culvert with Inlet Control.

Also available in the FHWA publication, are the design equations used to develop the inlet control nomographs. These equations, Equations F-4 through F-6, are presented below.

For **unsubmerged** inlet conditions (defined by $Q/AD^{0.5} \leq 3.5$), use Equation F-4 (Form 1) or Equation F-5 (Form 2). Refer to Table F.3 to determine the appropriate form of the equation to use.

Equation F-4: Headwater depth in unsubmerged inlet conditions (Form 1)~~: (F-4)~~

$$HW/D \quad = \quad H_c/D + K(Q/AD^{0.5})^M - 0.5S^*$$

where:~~,~~ HW = headwater depth above inlet invert (ft)
D = interior height of culvert barrel (ft)
H_c = specific head (ft) at critical depth ($dc + Vc_2/2g$)
Q = flow (cfs)
A = full cross-sectional area of culvert barrel (sf)
S = culvert barrel slope (ft/ft)
K = constant; see Table F.3
M = constant; see Table F.3

* For mitered inlets, use +0.7*S* instead of -0.5*S*.

Equation F-5: Headwater depth in unsubmerged inlet conditions (Form 2)~~: (F-5)~~

$$HW/D \quad = \quad K(Q/AD^{0.5})^M$$

where:~~,~~ HW = headwater depth above inlet invert (ft)
D = interior height of culvert barrel (ft)
Q = flow (cfs)
A = full cross-sectional area of culvert barrel (sf)
K = constant; see Table F.3
M = constant; see Table F.3

For **submerged** inlet conditions (defined by $Q/AD^{0.5} \geq 4.0$), use Equation F-6.~~;~~

Equation F-6: Headwater depth in submerged inlet conditions

$$HW/D = c * (Q/AD^{0.5})^2 + Y - 0.5S^*$$ ~~(F-6)~~

where:~~,~~

	HW	=	headwater depth above inlet invert (ft)
	D	=	interior height of culvert barrel (ft)
	H_c	=	specific head (ft) at critical depth ($dc + Vc_2/2g$)
	Q	=	flow (cfs)
	A	=	full cross-sectional area of culvert barrel (sf)
	S	=	culvert barrel slope (ft/ft)
	~~K,M,~~c~~,Y~~	=	constant~~s~~; see~~from~~ Table F.3~~.~~
	Y	=	constant; see Table F.3

* For mitered inlets, use +0.7*S* instead of -0.5*S.*

The specified head H_c is determined by Equation F-7:

Equation F-7: Specified head

$$H_c = d_c + V_c^2/2g$$ ~~(F-7)~~

where:~~,~~

	H_c	=	specified head (ft)
	d_c	=	critical depth (ft); see Figure F.~~13~~ 14
	V_c	=	flow velocity at critical depth (fps)
	g	=	acceleration due to gravity (32.2 ft/sec^2)

Note: Between the unsubmerged and submerged conditions, there is a transition zone ($3.5<Q/AD^{0.5}<4.0$) for which there is only limited hydraulic study information. The transition zone is defined empirically by drawing a curve between and tangent to the curves defined by the unsubmerged and submerged equations. In most cases, the transition zone is short, and the curve is easily constructed.

Table F.3 – Constants for Inlet Control Equations.

		Unsubmerged			Submerged	
Shape and Material	**Inlet Edge Description**	**Equation Form**	***K***	***M***	***c***	***Y***
Circular Concrete	Square edge with headwall Groove end with headwall Groove end projecting	1	0.0098 0.0078 0.0045	2.0 2.0 2.0	0.0398 0.0292 0.0317	0.67 0.74 0.69
Circular CMP	Headwall Mitered to slope Projecting	1	0.0078 0.0210 0.0340	2.0 1.33 1.50	0.0379 0.0463 0.0553	0.69 0.75 0.54
Rectangular Box	30° to 75° wingwall flares 90° and 15° wingwall flares 0° wingwall flares	1	0.026 0.061 0.061	1.0 0.75 0.75	0.0385 0.0400 0.0423	0.81 0.80 0.82
CM Boxes	90° headwall Thick wall projecting Thin wall projecting	1	0.0083 0.0145 0.0340	2.0 1.75 1.5	0.0379 0.0419 0.0496	0.69 0.64 0.57
Arch CMP	90° headwall Mitered to slope Projecting	1	0.0083 0.0300 0.0340	2.0 1.0 1.5	0.0496 0.0463 0.0496	0.57 0.75 0.53
Bottomless Arch CMP	90° headwall Mitered to slope Thin wall projecting	1	0.0083 0.0300 0.0340	2.0 2.0 1.5	0.0379 0.0463 0.0496	0.69 0.75 0.57
Circular with Tapered Inlet	Smooth tapered inlet throat Rough tapered inlet throat	2	0.534 0.519	0.333 0.64	0.0196 0.0289	0.89 0.90

Source: *FHWA HDS No. 5*

F.2.2.2 Outlet Control Analysis

Nomographs such as those provided in Figure F.12 and Figure F.13 may be used to determine the outlet control headwater depth at design flow for various types of culverts and inlets. Outlet control nomographs other than those provided can be found in *FHWA HDS No.5* or the *WSDOT Hydraulic Manual.*

Figure F.12 – Head for Culverts (Pipe w/n = 0.012) Flowing Full with Outlet Control.

Figure F.13 – Head for Culverts (Pipe w/n = 0.024) Flowing Full with Outlet Control.

Figure F.14 – Critical Depth of Flow for Circular Culverts.

The outlet control headwater depth may also be determined using the simple Backwater Analysis Method presented in Appendix F, Section F.2.1.2 for analyzing pipe system capacity. This procedure is summarized for culverts by Equation F-8:

Equation F-8: Outlet control headwater depth (Backwater Analysis Method)

$$HW = H + TW - LS \qquad \text{(F-1)}$$

where:~~,~~

HW	=	headwater depth above inlet invert (ft)
H	=	$H_f + H_e + H_{ex}$
H_f	=	friction loss (ft) = $(V^2n^2L) / (2.22R^{1.33})$ *Note*: If $(H_f + TW - LS) < D$, adjust H_f such that $(H_f + TW - LS) = D$. This will keep the analysis simple and still yield reasonable results (erring on the conservative side).
H_e	=	entrance head loss (ft) = K_e ~~*~~ $(V^2 / 2g)$
H_{ex}	=	exit head loss (ft) = $V^2 / 2g$
TW	=	tailwater depth above invert of culvert outlet (ft) *Note*: If TW < $(D + d_c)/2$, set TW = $(D + d_c)/2$. This will keep the analysis simple and still yield reasonable results.
L	=	length of culvert (ft)
S	=	slope of culvert barrel (ft/ft)
D	=	interior height of culvert barrel (ft)
V	=	barrel velocity (fps)
n	=	Manning's roughness coefficient; see ~~from~~ Table F.2.
R	=	hydraulic radius (ft)
K_e	=	entrance loss coefficient; see ~~(from~~ Table F.4~~)~~
g	=	acceleration due to gravity (32.2 ft/sec^2)
d_c	=	critical depth (ft); see Figure F.~~13~~14

Note: The above procedure should not be used to develop stage/discharge curves for level pool routing purposes because its results are not precise for flow conditions where the hydraulic grade line falls significantly below the culvert crown (i.e., less than full flow conditions).

Table F.4 – Entrance Loss Coefficients.

Type of Structure and Design Entrance	Coefficient, *Ke*
Pipe, Concrete, PVC, Spiral Rib, DI, and Lined CPE	
Projecting from fill, socket (bell) end	0.2
Projecting from fill, square cut end	0.5
Headwall, or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = $^{1}/_{12}$D)	0.2
Mitered to conform to fill slope	0.7
End section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal and Other Non-Concrete or D.I.	
Projecting from fill (no headwall)	0.9
Headwall, or headwall and wingwalls (square-edge)	0.5
Mitered to conform to fill slope (paved or unpaved slope)	0.7
End section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of $^{1}/_{12}$ barrel dimension or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of $^{1}/_{12}$ barrel dimension or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

* Note: "End section conforming to fill slope" are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections incorporating a closed taper in their design have a superior hydraulic performance.

F.2.3 Open Channels

As discussed in Volume II, Section 4.6.2~~ of Volume II of this manual~~, there are three acceptable methods of analysis for sizing and analyzing the capacity of open channels:

1. Manning's equation for preliminary sizing;
2. Direct Step backwater method; and
3. Standard Step backwater method.

Each of these methods are detailed in the sections below.

F.2.3.1 Manning's Equation for Preliminary Sizing

Manning's equation is used for preliminary sizing of open channel reaches of uniform cross-section and slope (i.e., prismatic channels) and uniform roughness. This method assumes the flow depth (or normal depth) and flow velocity remain constant throughout the channel reach for a given flow.

The charts in Figure 4.11 and Figure 4.12 may be used to obtain graphic solutions of Manning's equation for common ditch sections. For conditions outside the range of these charts or for more precise results, Manning's equation can be solved directly from its classic forms shown in Equations F-2 and F-3.

Table F.5 provides a reference for selecting the appropriate "*n*" values for open channels. A number of engineering reference books, such as *Open-Channel Hydraulics* by V.T. Chow, may also be used as guides to select "*n*" values. Figure 4.13 contains the geometric elements of common channel sections useful in determining area *A*, wetted perimeter *WP*, and hydraulic radius (*R*= *A/WP*).

If flow restrictions occur that raise the water level above normal depth within a given channel reach, a backwater condition (or subcritical flow) is said to exist. This condition can result from flow restrictions created by a downstream culvert, bridge, dam, pond, lake, etc., and even a downstream channel reach having a higher flow depth. If backwater conditions are found to exist for the design flow, a backwater profile shall be computed to verify that the channel's capacity is still adequate as designed. The Direct Step or Standard Step backwater methods presented in this section may be used for this purpose.

Table F.5 – Values of Roughness Coefficient "*n*" for Open Channels.

Type of Channel and Description	Manning's "n"* (normal)
A. Constructed Channels	
a. Earth, straight and uniform	
1. Clean, recently completed	0.018
2. Gravel, uniform section, 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 as #2, 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 feet~~.~~)	
a. Streams on plain	
1. Clean, straight, full stage no rifts or deep pools	0.030
2. Same as #1, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as #3, 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 stand 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

Table F.5 (continued) – Values of Roughness Coefficient "*n*" for Open Channels.

Type of Channel and Description (continued)	Manning's "n"* (normal)
B-2 Floodplains	
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 #2, 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 #4, but with flood stage reaching branches	0.120

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

F.2.3.2 Direct Step Backwater Method

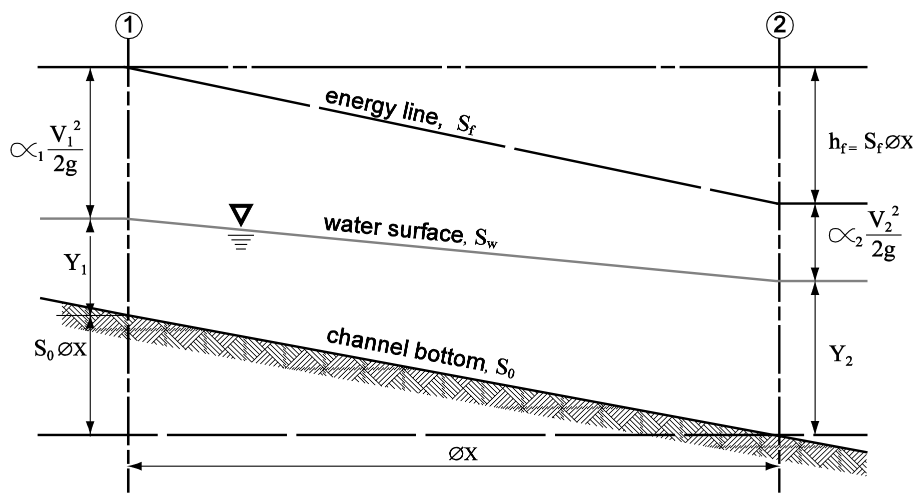
The Direct Step backwater method may be used to compute backwater profiles on prismatic channel reaches (i.e., reaches having uniform cross-section and slope) where a backwater condition or restriction to normal flow is known to exist. The method may be applied to a series of prismatic channel reaches in secession beginning at the downstream end of the channel and computing the profile upstream.

Calculating the coordinates of the water surface profile using this method is an iterative process achieved by choosing a range of flow depths, beginning at the downstream end, and proceeding incrementally up to the point of interest or to the point of normal flow depth. This is best accomplished by the use of a table (see Figure F.15 and the accompanying example in Figure F.16) or computer programs.

Figure F.15 – Open Channel Flow Profile Computation.

Figure F.16 – Open Channel Flow Profile Computation (Example).

To illustrate analysis of a single reach, consider the following diagram:



Use Equation F-9 to calculate ~~Equating~~ the total head at cross-sections 1 and 2~~, the Equation F-9 may be written:~~.

Equation F-9: Total head for a single reach (Direct Step Analysis Method)

$$S_o\Delta x + y_1 + \alpha_1\frac{V_1^2}{2g} = y_2 + \alpha_2\frac{V_2^2}{2g} + S_f\Delta x$$ ~~(F-9)~~

where:~~,~~ Δx = distance between cross-sections (ft)

y_1, y_2 = depth of flow (ft) at cross-sections 1 and 2

V_1, V_2 = velocity (fps) at cross-sections 1 and 2

α_1, α_2 = energy coefficient at cross-sections 1 and 2

S_o = bottom slope (ft/ft)

S_f = friction slope = $(n^2V^2)/(2.21R^{1.33})$

g = acceleration due to gravity, (32.2 ft/sec^2)

If the specific energy E at any one cross-section is defined in Equation F-10~~as follows:~~.

Equation F-10: Specific energy for a single reach (Direct Step Analysis Method)

$$E = y + \alpha \frac{V^2}{2g}$$ ~~(F-10)~~

and assuming $\alpha = \alpha_1 = \alpha_2$ where α is the energy coefficient that corrects for the non-uniform distribution of velocity over the channel cross-section, Equations F-9 and F-10 can be combined and rearranged to solve for Δx as shown in Equation F-11.~~:~~

Equation F-11: Distance between cross-sections (Direct Step Analysis Method)

$$\Delta x = (E_2 - E_1)/(S_o - S_f) = \Delta E/(S_o - S_f)$$ ~~(F-11)~~

Typical values of the energy coefficient α are as follows:

Channels, regular section	1.15
Natural streams	1.3
Shallow vegetated flood fringes (includes channel)	1.75

For a given flow, channel slope, Manning's "*n*," and energy coefficient α, together with a beginning water surface elevation y_2, the values of Δx may be calculated for arbitrarily chosen values of y_1. The coordinates defining the water surface profile are obtained from the cumulative sum of Δx and corresponding values of y.

The normal flow depth, y_n, should first be calculated from Manning's equation to establish the upper limit of the backwater effect.

F.2.3.3 Standard Step Backwater Method

The Standard Step backwater method is a variation of the Direct Step backwater method and may be used to compute backwater profiles on both prismatic and non-prismatic channels. In this method, stations are established along the channel where cross-section data is known or has been determined through field survey. The computation is carried out in steps from station to station rather than throughout a given channel reach as is done in the Direct Step backwater method. As a result, the analysis involves significantly more trial-and-error calculation in order to determine the flow depth at each station.

Computer Applications

There are a number of commercial software programs for use on personal computers that use variations of the Standard Step backwater method for determining water surface profiles. The most common and widely accepted programs include HEC-RAS, published and supported by the United States (US) Army Corps of Engineers Hydraulic Engineering Center, and SWMM, originally published by US Environmental Protection Agency.

F.3 Riprap Design Standards

Design standards for riprap and riprap filter systems are presented below.

F.3.1 Riprap

Research by the US Army Corps of Engineers has provided criteria for selecting the median stone weight, W_{50} (see Figure F.17). If the riprap is to be used in a highly turbulent zone (such as at a culvert outfall, downstream of a stilling basin, at sharp changes in channel geometry, etc.), the median stone W50 should be increased from 200 percent to 600 percent depending on the severity of the locally high turbulence. The thickness of the riprap layer should generally be twice the median stone diameter (D_{50}) or at least that of the maximum stone. The riprap should have a reasonably well graded assortment of stone sizes within the following gradation:

$1.25 \le D_{max}/D_{50} \le 1.50$

$D_{15}/D_{50} = 0.50$

$D_{min}/D_{50} = 0.25$

Detailed design methodology may be found in ~~the Corps publication *EM 1110-02-1601, Engineering and Design –*~~ *Hydraulic Design of Flood Control Channels* (Army Corps 1991). For a more detailed analysis and design procedure for riprap requiring water surface profiles and estimates of tractive force, refer to ~~the paper by~~ Maynord et al.~~ in *Journal of Hydraulic Engineering (A.S.C.E.),* July~~ (1989).

Figure F.17 – Mean Channel Velocity vs. Medium Stone Weight and Equivalent Stone Diameter.

F.3.2 Riprap Filter Systems

Riprap should be underlain by a sand and gravel filter (or filter fabric) to keep the fine materials in the underlying channel bed from being washed through the voids in the riprap. Likewise, the filter material shall be selected so that it is not washed through the voids in the riprap. Adequate filters can usually be provided by a reasonably well graded sand and gravel material where:

$D_{15} < 5 * d_{85}$

The variable d_{85} refers to the sieve opening through which 85 percent of the material being protected will pass, and D_{15} has the same interpretation for the filter material. A filter material with a D_{50} of 0.5 mm will protect any finer material including clay. Where very large riprap is used, it is sometimes necessary to use two filter layers between the material being protected and the riprap.

Example

Problem:

What embedded riprap design should be used to protect a streambank at a level culvert outfall where the outfall velocities in the vicinity of the downstream toe are expected to be about 8 fps?

Solution:

From Figure F.17, W_{50} = 6.5 lbs, but since the downstream area below the outfall will be subjected to severe turbulence, increase W_{50} by 400 percent so that:

W_{50} = 26 lbs, D_{50} = 8.0 inches

The gradation of the riprap is shown in Figure F.16, and the minimum thickness would be 1 foot (from Table 4.5); however, 16 inches to 24 inches of riprap thickness would provide some additional insurance that the riprap will function properly in this highly turbulent area.

Figure F.18 shows that the gradation curve for ASTM C33, size number 57 coarse aggregate (used in concrete mixes), would meet the filter criteria. Applying the filter criteria to the coarse aggregate demonstrates that any underlying material whose gradation was coarser than that of a concrete sand would be protected.

Figure F.18 – Riprap/Filter Example Gradation Curve.

Appendix G – Subsurface Investigation and Infiltration Testing for Infiltration BMPs

Appendix G: Subsurface Investigation and Infiltration Testing for Infiltration BMPs

G.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.

Recommendations that deviate from the minimum investigation requirements specified in this appendix shall be contained in a stamped and signed letter from a State of Washington licensed professional engineer, engineering geologist, geologist, or hydrogeologist, herein referred to as licensed professional, who has experience in infiltration and groundwater testing and infiltration ~~facility~~ BMP design, and must provide rationale and specific data supporting their professional judgment.

G.2 Subsurface Investigation

G.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

Underground Injection Control (UIC) wells ~~should~~shall demonstrate compliance with the UIC Program per Volume I, Section 4.13 in the Ecology Manual.

G.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.

G.2.2.1 Subsurface Investigation Locations

Subsurface investigations shall be performed at the site of the infiltration ~~facility~~BMP, unless demonstrated to be infeasible. In such case, the subsurface investigation shall be performed 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 (Appendix G, Section G.3).

G.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 Appendix G, Sections G.2.3 through G.2.5 for wet season and dry season requirements for the different types of subsurface investigations.

G.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 (Appendix G, Section G.5), at the site of the proposed ~~facility~~ BMP showing groundwater elevations not meeting the vertical separation requirements (Appendix G, Section G.2.2.4).
- Identification by the licensed professional of hydraulically-restrictive materials beneath the proposed ~~facility~~ BMP and within the vertical separation requirements (Appendix G, Section G.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.

G.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 ~~facility~~ BMP is defined as the deepest portion of the proposed BMP~~facility~~ 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 1 foot less than the minimum investigation depths summarized in Appendix G, Sections G.2.3 through G.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

G.2.2.5 Subsurface Report

Projects that are required to perform subsurface investigations per Volume II, Section 5.3 shall prepare a report documenting results of the subsurface investigations described in Appendix G, Sections G.2.3 through G.2.6 and infiltration tests described in Appendix G, Section G.3. Refer to report submittal requirements in Volume II, Chapter 1~~ of this manual~~.

G.2.3 Simple Subsurface Investigation

Refer to Table 5.4 in Volume II, Chapter 5 to determine the minimum subsurface investigation requirements for a project. The Simple Subsurface Investigation is conducted approximately 5 feet from the test hole.

A simple subsurface investigation report can be used to document the investigation and testing results. This report should include the following:

- Map of investigation and testing.
- Soil characteristics.
- Depth to groundwater (if encountered).

Table G.1. Simple Subsurface Investigation Elements

Minimum Investigation Depth and Vertical Separation Requirements			
All BMPs			
		Minimum Vertical Separation, ft[a]	
Season	**Minimum Investigation Depth (feet)[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			

Notes:

[a] The minimum investigation depth and vertical separation shall be measured from the bottom of the ~~facility~~BMP. The bottom of the ~~facility~~ BMP is defined as the deepest portion of proposed ~~facility~~ BMP where infiltrating water is expected to move into the underlying soil.

G.2.4 Standard Subsurface Investigation

This section summarizes the minimum requirements of a Standard Subsurface Investigation. Refer to Table 5.4 in Volume II, Chapter 5 to determine the minimum subsurface investigation requirements for a project.

Table G-2. Standard Subsurface Investigation Elements

<table>
<tr><td colspan="4"><u>Minimum Investigation Depth and Vertical Separation Requirements</u></td></tr>
<tr><th rowspan="2">Season</th><th rowspan="2">Minimum Investigation Depth (feet)[a]</th><th colspan="2">Minimum Vertical Separation (feet)[a]</th></tr>
<tr><th>Groundwater</th><th>Hydraulically-Restrictive Layer</th></tr>
<tr><td colspan="4">Infiltration Basins</td></tr>
<tr><td>Wet Season (November – March)</td><td>6</td><td>5</td><td>5</td></tr>
<tr><td>Dry Season (April – October)</td><td>7</td><td>6</td><td>5</td></tr>
<tr><td colspan="4">All Other Infiltration BMPs</td></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>4</td><td>3</td><td>1</td></tr>
<tr><td colspan="4"><u>Characterization for each soil and/or rock unit (strata with the same texture, color/mottling, density, and type)</u>
Unified Soil Classification System (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 V, Section 5.6 of the Ecology Manual)
<u>Detailed logs for each investigation</u>
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 II, Section 5.3.2 and Appendix G. If more than 2,000 square feet of the site infiltration will occur within a single BMP, the Standard Subsurface Investigation report shall be prepared by a licensed professional in accordance with Volume II, Chapter 1.</td></tr>
</table>

Notes:

[a] 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 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.

G.2.5 Comprehensive Subsurface Investigation

Refer to Table 5.4 in Volume II, Chapter 5 to determine the minimum subsurface investigation requirements for a project. The comprehensive subsurface investigation report shall be prepared by a licensed professional. Refer to report submittal requirements in Volume II, Chapter 1~~ of this manual~~.

Table G-3. Comprehensive Subsurface Investigation Elements

Minimum Investigation Depth and Vertical Separation Requirements			
Season	**Minimum Investigation Depth (feet)[a, b]**	**Minimum Vertical Separation (feet)[a]**	
		Groundwater	**Hydraulically-Restrictive Layer**
Infiltration Basins			
Wet Season (November – March)	6	5	5
Dry Season (April – October)	10	8	5
Permeable Pavement			
Wet Season (November – March)	2	1	1
Dry Season (April – October)	4	3	1
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 (Appendix G, Section G.2.4)			
Detailed logs for each investigation			
Same as Standard Subsurface Investigation (Appendix G, Section G.2.4)			

Notes:

[a] The minimum investigation depth and vertical separation shall be measured from the bottom of the ~~facility~~BMP. The bottom of the ~~facility~~ BMP is defined as the deepest portion of proposed ~~facility~~ BMP where infiltrating water is expected to move into the underlying soil. For Small PITs, sampling of distinct materials below the bottom of the ~~facility~~ 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 ~~facility~~ 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 ~~facility~~ BMP and the criteria for vertical separation to groundwater or hydraulically-restrictive materials listed above shall apply.

G2.6 Deep Infiltration Subsurface Investigation

Refer to Table ~~5.3~~5.4 in Volume II, Chapter 5 to determine the minimum subsurface investigation requirements for a project. The deep infiltration subsurface investigation report shall be prepared by a licensed professional. Refer to report submittal requirements in Volume II, Chapter 1~~ of this manual~~.

Table G-4. 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 (Appendix G, Section G.2.4)
Detailed logs for each investigation
Same as Standard Subsurface Investigation (Appendix G, Section G.2.4)

G.3 Determining the Measured (Initial) K_{sat} ~~Infiltration Tests~~

G.3.1 Description

A crucial element of BMP design is the long term (design) infiltration rate of the native soils. In order to determine the design infiltration rate, the designer must first determine the measured (initial) saturated hydraulic conductivity (K_{sat}).

This section provides procedures for the following infiltration testing methods to determine the measured (initial) K_{sat}, as required in Volume II, Section 5.3.2~~ in Volume II of this manual~~:

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

To determine which infiltration test method is required for a project, refer to Table ~~5.3~~5.4 in Volume II, Chapter 5.

If possible, perform infiltration testing at the location of the proposed infiltration BMP~~facility~~. Infiltration testing results from a nearby location within 50 feet of the proposed infiltration BMP~~facility~~ may be approved at the discretion of the licensed professional. If the infiltration testing is performed more than 50 feet from the final infiltration BMP~~facility~~ location due to existing site conditions (e.g., existing structure at location of proposed BMP~~facility~~) and greater than 5,000 sf is infiltrated on the site, then acceptance testing is required (see~~refer to~~ Volume II, Section 5.3.2).

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

A simplified and detailed approach are presented to use the initial K_{sat} to determine the design infiltration rate of the native soils (Appendix G, Section G.4). The design infiltration rate is used to size the infiltration BMP, including verification of compliance with the maximum drawdown time of 48 hours. ~~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 G.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 Kitsap County.

G.3.2 Simple Infiltration Test (SIT)

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 (Hinman et al. 2013 ~~https://fortress.wa.gov/ecy/publications/SummaryPages/1310027.html~~).

The Simple Infiltration Test does not require a licensed ~~professional, and~~professional and may only be applied for project sites located in rural areas, outside the UGA and UAs in accordance with Table 5.4~~5.3~~ in Volume II, Chapter 5.

The Simple Infiltration Test is not allowed for projects with no offsite point of discharge. These projects shall use a Small PIT (Appendix G, Section G.3.3).

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~~ BMP 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 Appendix G, Section G.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 2 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 5.5~~5.4~~ in Volume II, Chapter 5 for minimum infiltration rates for each type of infiltration BMP. Using the collected data, estimate the measured 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.

G.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. Refer to report submittal requirements in Volume II, Chapter 1~~ of this manual~~.

Procedure

1. Excavate the test pit to the depth of the bottom of the proposed infiltration ~~facility~~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 should be 12 to 32 square feet~~shall be a minimum of 12 square feet~~. Accurately 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. The rigid pipe may be a 3-inch diameter pipe for pits on the smaller end of the recommended surface area, or a 4-inch pipe for pits on the larger end of the recommended surface area.
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 6–12 inches above the bottom of the pit over a full hour. A rotameter can be used to measure the flow rate into the pit. The depth should not exceed the proposed maximum depth of water expected in the completed BMP.
    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 (between 6-inches and 1-foot)~~the design ponding depth)~~ on the measuring rod or pressure transducer readout. The specific depth should be the same as the maximum designed ponding depth (usually 6-12 inches).
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. A self-logging pressure sensor may also be used to determine water depth and drain-down.
9. At the conclusion of testing, 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 depth of excavation varies depending on soil type and depth to the hydraulic restricting layer and is determined by the engineer or certified soils professional (refer to Table 5.4 in Volume II, Chapter 5). The soils professional should judge whether a mounding analysis is necessary. ~~The investigation depth varies depending on the type of subsurface investigation required (refer to Table 5.3 in Chapter~~

~~5) and the seasonal timing of the geotechnical exploration conducted to evaluate clearance.~~ Minimum investigation depths are provided in Appendix G, Section G.2.

Data Analysis

Calculate and record the initial K_{sat} rate in inches per hour in 30-minute or 1-hour increments until 1 hour after the flow has stabilized.~~Using the established steady state flow rate, calculate and record the measured infiltration rate in inches per hour~~. Use statistical/trend analysis to obtain the hourly flow rate when the flow stabilizes. This would be the lowest hourly flow rate.~~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 Appendix G, Section G.4 to estimate the design infiltration rate.

G.3.4 Large Pilot Infiltration Test (Large PIT)

A Large PIT will more closely simulate actual conditions for the infiltration ~~facility~~BMP than a Small PIT and may be preferred at the discretion of the licensed professional if not already required per Table 5.4~~5.3~~ in Volume II, Chapter 5. 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. Refer to report submittal requirements in Volume II, Chapter 1~~ of this manual~~.

Procedure

1. Testing should occur between December 1 and April 1.
2. The horizontal and vertical locations of the PIT shall be surveyed by a licensed land surveyor and accurately shown on the design drawings.
3. ~~10.~~ Excavate the test pit to the depth of the bottom of the proposed infiltration ~~facility~~BMP into the native soil. Note that for some proposed BMPs, such as bioretention and permeable pavement, this will be below the finished grade. If native soils will have to meet the minimum subgrade compaction requirement (for example, the road subgrade using permeable pavement), compact the native soil to that requirement prior to testing.
4. ~~11.~~ Lay back the slopes sufficiently to avoid caving and erosion during the test. Alternatively, consider shoring the sides of the test pit.
5. ~~12.~~ The size of the bottom of the test pit should be approximately 100 square feet.~~as close to the size of the planned infiltration facility 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. Accurately document the size and geometry of the test pit.

Refer to Steps 4 through 9~~10~~ as described in the Small PIT procedure (Appendix G, Section G.3.3) ~~above~~ with the following modifications:

- Step 5: Use a rigid 6-inch diameter pipe with a splash plate.
- Step 7b: Data may be recorded every 15–30 minutes
- Keep adding water to the pit until 1 hour after the low rate into the pit has stabilized (constant flow rate; a goal of 5 percent or less variation in the total flow) while maintaining the same pond water level. The total of the pre-soak time plus 1 hour after the flow rate has stabilized should be no less than 6 hours.
- Step 8: After the flow rate has stabilized for at least 1 hour, turn off the water and record the rate of infiltration (the drop rate of the standing water) in inches per hour from the measuring rod data, until the pit is empty. Consider running this falling head phase of the test several times to estimate the dependency of infiltration rate with head.
- Step 9: Mounding is an indication that a mounding analysis is necessary.

Data Analysis

Refer to the data analysis guidance for small PITs in Appendix G, Section G.3.3.

G.3.5 Deep Infiltration Test

The design infiltration rate 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 rate.

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 professional and the reasoning is documented in the report. Refer to report submittal requirements in Volume II, Chapter 1 ~~of this manual~~.

Procedure

1. Perform the test by adding water (obtained from a potable water source) to the test well to maintain a hydraulic head in the well equal to approximately half the thickness of the unsaturated infiltration receptor soil layer.
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 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 professional 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.

~~V~~G.4 ~~Infiltration Rate Correction Factor~~Calculation of Design Infiltration Rate of the Native Soils

G.4.1 The Simplified Approach to Calculating the Design Infiltration Rate of the Native Soils

The simplified approach was derived from high ground water and shallow pond sites in western Washington, and in general will produce conservative designs. This approach can be used when determining the trial geometry of the infiltration BMP and for small BMPs serving short plats or commercial developments less than 1 acre of contributing area. Designs of infiltration BMPs for larger projects should use the detailed approach (described below) and may have to incorporate the results of a ground water mounding analysis as described in Appendix G, Section G.7. *Note*: A ground water mounding analysis is advisable for BMPs with drainage areas smaller than 1 acre if the depth to a low permeability layer (e.g., less than 0.1 inch per hour) is less than 10 feet.

Using the simplified approach, estimate the design (long-term) infiltration rate as follows:

- Use any of the options detailed in Appendix G, Section G.3 to estimate the initial K_{sat}
- Assume that the K_{sat} is the measured (initial) infiltration rate for the native soils
- Determine the design infiltration rate by adjusting the initial infiltration using the appropriate correction factors, as detailed below.

~~Measured infiltration rates described in Section G.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 II, Section 5.4~~ of this chapter~~.

Correction factors account for site variability, number of tests conducted, uncertainty of the test method, and the potential for long-term clogging due to siltation and bio-buildup. The specific correction factors used shall be determined based on the professional judgement of the licensed engineer in the state of Washington or other professional, considering all issues that may affect the infiltration rate over the long term, subject to the approval of Kitsap County.

Site variability and number of locations tested (CF_V)

The number of locations tested must be capable of producing a picture of the subsurface conditions that fully represents the conditions throughout the proposed location of the infiltration BMP. The partial correction factor used for this issue depends on the level of uncertainty that adverse subsurface conditions may occur. If the range of uncertainty is low—for example, conditions are known to be uniform through previous exploration and site geological factors—one pilot infiltration test may be adequate to justify a partial correction factor at the high end of the range.

If the level of uncertainty is high, a partial correction factor near the low end of the range may be appropriate. This might be the case where the site conditions are highly variable due to conditions such as a deposit of ancient landslide debris, or buried stream channels. In these cases, even with many explorations and several pilot infiltration tests, the level of uncertainty may still be high.

A partial correction factor near the low end of the range could be assigned where conditions have a more typical variability, but few explorations and only one pilot infiltration test is conducted. That is, the number of explorations and tests conducted do not match the degree of site variability anticipated.

Uncertainty of test method (CF_t)

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 (CF_m)

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.

For design of bioretention and permeable pavement facilities, the design guidance provided in Volume II, Section 5.4 shall be used to determine correction factors.

The overlying bioretention soil mix provides excellent protection for the underlying native soil from sedimentation. Accordingly, the correction factor for the sub-grade soil does not have to take into consideration the extent of influent control and clogging over time. The correction factor to be applied to in-situ, small-scale infiltration test results is determined by the number of tests in relation to the number of bioretention areas and site variability. Refer to Table G.1~~3.4.1 in the above-referenced section of the Ecology Manual~~. Correction factors range from 0.33 to 1 (no correction) and are determined by the licensed professional that performed the infiltration testing.

Table G-5. Correction Factors to be Used with In-Situ Saturated Hydraulic Conductivity Measurements to Estimate Design Rates

Issue	**Partial Correction Factor**
Site Variability and number of locations tested	$CF_V = 0.33$ to 1.0
Uncertainty of test method	
Simple Infiltration Test	$CF_t = 0.40$
Small-scale PIT	= 0.50
Large-scale PIT	= 0.75
Degree of influent control to prevent siltation and bio-buildup	$CF_m = 0.9$

The Total Correction Factor shall then be calculated as follows:

$$CF_T = CF_V \times CF_t \times CF_m$$

~~Simple Infiltration Test~~

~~A CF of 0.5 shall be applied to the measured infiltration rate to calculate the design infiltration rate.~~ The design infiltration rate (K_{sat}design) is calculated by multiplying the initial K_{sat} by the total correction factor:

$$K_{sat}\text{design} = K_{sat}\text{initial} \times CF_T$$

G.4.2 The Detailed Approach to Calculating the Design Infiltration Rate of the Native Soils

For BMPs where the simplified approach is not applicable, refer to Volume V, Section 5.4 of the Ecology Manual for the detailed approach.

~~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.~~

~~Site variability and number of locations tested – 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 facility site. If 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.~~

~~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 facility 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 facility 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.~~

G.5 Groundwater Monitoring

Groundwater monitoring wells (including the minimum subsurface investigation depth) shall be installed as determined in Appendix G, Sections G.2.3 through G.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 5.4~~5.3~~ in

Volume II, Chapter 5. 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 Appendix G, Section G.2. Refer to report submittal requirements in Volume II, Chapter 1~~ of this manual~~.

Groundwater monitoring is not required in the following situations:

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

In these situations, no further investigation is required to meet onsite, flow control, or runoff treatment requirements. These exceptions do not apply to deep infiltration BMPs.

G.6 Characterization of Infiltration Receptor

The infiltration receptor is the unsaturated and saturated soil receiving stormwater from an infiltration ~~facility~~BMP. Thresholds for triggering characterization of the infiltration receptor are summarized in Table 5.4~~5.3~~ in Volume II, Chapter 5.

Assessment and documentation by a licensed professional 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 ~~facility~~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.

- Impact of the infiltration rate and volume at the BMP site on groundwater mounding, flow direction, and water table; and discharge point or area of the infiltrating water. Conduct a groundwater mounding analysis at all sites where the depth to seasonal groundwater table or low permeability stratum is less than 15 feet from the estimated bottom elevation of the infiltration BMP, and the contributing basin to the infiltration BMP is more than 1 acre.

Note: As part of the infiltration receptor characterization for deep infiltration wells, the pre-treatment requirements shall be evaluated per Volume V, Section 5.3 in the Ecology Manual~~as in the *Guidance for Underground Injection Control Wells that Manage Stormwater* (Ecology 2006)~~.

G.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 ~~facility~~BMP may become less effective and/or adjacent structures or facilities may be impacted by the rising water table. In addition, if the infiltration ~~facility~~BMP is adjacent to a slope, slope stability may be decreased.

Thresholds for triggering groundwater mounding and seepage analysis are summarized in Table 5.4 of Volume II, Chapter 5.

The mounding analysis shall evaluate the impact of the infiltration ~~facility~~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 ~~facility~~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 should 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 ~~facilities~~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 ~~facilities~~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~~facilities~~, and is recommended in the 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~~facility~~ at a time, and generally will not be suitable for evaluating clustered ~~facilities~~BMPs.

The preferred program for simulating groundwater mounding beneath infiltration ~~facilities~~ 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 should conduct these analyses. It should also be noted that groundwater models do not provide specific ~~answers, but~~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.

G.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 ~~facilities~~BMPs.

Many of the data inputs for the groundwater mounding model should be available in the vicinity of the infiltration ~~facilities~~ BMPs from the subsurface investigation and infiltration testing performed for design of the ~~facilities~~BMPs. Outside the area of the infiltration ~~facilities~~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 Puget Sound.

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 ~~facilities~~ 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.

G.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~~facilities~~. 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 ~~facilities~~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 ~~facility~~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.

Appendix H – LID BMP Infeasibility Criteria

Appendix H: LID BMP Infeasibility Criteria

Table H.1 – Onsite Requirement Infeasibility Criteria Checklist: All Dispersion BMPs~~BMP's~~ and All Infiltration BMPs~~BMP's~~.

BMP	Infeasibility Criteria	Additional Information from Applicant
All Dispersion BMPs~~BMP's~~	• ~~Where~~A licensed professional ~~geotechnical evaluation~~ 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 an appropriately licensed professional). • The dispersion flow path does not provide positive drainage. • Only available dispersion flow path area is within an erosion hazard or a landslide hazard area (Title 19 KCC). • Only available dispersion flow path area is in or within 100 feet up-gradient of a known contaminated site or ~~abandoned~~ landfill (active or closed). • Only available dispersion flow path area is in a critical area (Title 19 KCC), steep slope (as defined in Section 5.3.1)~~>15%~~), or on or above slopes greater than 20%, or above erosion hazard areas~~setback to steep slope (calculated as 10 times the height of the steep slope to a 500-foot maximum setback)~~. • Only available dispersion flow path area is within the minimum horizontal setback requirements between stormwater control device and onsite sewage system components per Table 5.2 ~~up-gradient and within 10 feet of proposed or existing septic system or drain field~~.	
All Infiltration BMPs~~BMP's~~	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 an appropriately licensed professional (e.g., engineer, geologist, hydrogeologist): • ~~Where professional geotechnical evaluation~~Infiltration is not recommended ~~recommends infiltration not be used~~ due to reasonable concerns about erosion, slope failure, or flooding. • T~~Where t~~he only 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. • ~~Where the only area available for siting does not allow for a safe overflow pathway.~~	

BMP	Infeasibility Criteria	Additional Information from Applicant
	• ~~Where~~ The area available for siting ~~infiltrating water~~ would threaten shoreline structures such as bulkheads. The following criteria each establish that the BMP is infeasible, without further justification, though some criteria require professional services: • T~~Where t~~he horizontal setback criteria listed in Volume II, Section 5.3.2 cannot be met. Note: For most infiltration BMPs, setbacks are measured from the vertical extent of maximum ponding before overflow. For bioretention and rain gardens, setback distances are as measured from the bottom edge of the bioretention or rain garden soil mix (i.e., bioretention cell bottom at the toe of the side slope). • T~~Where t~~he following minimum vertical separation to the seasonal high water table or hydraulically-restrictive layer would not be achieved below the infiltration BMP: o 1-foot separation for a BMP that would serve a drainage area that is: 1) less than 5,000 square feet of pollution-generating hard surface (PGHS), and 2) less than 10,000 square feet of impervious surface; and, 3) less than three-quarter (3/4) acres of pervious surface. This clearance also applies to permeable pavement facilities regardless of size. Vertical separation requirements are larger if explorations are conducted during the dry season (see~~refer to~~ Volume II, Section 5.3.2). o 3-foot separation for a BMP that would serve a drainage area that meets or exceeds: 1) 5,000 square feet of PGHS, or 2) 10,000 square feet of impervious surface, or 3) three-quarter (3/4) acres of pervious surfaces. To use the 3-foot separation criterion, it must be demonstrated that the drainage areas cannot reasonably be broken down into amounts smaller than the drainage thresholds listed above. Vertical separation requirements are larger if explorations are conducted during the dry season (see~~refer to~~ Volume II, Section 5.3.2). • Site-specific infiltration rates are below minimum allowable rates in Table 5.5. • The area available for siting is within a steep slope area or landslide prone area (or setback) (see Volume II, Section 5.3.2) • The only area available for siting does not allow for a safe overflow pathway.	

BMP	Infeasibility Criteria	Additional Information from Applicant
	• Infiltration is restricted due to known contaminated soil or groundwater	

Table H.2 – Onsite Requirement Infeasibility Checklist.

BMP	Infeasibility Criteria	Additional Information from Applicant
Post Construction Soil Quality and Depth	• Portions of the site comprised of till soils with slopes greater than 33% can be considered infeasible for this BMP.	
Full Dispersion	• One or more of t~~T~~he infeasibility criteria for “All Dispersion BMPs” (Appendix H, Table H.1) apply. • The design criteria for full dispersion (Volume II, Section 5.4.4) cannot be met. • The dispersion area cannot meet the requirement to have a minimum area 6.5 times the area of the impervious surface draining to it.~~A 65 to 10 ratio of the native vegetation area to the impervious area is unachievable.~~ • Minimum dispersion flow path area and length requirements per Table 5.1 are unachievable. ~~A minimum native vegetation flow path length of 100 feet (25 feet for sheet flow from a non-native pervious surface) is unachievable.~~	
Downspout Dispersion	• One or more of t~~T~~he infeasibility criteria for “All Dispersion BMPs” (Appendix H, Table H.1) apply. • The design criteria for splashblock or trench downspout dispersion (Volume II, Section 5.4.4) cannot be met. • There are no downspouts. • The flow path setbacks to property lines, structures and other flow paths (Volume II, Section 5.4.4) cannot be achieved. Splashblock Dispersion • The vegetated flow path is less than 50 feet. • Greater than 700 square feet of surface area drains to the BMP. • The flow path does not meet the minimum horizontal setback requirements to property lines, structures, and other flow paths (Volume II, Section 5.4.4). • ~~A minimum 10 feet length of dispersion trench for every 700 square feet of drainage area followed by 25-foot minimum flow path is unachievable.~~	

BMP	Infeasibility Criteria	Additional Information from Applicant
	• A 50-foot minimum flow path for the dispersion area or a maximum of 700 square feet of drainage area to any splashblock is unachievable. Trench Dispersion • The minimum dispersion trench length of 10 feet for every 700 square foot of drainage area cannot be met. • The vegetated flow path is less than 25 feet. • The flow path is within the setbacks to property lines, structures, and other flow paths (Volume II, Section 5.4.4) • ~~A 50-foot minimum flow path for the dispersion area or a maximum of 700 square feet of drainage area to any splashblock is unachievable.~~	
Sheet Flow Dispersion	• One or more of ~~T~~the infeasibility criteria for "All Dispersion BMPs" (Appendix H, Table H.1) apply. • The design criteria for sheet flow dispersion (Volume II, Section 5.4.4) cannot be met. • Positive drainage for sheet flow runoff is unachievable. • Area to be dispersed (e.g., driveway, patio) cannot be graded to have less than a 15% slope. • The flow path does not meet the minimum horizontal setbacks to property lines, structures, and other flow paths (see~~refer to~~ Volume II, Section 5.4.4).~~ cannot be achieved.~~	
Concentrated Flow Dispersion	• One or more of t~~T~~he infeasibility criteria for "All Dispersion BMPs" (Appendix H, Table H.1) apply. • The design criteria for concentrated flow dispersion (Volume II, Section 5.4.4) cannot be met. • There are no concentrated flows to disperse. • The dispersion device and flow path requirements are unachievable: o A minimum 10-foot length of dispersion trench followed by a 25-foot minimum flow path or a rock pad with a 50-foot minimum flow path. o A maximum of 700 square feet of drainage area to any dispersion device. • The flow path does not meet the minimum horizontal setbacks to property lines, structures, and other flow paths (see~~refer to~~ Volume II, Section 5.4.4).~~ cannot be achieved.~~	
Bioretention	• The design criteria for bioretention (Volume II, Section 5.4.6) cannot be met. • Refer to the additional bioretention Infeasibility Criteria in the BMP T7.30 of the Ecology Manual.~~Ecology Manual, Volume V, Chapter 7.~~	

BMP	Infeasibility Criteria	Additional Information from Applicant
Rain Garden	• The design criteria for rain gardens (Volume II, Section 5.4.~~4~~5) cannot be met. • Refer to the additional rain garden Infeasibility Criteria in the Ecology Manual, Volume V, Chapter 7.	
Perforated Stub-out Connection	• One or more of ~~T~~the infeasibility criteria for "All Infiltration BMPs" (Appendix H, Table H.1) apply. • The design criteria for perforated stub-out connections (Volume II, Section 5.4.7) cannot be met. • The only location for the perforated pipe portion of the system is under impervious or heavily compacted (e.g., driveways and parking areas) surfaces. • A minimum of 10 feet of perforated pipe per 5,000 square feet of contributing roof area is unachievable. • The seasonal water table is less than 1 foot below the trench bottom. • The site cannot be reasonably designed to locate a catch basin between the perforated stub-out and point of connection to the public system.	
Permeable Pavement	• The Design Criteria for Permeable Pavement (Volume II, Section~~Ch.~~ 5.4.8) cannot be met. • Refer to additional permeable pavement Infeasibility Criteria in BMP T5.15 of the Ecology Manual. • Note that the infeasibility criteria for "All Infiltration BMPs" are not applicable and the minimum native soil infiltration rate differs, as described in BMP T5.15 of the Ecology Manual~~below~~). ~~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 an appropriate licensed professional (e.g., engineer, geologist, hydrogeologist):~~ ~~Where infiltrating and ponded water below permeable pavement area would compromise adjacent impervious pavements.~~ ~~• Where fill soils are used that can become unstable when saturated.~~ ~~• Where permeable pavements cannot provide sufficient strength to support heavy loads in areas with "industrial activity" as identified in 40 CFR 122.26(b)(14).~~ ~~• Excessively steep slopes where water within the aggregate base layer or at the sub-grade surface cannot be controlled by detention structures and may cause erosion and structural failure, or where surface runoff velocities may preclude adequate infiltration at the pavement surface.~~	

BMP	Infeasibility Criteria	Additional Information from Applicant
	~~The following criteria each establish that the BMP is infeasible, without further justification, though some criteria require professional services:~~ • ~~Where subgrade slopes exceed 5%.~~ • ~~Within 50 feet from the top of slopes that are steeper than 20% gradient.~~ • ~~At multi-level parking garages, and over culverts and bridges.~~ • ~~For properties with known soil or ground water contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):~~ • ~~Within 100 feet of an area known to have deep soil contamination;~~ • ~~Where ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water;~~ o ~~Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area;~~ o ~~Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under .~~ o ~~Where the site design cannot avoid putting pavement in areas likely to have long-term excessive sediment deposition after construction (e.g., construction and landscaping material yards).*~~ o ~~Where the site cannot reasonably be designed to have a porous asphalt surface at less than 5% slope, or a pervious concrete surface at less than 10% slope, or a permeable interlocking concrete pavement surface (where appropriate) at less than 12% slope. Note: grid systems upper slope limit can range from 6 to 12%; check with manufacturer and local supplier.~~ o ~~Where the native soils below a pollution-generating permeable pavement (e.g., road or parking lot) do not meet the soil suitability criteria for providing treatment. Refer to the Ecology Manual, Chapter 3 of Volume III.~~ o ~~Where underlying soils are unsuitable for supporting traffic loads when saturated. Soils meeting a California Bearing Ratio of 5% are considered suitable for residential access roads.~~ o ~~Where field testing indicates soils have a measured (a.k.a., initial) native soil infiltration rate~~	

BMP	Infeasibility Criteria	Additional Information from Applicant
	~~less than 0.3 inches per hour, permeable pavement facilities without underdrains are not considered feasible.~~ o ~~Where road has ADT exceeding 400 vehicles per day (very low volume road) or exceeding very low truck traffic. Areas with very low truck traffic volumes are roads 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.~~ • ~~Where replacing existing impervious surfaces unless the existing surface is a non-pollution generating surface over an outwash soil with an infiltration rate of four inches per hour or greater.~~ • ~~At sites defined as "high use sites" in Volume I, Appendix A.~~ • ~~In areas with "industrial activity" as identified in *.~~ • ~~Where the risk of concentrated pollutant spills is more likely, including, but not limited to, gas stations, truck stops, and industrial chemical storage sites.*~~ • ~~Where routine, heavy applications of sand occur in frequent snow zones to maintain traction during weeks of snow and ice accumulation.*~~ • ~~* These criteria also apply to impervious pavements that would employ stormwater collection from the surface of impervious pavement with redistribution below the pavement.~~ • ~~Where it is infeasible to prevent stormwater run-on to the permeable pavement from unstabilized, erodible areas without adequate pre-settling to prevent clogging of the permeable pavement surface.~~ • ~~Where field testing indicates soils have a measured (a.k.a., initial) native soil infiltration rate less than 0.3 inches per hour permeable pavement are not considered feasible. (Note: field infiltration tests are not required, but may be used to demonstrate infeasibility).~~ • ~~Where the site is a contaminated site or abandoned landfill.~~ • ~~Within 10 feet of an underground storage tank or connecting underground pipes. (Applicable to tanks used to store petroleum products, chemicals, or liquid hazardous wastes).~~ • ~~Where professional geotechnical evaluation recommends permeable pavement not be used anywhere within the project site due to reasonable concerns of erosion, slope failure, or flooding~~	

BMP	Infeasibility Criteria	Additional Information from Applicant
	~~(requires a signed and stamped written determination based on site-specific conditions from an appropriately licensed professional).~~	
Tree Retention and Tree Planting	• Space necessary for the mature height, size, and/or rooting depth for tree planting per Title 17 KCC is unachievable. • No existing trees with diameter equal to or greater than 6-inches diameter at breast height (DBH) on project site. DBH is defined as the outside bark diameter at 4.5 feet above the ground on the uphill side of a tree. • New and/or replaced ground level impervious surface not proposed within 20 feet of existing tree. • For tree(s) with a diameter greater than or equal to 6 inches, significant grading is unavoidable within the dripline. • For tree(s) with a diameter of 4–6 inches, significant grading is unavoidable within 5 feet of tree trunk. • Trees are considered danger trees according to KCC Section 19.150.230.	

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