CITY OF RAPID CITY

STORMWATER QUALITY

MANUAL

NOVEMBER 2007

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Erosion and Sediment Control

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Erosion Control

1.1 Introduction

This *Erosion and Sediment Control Standard* has been developed based on a model prepared by the Urban Drainage and Flood Control District of Denver, Colorado. It has been revised to reflect the needs of the City of Rapid City and provides a set of criteria and technical guidance for erosion and sediment control at construction sites. In addition, it describes plan submittal requirements, planning considerations, and general exemptions followed by the City. The practices contained in this document shall be viewed as minimum requirements. A glossary of terms is included in the Appendix.

1.1.1 General

The Environmental Protection Agency (EPA) issued regulations on November 16, 1990, that require steps be taken to improve the quality of storm water from industrial activities, including certain construction activities. These criteria were developed to help mitigate the increased soil erosion and subsequent deposition of sediment offsite during the period of construction from start of earth disturbance until final landscaping and storm water quality measures are effectively in place. Compliance with these criteria will help meet the requirements of the EPA storm water regulations.

Submittal of an Erosion and Sediment Control Plan to the City does not supersede the requirement for the applicant to also obtain any required permits from the State of South Dakota, such as a South Dakota Storm Water Discharge Permit for Construction Activities. In most cases, the applicant will also have to submit a Notice of Intent to discharge storm water associated with construction activity to the South Dakota Department of the Environment and Natural Resources as well as meet the requirements of the South Dakota Storm Water Discharge Permit for Construction Activities.

Implementation and maintenance of erosion control measures are ultimately the responsibility of the property owner. Because site conditions will affect the suitability and effectiveness of erosion control measures, a plan specific to each site is required. In addition, should the approved plan not function as intended, and it is determined by the City that additional measures are needed, the owner will have to provide additional measures needed to reduce soil erosion and sediment discharged from the construction site.

It is not the intent of this Chapter to preclude the use of other techniques or to override the designer's ability or responsibility to use the most appropriate methods of analysis or practices. When conditions warrant special consideration or when more sophisticated methods are justified by engineering or economic considerations, the designer is encouraged to use these methods. Approval to use such methods shall be obtained from the City Engineer.

Low temperature weather does not preclude the use of erosion and sediment controls.

Nothing in this Chapter limits the right of the City to impose additional or more stringent standards.

1.1.1.1 Exemptions.

1. Exemptions from the erosion and sediment control planning process will be considered for any of the following; however, exempting the owner from preparing an erosion and sediment control plan and applying for a Grading Permit does not exempt the owner from controlling erosion of soil at each construction site through the use of the techniques described in this manual:

    a. Agricultural use of land.

    b. A sidewalk or driveway.

    c. Individual lots involving less than one [1] acre of disturbed area in a larger subdivision project shall not be considered separate development projects, but rather as a part of the subdivision development as a whole. It will be the responsibility of the homeowner and homebuilder to conform to all requirements of the locally-approved *Erosion and Sediment Control Plan* for the subdivision. As part of any Building Permit for which a specific erosion and sediment control plan is not required, the following statement must be included: "We have reviewed the *Erosion and Sediment Control Plan* for (subdivision name) and agree to conform to all requirements contained therein and all erosion control requirements of the City of Rapid City. We further agree to construct and maintain all erosion and sediment control measures required on the individual lot(s) subject to this Building Permit and/or in accordance with the provisions of the City of Rapid City *Erosion and Sediment Control Standards*."

    d. Underground utility construction, including the installation, maintenance, and repair of all utilities under hard-surfaced roads, streets, or sidewalks, provided such land-disturbing activity is confined to the hard-surfaced area and provided that runoff and erosion from soil stockpiles are confined and will not enter the drainage system.

    e. Gravel, sand, dirt, or topsoil removal as authorized pursuant to approval of the South Dakota Board of Minerals and Environment, provided said approval includes an erosion and sediment control plan that meets the minimums specified.

1.1.1.2 Variances

The City Engineer may temporarily waive or modify the standards of this chapter for the entire city due to severe local conditions. Any such city wide waiver must be determined to be necessary to prevent loss of life, personal injury, or severe property damage.

Upon request, the City Engineer may consider waiving or modifying any of the standards which are deemed inappropriate or too restrictive for site specific conditions by granting a variance. These site specific variances may be granted at the time of plan submission or formal request for plan revision. Request for variances shall include the following and must be submitted in a format that is deemed acceptable by the City Engineer.

1. The standard from which the applicant seeks a variance.
2. The justification for not complying with the standard.
3. Alternate criteria or standard measures to be used in lieu of the standard. The standards specified with this Chapter relate to the application of specific erosion and sediment control practices. Other practices or modifications to these standards may be used if approved by the City Engineer prior to installation. Such alternative practice must be thoroughly described and detailed to the satisfaction of the City Engineer.

To expedite the review and decision on variance requests, the variance request should be submitted with, or submitted prior to the initial Erosion and Sediment Control Plan submittal.

1.1.2 Performance Objectives

The objectives for erosion and sediment control during construction include the following:

1. Conduct all land-disturbing activities to effectively reduce accelerated soil erosion and reduce sediment movement and deposition offsite.

2. Schedule construction activities to minimize the total amount of soil exposed at any given time to reduce the period of accelerated soil erosion.

3. Establish temporary or permanent cover on areas that have been disturbed as soon as possible after final grading is completed.

4. Design and construct all temporary or permanent facilities for the conveyance of water around, through, or from the disturbed area to limit the flow of water to non-erosive velocities.

5. Remove sediment caused by accelerated soil erosion from surface runoff water before it leaves the site.

6. Stabilize the areas of land disturbance with permanent vegetative cover or storm water quality control measures.

1.1.3 *Erosion and Sediment Control Plan and Report*

An *Erosion and Sediment Control Plan* consisting of a written narrative report and a site plan map must be submitted to the City for review and approval prior to any unauthorized soil disturbance activities. An example Narrative Report is shown in the Appendix.

An erosion and sediment control plan for a site shall be prepared by a licensed professional.

The approved *Erosion and Sediment Control Plan* must be reviewed to ensure compliance with these standards anytime a site's planned development changes impact the soil disturbance activities. If this review determines that the *Erosion and Sediment Control Plan* needs revision, it must be resubmitted and approved by the City prior to the soil disturbance activities caused by the planned development changes.

1.1.3.1 Narrative Report. The narrative report must contain, or refer to, the drainage report and shall contain the following:

1. **Name, address, and telephone number of the applicant.** The name, address, and telephone number of the professional engineer preparing the *Erosion and Sediment Control Report* shall also be included if different from the applicant.

2. **Project description.** A brief description of the nature and purpose of the land-disturbing activity, the total area of the site, the area of disturbance, and project location including township, range, section, and quarter-section, or the latitude and longitude of the approximate center of the project.

3. **Existing site conditions.** A description of the existing topography, vegetation, and drainage; and identify any wetlands on the site.

4. **Adjacent areas.** A description of neighboring areas such as streams, lakes, residential areas, roads, etc., that might be affected by the land disturbance.

5. **Soils.** A brief description of the soils on the site, including information on soil type and names, mapping unit, erodibility, permeability, hydrologic soil group, depth, texture, and soil structure. (This information may be obtained from the soil report for the site, or, if available, from soils reports from adjacent sites.)

6. **Areas.** An estimate of the surface area (in acres) of the proposed disturbance.

7. **Erosion control measures.** A description of the methods which will be used to control erosion and sediment on the site.

8. **Construction site nonstructural control measures.** A description of the methods described in the Rapid City *Erosion and Sediment Control* chapter, which will be used to control storm water pollution, erosion, sediment, and spills on the site. During the construction process, the developer is responsible for maintaining all compliance documentation records.

9. **Time schedule.** A time schedule indicating the anticipated starting and completion time periods of the site grading and/or construction sequence, including workday, week, or date of completion. The schedule will include the installation and removal time periods of erosion and sediment control measures, and the time of exposure of each area prior to the completion of temporary erosion and sediment control measures.

10. **Permanent stabilization.** A brief description, including specifications of how the site will be stabilized after construction is completed.

11. **Storm water management considerations.** Explain how storm water runoff from and through the site will be handled during construction. Provide a brief description of the post-construction storm water quality control measures to be included as a part of the site development.

12. **Maintenance.** A schedule of regular inspections during construction and repair of erosion and sediment control structures shall be described. A description of routine sediment basin maintenance shall also be included.

13. **Other information.** Other information or data as may be reasonably required by the City Engineer.

14. **The following note.** "This *Erosion and Sediment Control Report* and attached *Site Construction Plan* appears to fulfill the technical criteria and the criteria for erosion and sediment control requirements of the City of Rapid City. I understand that additional erosion control measures may be needed if unforeseen erosion or sediment control problems occur or if the submitted plan does not function as intended. The requirements of this plan shall run with the land and be the obligation of the landowner until such time as the plan is properly completed, modified, or voided."

15. **Signature page and statement.** Signature page for owner/developer and general contractor acknowledging the review and acceptance of responsibility, and a statement by the professional engineer acknowledging responsibility for the preparation of the *Erosion and Sediment Control Plan*.

1.1.3.2 ***Erosion and Sediment Control Plan.*** The *Erosion and Sediment Control Plan* shall be separate from the narrative report. The erosion and sediment control plan stored on-site shall be updated as erosion and sediment controls are revised. The plan shall be prepared at a minimum scale of one (1) inch equals one hundred (100) feet and include the following:

1. **Property line.** The property lines for the site where the work will be performed.

2. **Existing topography.** Existing topography with one- (1) or two foot (2) contour intervals, and encompass the area shown on the final drainage plan (drawn to scale). Additional information may be required.

3. **Proposed topography.** Proposed topography with **one (1) or two foot (2)** contour intervals; the map shall show elevations, dimensions (drawn to scale), location, extent, and the slope of all proposed grading.

4. **Existing Facilities.** Location of any existing structures or hydrologic features on the site.

5. **Existing Conditions.** Location of all structures or natural features on the land adjacent to the site as required for the final drainage plan. The plan shall show the location of the street, street right-of-way, storm sewer, channel, or other waters receiving storm water runoff from the site. Any potential wetlands identified on inventory maps or observed shall be clearly shown.

6. **Proposed Facilities.** Show all proposed structures and development on the site.

7. **Limits of clearing and grading**. Areas that are to be cleared and graded.

8. **Location of sediment disturbance activities such as sawcutting, blasting, etc**.

9. **Location of soil stockpiles**. Areas designated for topsoil and subsoil storage.

10. **Location of storage areas**. Areas designated for equipment, fuel, lubricants, chemical, and waste storage.

11. **Location of temporary roads** designated for use during the construction period.

12. **Plans of all drainage features.** Show all structural and nonstructural erosion controls, paved areas, retaining walls, cribbing, planting, temporary or permanent soil erosion control measures, or other features to be constructed in connection with, or as a part of, the proposed work, together with a map

showing the drainage area of land tributary to the site and estimated two-year runoff of the area served by all drains.

13. **Detail drawings**. Design drawings of sediment controls, temporary diversions, and any practices used that are not referenced in this chapter.

14. **Other information.** Other information or data as may be reasonably required by the local jurisdiction.

15. **Detailed schedule.** Detailed schedule of events including dates (workday or week) of completion of the erosion control measures and inspections.

16. **Display Requirements.** Provide location for sign that complies with Section 1.8.5.3.

1.1.3.3 Erosion and Sediment Control for Individual Lots of a Subdivision

Individual lots in a subdivision, which has an approved erosion and sediment control permit and plan, shall not be considered a separate construction project, but rather as a part of the subdivision development as a whole. It will be the responsibility of the homeowner and their contractors to conform to all requirements of the locally approved *Erosion and Sediment Control Plan* for the subdivision. Subdivision *Erosion and Sediment Control Plans* must incorporate a separate detail drawing and narrative describing minimum erosion control measures of individual lots within the approved subdivision. It is understood that the City of Rapid City may require additional erosion and sediment control measures if unforeseen erosion or sediment control problems occur or if the submitted *Erosion and Sediment Control Plan* does not function as intended.

If any individual lot within a subdivision or larger common plan of development or sale is greater than one (1) acre or does not want coverage under the subdivision's *Erosion and Sediment Control Plan*, that lot owner must submit an erosion and sediment control permit application with applicable accompanying information for approval.

1.1.3.3.1 Individual Lot Erosion and Sediment Control Detail Drawing

A separate detail drawing demonstrating the typical minimum erosion and sediment control measures for a standard platted lot within the approved subdivision shall include the following:

a. Subdivision Name

b. Subdivision Location

c. Limits of Construction

i. Limits of construction shall be at the property lines or no more than ten (10) feet beyond property lines with authorization by adjacent property owner.

ii. Authorized limits of construction must be physically demarcated on the property.

d. Erosion Control Soil Surface Stabilization is Required.

i. BMP approved under Section 1.2 or an approved alternative.

e. Stabilized Staging Area as Deemed Necessary.

f. Concrete Washout Area as Deemed Necessary.

g. Stockpile Area as Deemed Necessary.

h. Non-structural BMP as Deemed Necessary.

i. Detailed Sediment Control Structural BMP(s).

1.1.3.3.2 Individual Lot Erosion and Sediment Control Narrative

Subdivision Construction Plans shall have a separate Narrative describing the minimum typical erosion control measures for a standard platted lot within the approved subdivision. Narrative shall include the following:

a. Lot owner or general contractor is responsible for training all subcontractors to follow this erosion and sediment control plan prior to entering the work area. Training/discussions with subcontractors shall include but not be limited to:

i. Define limits of construction and the method and location of physical demarcations.

ii. Define location and limits of stockpile areas if required.

iii. Removal of sediment and debris leaving property.

iv. Location of stabilized staging area and protection requirements if required.

v. Restricted use of vehicles or equipment on and off of unstabilized areas with entrance and egress through the lots vehicle tracking station.

vi. Location of Concrete Washout Area on lot or subdivision if required.

vii. Identify required structural and nonstructural BMP that must be maintained.

viii. Identify soil surface stabilization measures that should not be disturbed.

b. Any proposed structural BMP (i.e., silt fence, vehicle tracking) shall be inspected and maintained by the owner or his representative at least every fourteen (14) calendar days or after precipitation, snowmelt, or runoff that causes surface erosion, sediment transport, or vehicle tracking of debris off of property

c. Individual lot owner and/or their general contractor shall be responsible for implementing and maintaining the subdivision's approved structural BMP that is now located on their property and within their approved limits of construction.

d. Lot owner and general contractor or their representative shall ensure that soil, landscape materials, rock, or mulch is not stockpiled, stored, or placed on streets, sidewalks, or storm water flow lines.

1.1.3.4 Acceptance of Erosion and Sediment Control Plan.

An *Erosion and Sediment Control Plan* must be accepted prior to any earth disturbing activities unless the activity is defined in the ordinance as an exception. Acceptance of the *Erosion and Sediment Control Plan* does not imply acceptance or approval of drainage plans, utility plans, street or road plans, design of retaining walls, or any other aspect of site development.

1.2 Erosion Control

Planning for the installation of permanent or temporary soil erosion controls is needed in advance of all major soil disturbance activities on the construction site. After construction begins, soil surface stabilization shall be applied within 14 days to all disturbed areas that may not be at final grade but will remain dormant (undisturbed) for periods longer than an additional 21 calendar days. Within 14 days after final grade is reached on any portion of the site, permanent or temporary soil surface stabilization shall be applied to disturbed areas and soil stockpiles. When the initiation of stabilization measures are stopped due to snow cover or arid conditions, stabilization measures shall be initiated as soon as possible.

Soil surface stabilization protects soil from the erosive forces of raindrop impact, flowing water, and wind. Erosion control practices include surface roughening, mulching, erosion control blankets, and, establishment of vegetative cover by seeding and mulching, and the early application of gravel base on areas to be paved. Stabilization measures to be used shall be appropriate for the time of year, site conditions, and estimated duration of use. The maximum time limits of land exposure for selection of erosion controls are summarized in Table 1.1.

1.2.1 Surface Roughening

Surface roughening, also referred to as scarification, provides temporary stabilization of disturbed areas from wind and water erosion. It is particularly useful where temporary revegetation cannot be immediately established due to seasonal planting limitations.

The soil surface is considered roughened if depressions are created two (2) to four (4) inches deep and are spaced approximately four (4) to six (6) inches apart. If slopes are sufficiently rough after final grading, no further treatment is required. The surface of exposed soil can be roughened by a number of techniques and equipment. A chisel or ripping implement can be used in most soil conditions. Roughening cannot be performed in very sandy or rocky soil.

Surface roughening, also referred to as scarification, shall be performed after final grading. Fill slopes can be constructed with a roughened surface. Cut slopes that have been smooth graded can be roughened as a subsequent operation. Roughening of ridges and depressions shall follow along the contours of the slope. On slopes steeper than 2:1, the tracks left by a dozer working perpendicular to the contour can leave acceptable horizontal depressions.

Care shall be taken not to drive vehicles or equipment over areas that have been scarified. Tire tracks will smooth the roughened surface and encourage runoff to collect into channels. As surface roughening is only a temporary control, additional treatments may be necessary to maintain the soil surface in a roughened condition.

1.2.2 Mulching

All disturbed areas shall be mulched, or seeded and mulched, within 14 days after final grade is reached on any portion of the site not otherwise permanently stabilized. Areas that will remain in an interim condition for more than one (1) year shall also be seeded. See Sections 70 and 72 of the Standard Specifications for Public Works Construction (Standard Specifications).

To protect newly seeded areas and to provide temporary cover on other disturbed areas that will not require temporary revegetation or cannot be seeded due to seeding date limitations, a mulch or compost shall be applied per Section 72 of the Standard Specifications.

Mats, blankets, and nets are available to help stabilize steep slopes and drainage channels. Depending on the product, these may be used alone or in conjunction with straw mulch, fiber mulch or compost. Normally, use of these products will be restricted to relatively small areas. Mats made of jute, coconut fiber, or various geosynthetic fibers can be used instead of mulch. Blankets are straw mulch that have been woven and oftentimes include a synthetic layer or net. Plastic netting may be used to anchor mulch. See Section 146 of the Standard Specifications.

1.2.3 Erosion Control Blankets or Turf-Reinforcement Mats (TRMs)

Erosion control blankets are biodegradable, open-weave blankets used for establishing and reinforcing vegetation on slopes, ditch bottoms and shorelines. TRMs are synthetic, non-degradable mats that are usually buried to add stability to soils. They come in a wide range of designs and have been proven to be valuable on slopes and in channel-lining applications. Erosion control blankets and TRMs are especially useful in critical areas such as swales, long channels and slopes steeper than 3:1. See Section 146 of the Standard Specifications.

1.2.4 Revegetation

A viable vegetative cover shall be established within one (1) year on all disturbed areas and soil stockpiles not otherwise permanently stabilized. Vegetation is not considered established until a ground cover is achieved, which, in the opinion of the City, is sufficiently mature to control soil erosion and can survive severe weather conditions.

1.2.4.1 Seedbed Preparation. See Section 70 of the Standard Specifications.

1.2.4.2 Temporary Revegetation. Temporary revegetation is required on all disturbed areas having a period of exposure prior to final stabilization of one (1) year or longer. All temporary seeding shall be protected with mulch.

To provide temporary vegetative cover on disturbed areas that will not be paved, built upon, or fully landscaped within 12 months but will be completed within 24 months, plant an appropriate annual grass and mulch the planted areas.

1.2.4.3 Permanent Revegetation. To provide vegetative cover on disturbed areas not paved or built upon for two years or longer, or for an indeterminate length of time, a perennial grass mix shall be planted. Each site will have different characteristics, and a landscape professional should be contacted to determine the most suitable seed mix for a specific site. See Section 70 of the Standard Specifications. All permanent seeding shall be protected with mulch.

1.2.5 Roads and Soil Stockpiles

Road cuts, road fills, and parking lot areas shall be covered with the appropriate aggregate base course on the surfaces to be paved in lieu of mulching. Early application of road base is suitable where a layer of course aggregate is specified for final road or parking lot construction. This practice may not be desirable in all instances, and is not needed when final pavement construction will take place within 30 days of grading to final contours. All non-paved portions of road cut, fill, and parking lot areas shall be seeded and mulched as soon as possible after final grading has occurred, but in no case later than 14 days after grading has been completed.

Soils stockpiled for more than 60 days shall be seeded with a temporary or permanent grass cover within 14 days after completion of stockpile construction. Mulching is recommended to assure vegetation establishment. If stockpiles are located within close proximity to a drainageway (i.e., one hundred [100] feet), additional sediment control measures, such as a temporary diversion dike, silt fence or filter sock shall be provided.

1.2.6 Riprap at Inlets and Outlets

Inlets and outlets shall be properly protected to prevent soil erosion. See Section 4.8 in the Stormwater Design Criteria Manual for inlet and outlet riprap design criteria.

1.3 Sediment Control

Installation of Sediment Control Measures. All construction sites must install necessary perimeter sediment control measures called out in their approved *Erosion and Sediment Control* Plan prior to any earth disturbing activities unless the activity is defined in the ordinance as an exception. This only allows the minimum amount of soil disturbance necessary that is directly related to the installation of these sediment control measures.

The installation of all other sediment entrapment and control facilities shall begin before major land disturbance activities begin on a construction site in accordance with their time schedule established in their *Erosion and Sediment Control Plan*.

Sediment control will be site specific (located on the site under construction unless designated and approved by the City Engineer) and can include vehicle tracking controls; sod buffer strips around the lower perimeter of the land disturbance; sediment barriers, filters, dikes, traps, or sediment basins; or a combination of any or all of these measures.

Sediment controls shall be constructed before land disturbance takes place. Earthen structures such as dams, dikes, and diversions shall be mulched within 14 days of installation. Earthen structures that are expected to remain in place for more than one (1) year shall be seeded and mulched.

1.3.1 Vehicle Tracking

Wherever construction vehicles enter onto paved public roads, provisions shall be made to prevent the transport of sediment (mud and dirt) by vehicles tracking onto the paved surface. Stabilized access, parking, staging, and loading and unloading areas will reduce the likelihood that vehicles will come into contact with mud. Sites that have not voluntarily implemented these practices may be required to construct a stabilized vehicle tracking control device. See Section 146 of the Standard Specifications.

For sites greater than two (2) acres, a stabilized vehicle tracking control shall be constructed. Whenever deemed necessary by the City, wash racks shall be installed to remove mud and dirt from the vehicle and its tires before it enters onto public roads.

Whenever sediment is transported onto a public road, regardless of the size of the site, the road shall be cleaned 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 not be allowed until after sediment is removed in this manner. Storm sewer inlet protective measures shall be in place at the time of street washing.

1.3.2 Slope—Length and Runoff Considerations

Cut-and-fill slopes shall be designed and constructed to minimize erosion. This requires consideration of the length and steepness of the slope, the soil type, upslope drainage area, groundwater conditions, and other applicable factors. Slopes that are found to be eroding excessively will require additional slope stabilization until the problem is corrected. The following guidelines shall assist site planners and plan reviewers in developing an adequate design:

1. Rough soil surfaces are preferred over smooth surfaces on slopes (see Section 1.2.1).

2. Temporary slope diversion dikes (as discussed in Section 1.3.2.1) can be constructed at the top of long or steep slopes, or hill slopes that have an upslope tributary drainage area over five (5) acres. Diversion dikes or terraces (Sections 1.3.2.1 and 1.3.2.3) may also be used to reduce slope length within the disturbed area.

   Temporary diversion dikes shall be provided whenever:

   $$S^2L>2.5 \qquad \text{(Equation 1)}$$

   Where: S = slope of the upstream tributary area (in feet/foot); and
   L = length of the upstream slope (in feet)

3. Concentrated storm water shall not be allowed to flow down cut or fill slopes unless contained within an adequately-sized temporary channel diversion, a permanent channel, or temporary slope drain (see Section 1.3.2.4).

4. Wherever a slope face crosses a water seepage plane that endangers the stability of the slope, adequate drainage shall be provided.

5. Provide sediment traps, basins, or barriers below slopes to reduce off-site sediment transport or to reduce slope lengths.

1.3.2.1 Slope Diversion Dikes. A temporary slope diversion dike is a horizontal ridge of soil placed perpendicular to the slope and angled slightly to provide drainage along the contour. Temporary diversion dikes can be constructed by excavation of a V-shaped trench or ditch and placement of the fill on the downslope side of the cut.

There are two types of temporary slope diversion dikes:

1. A diversion dike located at the top of a slope to divert upland runoff away from the disturbed area. The discharge from undisturbed or previously-developed upland areas collected by these diversion dikes may be directed to a permanent channel or temporary channel diversion. (See Section 1.4.2)

2. A diversion dike located at the base or midslope of a disturbed area to divert sediment-laden water to a sediment trap or basin. The discharge from these diversion dikes may be directed to a temporary slope drain or sediment basin.

1.3.2.2 Roads and Roadside Swales. The drainage system provided for roads will define to some extent the length and area of individual slope segments within the disturbed area. A number of smaller hillslope segments will be created by construction of roads. These areas shall require erosion control as described in Section 1.2, and sediment controls dependent on the size of upslope tributary area. (See Section 1.3.3)

For road areas that are not paved within 30 days of final grading, and have not received early application of roadbase (see Section 1.2.4), rough-cut street controls shall be used. These are runoff barriers that are constructed at intervals down the road. The barrier projects perpendicular to the longitudinal slope from the outer edge of the roadside swale to the crown of the road. The barriers are positioned alternately from the right and left side of the road to allow construction traffic to pass in the unbarricaded lane.

1.3.2.3 Terracing. Sediment can be controlled on slopes that are particularly steep by using terracing. During grading, relatively flat sections, or terraces, are created and separated at intervals by steep slope segments. The steep slope segments are prone to erosion, however, and must be stabilized in some manner. Retaining walls, gabions, cribbing, deadman anchors, rock-filled slope mattresses, and other types of soil retention systems are available for use. These shall be specified in the plan and installed according to manufacturer’s instructions.

1.3.2.4 Slope Drains. There are certain instances when runoff must be directed down a slope within the disturbed area. A temporary slope drain can be used to protect these hillslope areas from scour and additional erosion. A number of alternative designs and materials can be used for a slope drain.

The sizing of temporary slope drains shall be defined but do not need rigorous hydraulic analysis. Slope drains shall be sized for a two-year storm event. The discharge from all slope drains shall be directed to a stabilized outlet. (See Section 1.4.3)

1.3.3 Sediment Entrapment Facilities

Sediment entrapment facilities are necessary to reduce sediment discharges to downstream properties and receiving waters. Sediment entrapment facilities include silt fences, sod filter strips, sediment traps, sediment basins, silt ditches, wattles, logs and compost socks. The type of sediment entrapment facility to be used depends on the tributary area, basin slope, and slope length of the upstream area. Table 1.2 summarizes the recommended maximum tributary areas, slope lengths, and slopes for seven types of sediment entrapment facilities.

All runoff leaving a disturbed area shall pass through a sediment entrapment facility before it exits the site and flows downstream.

An established green filter strip may be adequate for small sites, provided the limits for tributary slope are not exceeded and the flow is not concentrated. Silt fences, wattles, or compost socks may be used for somewhat larger areas, depending on the upslope drainage area. When the tributary area is less than five (5) acres but greater than that allowed for silt fences, wattles, or compost socks, runoff shall be collected in diversion swales and routed through temporary sediment traps.

1.3.3.1 Silt Fence. A silt fence is made of a woven synthetic material that filters runoff. Silt fence can be placed as a temporary barrier at the base of a disturbed area but is not recommended for use in a channel or swale. The material is durable and will last for more than one season if properly installed and maintained. See Section 146 in the Standard Specifications.

1.3.3.2 Compost Berm. Mulch berms are sediment-trapping devices using composted materials applied with a pneumatic blower device or equivalent. Mulch berms trap sediment by filtering water passing through the berm and allowing water to pond, creating a settling of solids. Mulch berms can be used in areas where runoff is in the form of sheet flow. Mulch berms can also be used in sensitive environmental areas, where migration of aquatic life is impeded by the use of silt fence. These shall be specified in the plan and installed according to the Rapid City MRF Facility Supervisor’s instructions.

1.3.3.3 Compost Socks, Straw Wattles, Excelsior Logs. These devices are sediment trapping devices which trap sediment by filtering water passing through the sock, wattle, or log and allowing water to pond, allowing the settling of solids. These devices may be used in sensitive environmental areas, where migration of aquatic life is impeded by the use of silt fence. Since trenching is not required for the installation of these devices, these devices may be used in a number of situations where disturbance of the ground is not possible or preferable, including on: frozen ground, pavement, hard or compacted surfaces, rocky soil, or areas where trenching is not allowed due to it causing additional sediment disturbing activities. These devices shall be specified in the plan and installed according to manufacturer's instructions.

1.3.3.4 Filter Strips. Vegetated filter strips cause deposition of sediment within the area of vegetation. Buffer strips of natural vegetation can be left at the time of site grading, or can be created by using sod. A dense ground cover is necessary or runoff will channelize within the area. A minimum width of 20 feet is recommended.

1.3.3.5 Sediment Traps. A sediment trap is a temporary structure that is designed to fill with sediment. A sediment trap can be constructed by either excavating below grade or building an embankment across a swale. Excavated traps are less prone to failure than embankments. No pipe is used at the outlet, as in a sediment basin, and an open-channel spillway shall be included in the design. A minimum of 3,600 cubic feet of storage volume shall be provided for each tributary acre.

If sediment traps are incorporated into the *Erosion and Sediment Control Plan*, provide the following guidance for the contractor:

- Sediment volume required and provided.
- Length, width, and depth of the trap.
- Provide the top elevation of the berm, and length, and elevation for the overflow assembly.

1.3.3.6 Sediment Basins. Areas draining more than ten (10) acres shall be routed through a sediment basin. Sediment basins shall be designed to a minimum 3,600 cubic feet of volume per tributary acre and be cleaned out prior to becoming half full.

Tributary acres shall be the total potential disturbed acres at one time drained to the sediment basin from a construction site or larger common plan of development or sale. This does not have to apply to storm water flows from acres that are:

- Undisturbed onsite areas with no erosion and sediment control issues.
- Previously disturbed onsite areas that have achieved final stabilization.
- Disturbed or undisturbed areas not within the construction site or larger common plan of development or sale.

If the site is to include a post construction storm water quality or flood control detention facility, the permanent detention facility may be used as the temporary sediment basin, provided the outlets are designed for construction activities and are later modified for post construction activities upon completion of construction and final stabilization of disturbed soils. Such permanent detention facilities or post construction water quality BMP's shall be restored to design grades, volumes, and configurations after site development is completed and the project is finalized. The outlet from a sediment basin shall be designed to empty its volume in no less than 16 hours; namely, to have an average outflow rate of 28.0 gallons/minute/tributary acre, or less. When practicable the basin length shall be no less than twice the basin width. The inflow structures at the entrance of the basin shall be designed to dissipate inflow energy and to spread the flow so as to achieve uniform flow throughout the basin's width. The gravel and rip rap horseshoe sediment basin should be utilized when drainage culverts are already in place prior to site construction activities since existing culverts and roadway fill sections readily afford sediment storage area.

If sediment basins are incorporated into the *Erosion and Sediment Control Plan*, provide the following information in the plan to provide necessary guidance for the contractor:

- Delineate the tributary drainage area to each sediment basin on the erosion control plan.
- Sediment volume required and provided.
- Length, width, and depth of the basin.
- For sediment basins, give the top elevation of the berm, and length, and elevation for the overflow assembly. The outlet structure size and invert elevations will also be provided.

For drainage locations serving less than ten (10) acres, a sediment basin or a combination of sediment basin(s) and sediment traps providing storage for three thousand six hundred (3,600) cubic feet of storage per acre drained may be required along with silt fences, socks, wattles, logs, silt ditches, or equivalent sediment controls on all sideslope and downslope boundaries of the construction area.

1.3.3.7 Silt Ditch. A silt ditch is constructed by excavating a small channel along and parallel to the existing contours of the land. Silt ditch can be placed as a temporary barrier at the base of a disturbed area but is not recommended for use in a channel or swale. Silt ditch shall be designed to a minimum 3,600 cubic feet of volume per tributary acre. The berm constructed on the downstream side of the excavated channel shall be seeded and mulched immediately after construction.

1.4 Drainageway Protection

At times, construction activities must occur adjacent to or within a drainageway. Whenever this occurs, bottom sediments will be disturbed and transported downstream to minimize the movement of sediments resulting from construction activities that take place within any drainageway. Temporary facilities can be installed to divert flowing water around such sediment-generating construction activities within drainageways.

1.4.1 Working Within or Crossing a Waterway

Whenever work occurs within a waterway, the following shall be considered as appropriate:

1. Construction vehicles shall be kept out of a waterway to the maximum extent practicable. Where in-channel work is necessary, steps, such as temporary channel diversions, shall be taken to stabilize the work area during construction to control erosion. The channel (including bed and banks) shall be restabilized immediately after in-channel work is completed.

2. Where an actively-flowing watercourse must be crossed regularly by construction vehicles, a temporary crossing shall be provided. Two primary methods are available: a culverted crossing and a stream ford.

   A culverted crossing shall be designed to pass the two-year design flow.

   A ford shall be lined with a minimum six (6) inch thick layer of one and a half (1.5) inch diameter rock.

   A permit is required for placement of fill in a waterway under Section 404 of the Clean Water Act. The Corps of Engineers office in Pierre, South Dakota, shall be contacted about the requirements for obtaining a 404 permit.

3. Whenever feasible, a temporary channel diversion (see Section 1.4.2) shall be used to bypass the work areas when work takes place within a channel.

4. Whenever possible, construction in a waterway shall be sequenced to begin at the most downstream point and work progressively upstream installing required channel and grade control facilities.

5. Complete work in small segments, exposing as little of the channel at a time as possible.

6. Where possible, perform all in-channel work between September 15 and April 15.

7. A Floodplain Development Permit may be required for work in a waterway per FEMA regulations

1.4.2 Temporary Channel Diversions

Limiting construction activities within actively-flowing water will significantly reduce sediment movement downstream from these activities. This can be done by using a temporary diversion facility that carries water around construction activities taking place within a waterway.

Permanent drainage channels shall be constructed at the earliest possible stage of development. Temporary channel diversions shall not remain in place for more than two years prior to removal or replacement by permanent facilities.

1.4.2.1 Stability Considerations. Temporary channels are not likely to be in service long enough to establish adequate vegetative lining. Temporary channel diversions must be designed to be stable for the design flow with the channel shear stress less than the critical tractive shear stress for the channel lining material. Unlined channels shall not be used unless it can be demonstrated that an unlined channel will not erode during the design flow. Design procedures for temporary channels are described in detail in the Stormwater Design Criteria Manual.

1.4.3 Outlet Protection

The outlets of slope drains, culverts, sediment traps, and sediment basins shall be protected from erosion and scour. Outlet protection shall be provided where the velocity of flow will exceed the maximum permissible velocity of the material where discharge occurs. This may require the use of a riprap apron at the outlet location. Check dams can be used in ditches or swales and downstream of the outlets of temporary slope drains, culverts, sediment traps, and sediment basins. Check dams reduce the velocity of concentrated flows and trap sediment eroded from the upstream ditch or swale. They are not a primary sediment trapping facility and are a temporary flow-control structure.

Check dams may be used under the following conditions:

1. In temporary or permanent swales that need protection during the establishment of grasses;
2. In permanent swales that need protection prior to installation of a non-erodible lining;
3. In temporary ditches or swales that need protection where construction of a non-erodible lining is not practicable.

Check dams shall be constructed of four (4) to six (6) inch angular rock or compost socks to a maximum height of two (2) feet. The center of the top of the dam shall be six (6) inches lower than the sides to concentrate the flow to the channel center. Where multiple check dams are used, the top of the lower dam shall be at the same topographical elevation as the toe of the upper dam.

Sediment that collects behind a check dam shall be removed when the sediment reaches the spillway level. Check dams constructed in permanent swales shall be removed when perennial grasses have become established, or immediately prior to installation of a non-erodible lining. All of the rock and accumulated sediment shall be removed, and the area seeded and mulched, or otherwise stabilized. The compost sock check dam may remain in place if it is intended to be permanently vegetated.

1.4.4 Inlet Protection

All storm sewer inlets that are made operable during construction shall be protected to prevent sediment-laden runoff from entering the conveyance system without first being filtered or otherwise treated to remove sediment. There are numerous methods and devices that can be used to protect inlets. These methods and devices shall be specified in the plan and installed according to manufacturer's instructions.

Inlets may be temporarily blocked to prevent sediment-laden runoff from entering storm sewers. Inlet protection measures shall be removed after upstream disturbed areas are stabilized.

Caution must be used in temporarily blocking inlets to assure that localized flooding conditions do not develop.

Inlet protection shall be removed from storm sewer inlets within paved street sections or parking lots during the winter months between December 1 and February 15. The City may require removals earlier than December 1 or installations later than February 15. During the period when inlet protection has been removed, alternate erosion control methods for inlet protection must be employed if ground is not stabilized by frozen conditions.

1.5 Underground Utility Construction

The construction of underground utility lines that are not exempted (see Section 1.1.1.1) shall be subject to the following criteria:

1. No more than three hundred (300) feet of trench are to be opened at one time.

2. Where consistent with safety and space considerations, excavated material is to be placed on the uphill side of trenches.

3. Trench dewatering devices shall discharge in a manner that will not adversely affect flowing streams, wetlands, drainage systems, or offsite from the property. Site dewatering permit requirements shall be discussed with the South Dakota Department of Environment and Natural Resources.

4. Provide storm sewer inlet protection (see Section 1.4.4) whenever soil erosion from the excavated material has the potential for entering the storm drainage system.

1.6 Disposition of Temporary Measures

All temporary erosion and sediment control measures shall be removed and disposed within 30 days after final site stabilization is achieved, or after the temporary measures are no longer needed, whichever occurs earliest, or as authorized by the Office of the City Engineer. For example, a site containing only one building shall have temporary erosion control measures removed after building construction is complete and final landscaping is in place. Temporary erosion control measures shall be removed from a commercial construction site or residential subdivision only after streets are paved and all areas have achieved final stabilization. Trapped sediment and disturbed soil areas resulting from the disposal of temporary measures shall be returned to final plan grades and permanently stabilized to prevent further soil erosion.

The certified professional preparing the *Erosion and Sediment Control Plan* shall submit, as part of the narrative report, a schedule of removal dates for temporary control measures. The schedule shall be consistent with key construction items such as street paving, final stabilization of disturbed areas, or installation of structural storm water controls.

1.7 Maintenance

All temporary and permanent erosion and sediment control practices shall be maintained and repaired by the owner during the construction phase as needed to assure continued performance of their intended function. Sediment traps and basins will require periodic sediment removal when the design storage level is half full. All facilities shall be inspected by the owner or owner’s representative following each heavy precipitation or snowmelt event that results in runoff.

As part of the narrative report, the professional engineer preparing the erosion and sediment control plan shall submit a schedule of planned maintenance activities for temporary and permanent erosion and sediment control measures. The schedule shall be consistent with the level of maintenance required for the control measures proposed in the plan. A suggested maintenance plan is located in the Appendix as Table 1.5.

1.8 Pollution Prevention Using Nonstructural BMPs

Nonstructural BMPs are to be a part of construction activities.

1.8.1 Objectives in the Use of Nonstructural BMPs

Nonstructural BMPs differ from the structural BMPs because they focus on activities to control water quality rather than physical structures. Because they rely on actions and not structures, nonstructural BMPs must be implemented constantly and repetitively over time. There are two main objectives of using nonstructural BMPs. These are:

1. Reduce or eliminate the pollutants that impact water quality at their source, thus

reducing the need for structural control requirements. The use of nonstructural BMP practices may assist structural BMP efficiency and may eliminate the need for additional storm water treatment.

2. Address water quality concerns that are not considered cost-effective by structural controls such as implementing a spill prevention and containment program.

1.8.2 Nonstructural BMP Effectiveness

To be effective, nonstructural BMPs need to prevent or reduce the sources of storm water pollution. They fall into the general categories of prevention and source controls. The objectives for promoting the use of nonstructural BMPs are as follows:

1. Improve the quality of receiving waters.
2. Increase consistency with storm water quality objectives.
3. Increase consistency with structural BMPs.
4. Improve cost-effectiveness.
5. Widespread applicability in all urban areas.
6. Widespread public acceptance.

1.8.3 Pollutant Removal Mechanisms

Nonstructural BMPs can, to some degree, prevent the deposition of pollutants on the urban landscape or remove pollutants at their source. The source of pollutants for assimilation into storm water is the land surface itself, especially the impervious surfaces in the urban area. Thus, it is expected that when nonstructural measures are effectively implemented, they will reduce the amount of pollutants being deposited on land surfaces for eventual contact with storm water and transported to the receiving water system.

1.8.4 Selection of Appropriate Nonstructural BMPs

Development projects shall include nonstructural BMPs as listed in Table 1-3.

1.8.5 Good Housekeeping

1.8.5.1 Descriptions. Good housekeeping requires keeping potential areas where pollutants exist clean and orderly.

1.8.5.2 Application. Good housekeeping practices are designed to maintain a clean and orderly work environment. The most effective first steps towards preventing pollution in storm water from work sites simply involves using good common sense to improve the facility’s basic housekeeping methods. Some simple procedures a site can use to promote good housekeeping are improved operation and maintenance of machinery and processes, material storage practices, material inventory controls, routine and regular cleanup schedules, maintaining well organized work areas, signage, and educational programs for employees and the general public about all of these practices.

1.8.5.3 Contact Information Display Requirement. The permittee shall post a 24-hour, 7 days-a-week sign with the contractor contact name and contractor phone number readily visible at the development site entrance. A City of Rapid City approved 24-hour contact number to register complaints must also be included on the sign. The contact information shall be clearly readable, securely anchored, and appropriately weatherproofed to assure its integrity throughout construction. The following or similar format shall be used:

1. To report an erosion, sediment, spill, or other problem at this construction site to the responsible contractor call:

    Contractor Name
    Contractor Phone

    To register a complaint about this construction site to the City of Rapid City call:

    Approved City of Rapid City Contact Number

1.8.5.4 Implementation. These BMPs are applicable to the following areas: operation and maintenance, material storage, material inventory, and training and participation.

1.8.5.4.1 Operation and Maintenance. To assure that equipment and work related processes are working well, the following practices can be implemented:

1. Maintain dry and clean floors and ground surfaces by using brooms, shovels, vacuum cleaners, or cleaning machines rather than wet cleanup methods.

2. Regularly pick up and dispose of garbage and waste material.

3. Make sure all equipment and related processes are working properly and preventative maintenance is kept up with on both.

4. Routinely inspect equipment and processes for leaks or conditions that could lead to discharges of chemicals or contact of storm water with raw materials, intermediate materials, waste materials, or products used on site.

5. Assure all spill cleanup procedures are understood by employees. Training of employees on proper cleanup procedures shall be implemented.

6. Designate separate areas of the site for auto parking, vehicle refueling, and routine maintenance.

7. Clean up leaks, drips, and other spills immediately.

8. Cover and maintain dumpsters and waste receptacles.

1.8.5.4.2 Material Storage Practices. Improperly storing material on site can lead to the release of materials and chemicals that can cause storm water runoff pollution. Proper storage techniques include the following:

1. Provide adequate aisle space to facilitate material transfer and ease of access for inspection.

2. Store containers, drums, and bags away from direct traffic routes to prevent accidental spills.

3. Stack containers according to manufacturer's instructions to avoid damaging the containers from improper weight distribution.

4. Store containers on pallets or similar devices to prevent corrosion of containers that results from containers coming in contact with moisture on the ground.

5. Store toxic or hazardous liquids within curbed areas or secondary containers.

6. Assign responsibility of hazardous material inventory to a limited number of people who are trained to handle such materials.

1.8.5.4.3 Material Inventory Practices. An up-to-date inventory kept on all materials (both hazardous and nonhazardous) present on site will help track how materials are stored and handled onsite, and identify which materials and activities pose the most risk to the environment. The following description provides the basic steps in completing a material inventory:

1. Identify all chemical substances present at work site. Perform a walk-through of the site, review purchase orders, list all chemical substances used, and obtain Material Safety Data Sheets (MSDS) for all chemicals.

2. Label all containers. Labels shall provide name and type of substance, stock number, expiration date, health hazards, handling suggestions, and first aid information. This information can also be found on an MSDS.

3. Clearly mark on the hazardous materials inventory which chemicals require special handling, storage, use, and disposal considerations. Decisions on the amounts of hazardous materials that are stored on site shall include an

evaluation of any emergency control systems that are in place. All storage areas shall be designed to contain any spills.

1.8.5.4.4 Training and Participation. Frequent and proper training in good housekeeping techniques reduces the possibility of chemicals or equipment that will be mishandled. Reducing waste generation is another important pollution prevention technique. The following are ways to get people involved in good housekeeping practices:

1. Provide information sessions on good housekeeping practices in training programs.

2. Discuss good housekeeping at meetings.

3. Publicize pollution prevention concepts through posters or signs.

1.8.6 Spill Prevention and Response

1.8.6.1 Primary Users. Facilities with fluids such as fuel, paints, and other liquids both hazardous and nonhazardous.

1.8.6.2 Description and Application. This BMP includes measures to be taken to assure that spills do not result in water quality impacts. Spills and leaks together are one of the largest sources of storm water pollutants, and in most cases are avoidable.

1.8.6.3 Implementation.

1.8.6.3.1 Spill Prevention Measures*.* The following preventative strategies are recommended where fluids are commonly present:

1. Identify all equipment that may be exposed to storm water, pollutants that may be generated, and possible sources of leaks or discharges.

2. Perform regular maintenance of each piece of equipment to check for: proper operation, leaks, malfunctions, and evidence of leaks or discharge (stains). Develop a procedure for spill reporting, cleanup, and repair.

3. Drain or replace motor oil or other automotive fluids in an area away from streams or storm or sanitary sewer inlets. Collect spent fluids and recycle or dispose of properly.

4. In fueling areas, clean up spills with dry cleanup methods (absorbents), and use damp cloths on gas pumps and damp mops on floors instead of a hose.

An important part of spill prevention is employee training. Make sure employees are trained in spill prevention practices and adhere to them.

The best way to prevent pollutants from entering the storm drains is to prevent storm water from contacting equipment or surfaces that may have oil, grease, or other pollutants. Some good activities to help prevent negative impacts on storm water quality include:

1. Properly dispose of storm water that has collected in containment areas (may need permit if contaminated).

2. Adopt effective housekeeping practices.

3. Assure adequate security to prevent vandalism.

1.8.7 Identification of Spill Areas

It is important to identify potential spill areas and their drainage points to determine preventative measures and spill response actions. Areas and activities that are most vulnerable to spills include transportation facilities where vehicle spills could be a problem:

1. Loading and unloading areas
2. Storage areas
3. Process activities
4. Dust or particulate generating processes
5. Waste disposal activities

In addition to these areas, evaluate spill potential in other areas (access roads, parking lots, power generating facilities, etc.). It is also important to estimate the possible spill volume and drainage paths.

1.8.8 Material Handling Procedures

Outdoor materials handling procedures include:

1. For permanent and long-term (greater than three months) storage, keep bulk solid materials (including raw materials, sand, gravel, topsoil, compost, concrete, packing materials, and metal products) covered or protected from storm water.

2. Isolate and consolidate bulk materials from storm water runoff by providing berms or other means to keep the material from migrating into drainage systems.

3. When possible, store materials such as salt, hazardous materials, and other materials prone to leaching when exposed to storm water on a paved surface.

4. Locate material storage areas away from storm drains, ponds, and drainageways.

5. Hazardous materials must be stored according to federal, state, and local HazMat requirements.

6. Adopt procedures that reduce the chance of spills or leaks during filling or transfer of materials.

7. Substitute less or nontoxic materials for toxic materials.

1.8.9 Spill Response Procedures and Equipment.

1. Wipe up small spills with a shop rag, store shop rags in covered rag container, and dispose of properly (or take to professional cleaning service and inform them of the materials on the rag).

2. Contain medium-sized spills with absorbents (kitty litter, sawdust, etc.) and use inflatable berms or absorbent rolls or “snakes” as temporary booms for the spill. Store and dispose of absorbents properly. Wet/dry vacuums may also be used, but not for volatile fluids.

3. For large spills, first contain the spill and plug storm drain inlets where the liquid may migrate offsite, then clean up the spill. Contact appropriate emergency response agency according to state and local requirements.

1.8.9.1 Spill Plan Development. A Spill Prevention Control and Countermeasure Plan (SPCC) identifies areas where spills can occur on site, specifies materials handling procedures, storage requirements, and identifies spill cleanup procedures. The purpose of this plan is to establish standard operating procedures, and the necessary employee training to minimize the likelihood of accidental releases of pollutants that can contaminate storm water runoff.

Storm water contamination assessment, flow diversion, record keeping, internal reporting, employee training, and preventative maintenance are associated BMPs that can be incorporated into a comprehensive Spill Prevention Plan.

A SPCC is applicable to facilities that transport, transfer, and store hazardous materials, petroleum products, and fertilizers that can contaminate storm water runoff.

Emergency spill cleanup plans shall include the following information:

1. A description of the facility including the nature of the facility activity and general types and quantities of chemicals stored at the facility.

2. A site plan showing the location of storage areas of chemicals, the location of storm drains, site drainage patterns, firefighting equipment and water source locations, and the location and description of any devices used to contain spills such as positive control valves.

3. Notification procedures to be implemented in the event of a spill such as phone numbers of key personnel and appropriate regulatory agencies.

4. Instructions regarding cleanup procedures.

5. Designated personnel with overall spill response cleanup responsibility.

6. Quick notification of Rapid City Fire and Rescue for spills that cannot be handled by local site staff.

A summary of the plan shall be written and posted at appropriate points identifying the spill cleanup coordinators, location of cleanup kits, and phone numbers of regulatory agencies to be contacted in the event of a spill. Cleanup of spills shall begin immediately. No emulsifier or dispersant shall be used. In fueling areas, absorbent shall be packaged in small bags for easy use and small drums shall be available for storage of absorbent and/or used absorbent. Absorbent materials shall not be washed down the floor drain or into the storm sewer.

Emergency spill containment and cleanup kits shall be located at the facility site. The contents of the kit shall be appropriate to the type and quantities of chemicals or goods stored at the facility.

The following procedures shall be followed when implementing an emergency spill cleanup plan:

1. Key personnel shall receive formal training in plan execution with additional training to the people who are likely to be the first on the site. All employees shall have a basic knowledge of spill control procedures.

2. A plan summary shall be posted at appropriate site locations. The summary shall include the identification of the spill cleanup coordinators, location of cleanup equipment, and phone numbers of site personnel and regulatory agencies to be contacted in the event of a spill.

3. Perform the following notifications in the event of a spill:

   a. Rapid City Fire Rescue
   b. Rapid City Health Department
   c. State and federal agencies as required by the material

4. Containment and cleanup of any spills shall begin immediately.

5. Absorbents shall be readily used in fueling areas.

6. An inventory of cleanup materials shall be maintained on site and strategically deployed based on the type and quantities of chemicals present.

1.8.9.2 Advantages and Disadvantages. Table 1.4 lists the advantages and disadvantages of different BMPs for spills.

1.9 Inspections

The permittee shall assure that qualified personnel inspect the site at least once every seven calendar days and within 24 hours of the end of a storm that is one-half (0.5) inch or greater to confirm plan compliance. Based on the results of the inspection, the plan shall be revised and implemented, in no case later than seven calendar days following the inspection.

The inspection shall look for evidence of or the potential for pollutants entering the drainage system or leaving the site and shall include disturbed areas of the construction site that have not been finally stabilize, areas used for storage of materials, structural and nonstructural control measures, and locations where vehicles enter or exit the site.

A report summarizing the areas inspected, name(s) and title(s) of personnel making the inspection, the date(s) of the inspection, major observations, and corrective actions taken shall be made and retained as part of the plan for a least three years. Such reports shall identify any incidents of noncompliance. Where an inspection does not identify any incidents of noncompliance, the report shall contain a certification that the site is in compliance with the plan and permit.

Compliance documentation is the responsibility of the Contractor/Developer as identified in Section 1.1.3.1.

Appendix

Example Erosion and Sediment Control Plan

Prepared For:

Ajax Development Inc.
1234 A Street
Rapid City, SD 57701
Phone: 605-555-0000

Prepared By:

Acme Consultants, Inc.
43560 Square Feet Street
Rapid City, SD 57702
Phone: 605-555-1212

February 2007

I. Introduction

Name, Address, and Telephone Number

Owner:

Ajax Development, Inc.
1234 A Street
Rapid CIty, SD 57701
Phone: 605-430-0000

Erosion Control Consultant:

Acme Consultants, Inc.
43560 Square Feet Street
Rapid City, SD 57702
Phone: 605-430-1212

Project Description

The Project consists of the development of a 6.2-acre parcel with two office buildings. The project is located in the SW quarter of Section #, Township, Range of the 7th principal meridian located in Pennington County, South Dakota. The project involves grading of 5.2 acres of the parcel, constructing two office buildings, two parking lots, an access road, a box culvert over Rapid Creek and associated site utilities.

Existing Site Conditions

Most of the existing site is vegetated with native grass. The plant density is estimated to be 50 percent coverage of the ground surface. Cottonwood trees and other riparian vegetation are found adjacent to Rapid Creek. The site drains to Rapid Creek except the southeast portion which drains off-site to the southeast. About 0.2 acres of wetlands are found next to Rapid Creek. The riparian and wetland vegetation will not be disturbed by the site development. The existing slopes on the site range from 2 percent to 19 percent adjacent to the creek.

Silt fence will be installed next to the creek for the areas where runoff is not intercepted by the diversion channels.

Schedule

The construction schedule is as follows:

Install Construction Entrance, Sediment Traps and Silt Fence:	September 15–September 30
Site Grading:	September 30–October 15
Install Base Course and Mulch to All Exposed Soil Areas:	October 15–October 20
Utility and Building Construction:	October 20–April 1
Paving and Landscaping:	April 1–April 15
Removal of Erosion Control Measures:	April 15–April 20

The schedule will minimize the exposure of unprotected areas to less than 30 days. The perimeter controls will be installed prior to site grading.

Permanent Stabilization Measures

Permanent landscaping will include bluegrass sod and trees and shrubs. The two sediment traps will be converted to the site detention ponds after sod is installed (refer to the site Drainage Report for the detention requirements). The box culvert will be constructed early in the construction period to provide access across the creek during construction.

Storm water Management Considerations

Storm water will sheet flow from the building areas toward the creek, then be intercepted and routed to sediment traps during construction. All areas that will not be intercepted by the diversions will be protected with silt fence and straw wattles. Post-development storm water quality control will be provided by the vegetated filter strip adjacent to Rapid Creek.

Slope Diversion Channel Sizing:

$Q = C\ I\ A$
$C = 0.2$
$A = 2.0$ acres each
$Q = 0.2 \times 2.6 \times 2.0 = 1.04$ cfs

Try a triangular channel with depth of 0.5 ft. and four to one sideslopes. (Actual depth will be 1.0 ft. allowing 0.5 ft. as freeboard.)

Proposed Slope = 0.75 percent

$A = 1\ ft^2$, P = 4.47 ft.   R = 0.224 ft.

Use a fiber blanket for erosion control.

n = 0.035

from Manning's Equation:

$V = 1.486/0.035 \times (.0075)^{12}$ = 1.35 feet per second
Q = A V = 1.35 cfs
(more than 1.04 so this channel section is acceptable)

Sediment Traps

Tributary Area = 2.0 acres
Required Volume = $3{,}600\ ft^3$/acre x 2.0 acres = $7{,}200\ ft^3$
Use a 60 ft. x 60 ft. x 2.0 ft. deep sediment trap

Glossary of Terms

Erodibility: The susceptibility of a particular soil type to erosion by water or wind.

Erosion: The wearing away of the land surface by water, wind, ice, or other geological agents, including the detachment and movement of soil or rock fragments by water, wind, ice, or gravity.

Erosion Control Measures: Practices that slow or stop erosion.

Final Stabilization: Completion of all land disturbing activities, removal of all temporary sediment controls, establishment of vegetative cover on exposed soil areas, and installation of permanent roads and structural storm water quality best management practices.

Land Disturbing Activity: Grading, cut, fill, stockpiling of dirt, removal of vegetation, or any other alteration or disturbance of the ambient land surface.

Mapping Unit: Soil name and symbol given in the Soil Conservation Service Soil Survey for each soil type.

Permanent: Installation of land-surface cover, or erosion and sediment control measures that will remain in place for a long period of time.

Sedimentation: The process of solid materials, both inorganic (mineral) and organic, coming to rest on the earth’s surface either above or below sea level.

Sediment: Particulate solid material, either inorganic or organic, that will settle or be deposited in a liquid under the force of gravity.

Sediment Barrier: Device which prevents sediment from traveling past the installation point.

Sediment Basin: A depression, either excavated or formed by a dam, that holds water and debris and facilitates sedimentation of soil particles. Normally used for drainage areas equal to and greater than 5.0 acres.

Sediment Trap: A small depression that holds water and debris and facilitates sedimentation. Normally used for drainage areas less than 5.0 acres.

Temporary: Installation of erosion or sediment control measures, either structural or nonstructural, that are planned to be removed or inactivated after a period of time.

Viable Vegetative Cover: A measure of performance for establishment of appropriate vegetative cover (or density) on sites planned for revegetation for the period of duration or successful growth as accepted by the City and county of jurisdiction.

General Criteria 1 and 2.

GC-1 Stabilization of Disturbed Areas and Soil Stockpiles

A. Permanent or temporary soil stabilization shall be applied to disturbed areas within two weeks after rough grading. Soil stabilization refers to measures which protect soil from erosive forces of raindrop impact and flowing water. Applicable practices include vegetative establishment, mulching, and early application of gravel base on areas to be paved. Soil stabilization measures selected shall be appropriate for the time of year, site conditions, and estimated duration of use.

B. Soil stockpiles shall be established or protected with sediment-trapping measures to prevent soil loss.

GC-2 Establishment of Permanent Vegetation

A permanent vegetative cover must be established on denuded areas not otherwise permanently stabilized. Permanent vegetation is not to be considered established until a ground cover is achieved which is mature enough to control erosion satisfactorily.

Will construction be absent two years or more?

Protect with 1.2.3.2 Temporary Revegetation, or 1.2.2 Mulching

Yes

See 1.2.3.3 Permanent Revegetation

Is a seed mix available for the time of year seeding will take place?

Protect with 1.2.2 Mulching or 1.2.3.2 Temporary Revegetation until permanent seeding date.

Yes

Seed according to Section 70 of the Standard Specifications

Are slopes 3:1 or greater?

Consider use of blanket mulch in 1.2.2 Mulching, for critical areas.

No

Mulch according to 1.2.2 Mulching

Table 1.1
Maximum Time Limits of Land Exposures for Selection of Erosion Controls

Erosion Control Method	Maximum Allowable Period of Exposure (Months)
Surface Roughening	1
Mulching	12
Temporary Revegetation	12–24
Permanent Revegetation	24 or more
Soil Stockpile Revegetation	2
Early Application of Road Base	1

Table 1.2
Sediment Entrapment Facility Limitations

	Allowable Limits		
Sediment Control Facility	**Max Tributary Drainage Area (ac)**	**Max Tributary Slope Lengths (ft)**	**Tributary Slope Gradients**
Sod Filter Strips	n/a	50	6:1 (17%)
Silt Fence	0.50 per 100 lineal ft	50	2:1 (50%)
		75	3:1
		125	4:1
		175	5:1
		200	Flatter than 5:1
Silt Ditch	0.5 per 100 lineal ft	n/a	n/a
Sediment Trap	5.0	n/a	n/a
Sediment Basin	n/a	n/a	n/a
Straw Wattle-9" Diameter	n/a	20*	2:1
		20*	3:1
		20*	4:1
		50	5:1
		75	Flatter than 5:1
Compost Sock-8" Diameter	n/a	25*	2:1
		50*	3:1
		75	4:1
		100	5:1
		125	Flatter than 5:1
Compost Sock-12" Diameter	n/a	25	2:1
		50	3:1
		100	4:1

		125 250	5:1 Flatter than 5:1
Compost Sock-18” Diameter	n/a	50 75 150 200 300	2:1 3:1 4:1 5:1 Flatter than 5:1
Compost Sock-24” Diameter	n/a	75 100 200 250 350	2:1 3:1 4:1 5:1 Flatter than 5:1
Compost Berm	n/a	25 50 100 125 250	2:1 3:1 4:1 5:1 Flatter than 5:1

Table 1.3 Nonstructural BMP Requirements for Various Projects	
Nonstructural BMP	**Project Description and Requirement**
Good Housekeeping	Required for all projects.
Spill Prevention and Response	Small projects with nonreportable quantities of hazardous materials: select BMPs as appropriate. Medium sized projects with nonreportable quantities of hazardous materials: selected BMPs as appropriate; spill prevention plan reviewed on case by case basis. Reportable quantities of hazardous materials or large projects: spill prevention plan required.

Table 1.4 Advantages and Disadvantages of BMPs for Spill Prevention and Response BMPs
Best Management Practice Advantages Disadvantages
Drip pans. Pans used to contain small volumes of leaks. Inexpensive; simple installation and operation; possible reuse/recycle of material; empty/discarded containers can be used as drip pans. Small volumes; inspected and cleaned frequently; must be secured during poor weather conditions, and personnel must be trained in proper disposal methods.
Covering. Enclosure of outdoor materials, equipment, containers, or processes. Simple and effective; usually inexpensive. Frequent inspection, possible health/safety problems if built over certain activities, large structures can be expensive.
Vehicle positioning. Locating trucks or rail cars to prevent spills during transfer of materials. Inexpensive, easy, effective. May require redesign of loading and unloading areas, requires signage to designated areas.
Loading/Unloading by Air
Pressure or Vacuum. For transfer of dry chemicals or solids. Quick and simple; economical if materials can be recovered; minimize exposure of pollutants to storm water. Costly to install and maintain; may be inappropriate for denser materials, site-specific design; dust collectors may need permit under Clean Air Act.
Sweeping. With brooms to remove small quantities of dry chemicals/solids exposed to precipitation. Inexpensive, no special training; recycling opportunities. Labor-intensive; limited to small releases of dry materials, requires disposal to solid waste container.
Shoveling. For removal of large quantities of dry materials, wet solids and sludge. Inexpensive; recycling opportunities, remediate larger releases; wet and dry releases. Labor-intensive; not appropriate for large spills, requires backfill of excavated areas to maintain grade.
Excavation. By plow or backhoe for large releases of dry material and contaminated areas. Cost-effective for cleaning up dry materials release; common and simple. Less precise, less recycling and reuse opportunities, may require imported material for backfill.
Dust Control (Industrial). Water spraying, negative pressure systems, collector systems, filter systems, street sweeping. May reduce respiratory problems in employees around the site; may cause less loss of material and save money; efficient collection of larger dust particles. More expensive than manual systems; difficult to maintain by plant personnel; labor and equipment intensive; street sweepers may not be effective for all pollutants.
Signs and Labels. Inexpensive and easily used. Must be updated/maintained so they are legible, subject to vandalism and loss.

Table 1.4 **Advantages and Disadvantages of BMPs for Spill Prevention and Response BMPs**
Security. To prevent accidental or intentional release of materials. Preventative safeguard; easier detection of vandals, thieves, spills, leaks, releases; prevents spills with better lighting, no unauthorized access to facility. May not be feasible for smaller facilities; may be costly; may increase energy costs due to increased lighting; dispersed locations require individuals enclosures, requires maintenance.
Area Control Measures. Good housekeeping measures, brushing off clothing before leaving area, etc. Easy to implement; results in cleaner facility and improved work environment. May be seen as tedious by employees and may not be followed.
Preservation of Natural Vegetation. Can handle more storm water runoff than newly seeded areas; effective immediately; increases filter capacity; enhances aesthetics; provides areas for infiltration; wildlife can remain undisturbed; provides noise buffers; less maintenance than new vegetation. Planning required to preserve and maintain existing vegetation; may not be cost-effective with high land costs; may constrict area available for construction activities, may require signage or fencing, subject to disturbance.
Temporary Seeding. Short-term vegetative cover on disturbed areas. Inexpensive and easy to do; establishes plant cover quickly in good conditions; stabilizes soils well; aesthetic; sedimentation controls for other site areas; helps reduce maintenance costs of other controls. Requires soil preparation, may require mulching or reseeding of failed areas, seasonally limited, may require signage or fencing, subject to disturbance.

Table 1.5 Maintenance Activities for Erosion and Sediment Control BMPs
Vehicle Tracking Pad. The street areas adjacent to the tracking pad shall be cleaned daily at the end of each construction day with a street sweeper with vacuum capabilities. New rock shall be added to the tracking pad whenever the existing rock becomes buried. Periodic top-dressing with additional rock, or removal and reinstallation of the pad may be necessary to prevent tracking of mud onto paved roads.
Grading. Periodically check all graded areas and the supporting erosion and sediment control practices, especially after heavy rainfalls. Promptly remove all sediment from diversions and other water-disposal practices. If washouts or breaks occur, repair them immediately. Promptly maintain small, eroded areas before they become significant gullies.
Check Dams. Inspect check dams and drainage ways for damage after each runoff event. Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam. Correct all damage immediately. If significant erosion occurs between dams, additional protection may be required. This may include a protective liner in that portion of the channel or placing additional check dams. Remove sediment accumulated behind the dams as needed to prevent damage to channel vegetation, allow the channel to drain through the check dam, and prevent large flows from carrying sediment over the dam. Add materials or remove and replace materials in the dams as needed to maintain design height, cross section, and flow through characteristics.
Silt Fence. Inspect silt fence at least once a week and after each rainfall event of greater than 0.5 inches. Make any required repairs immediately. Repair scoured areas on the back side of the fence at this time to prevent future problems. Repair silt fence fabric that has torn, collapsed, decomposed or otherwise become ineffective within 24 hours of discovery. Remove silt deposits once they reach 30 percent of the height of the fence to provide storage volume for the next rain and to reduce pressure on the fence. Silt fences are to be removed upon stabilization of the contributing drainage area. Accumulated sediment may be spread to form a surface for turf or other vegetation establishment, or disposed of elsewhere. The area should be reshaped and revegetated to permit natural drainage.

Table 1.5 Maintenance Activities for Erosion and Sediment Control BMPs
Compost Socks, Straw Wattles, Excelsior Logs. Inspect device at least once a week and after each rainfall event of greater than 0.5 inches. Make any required repairs immediately. Repair scoured areas on the back side of the device at this time to prevent future problems. Repair the device fabric that has torn, decomposed or otherwise become ineffective within 24 hours of discovery. Remove silt deposits once they reach 33 percent of the height of the device to provide storage volume for the next rain. These devices shall be routinely inspected to make sure they hold their shape and are producing adequate flow through.
Compost Berms. Inspect the compost berm at least once a week and after each rainfall event of greater than 0.5 inches. Make any required repairs immediately. Repair scoured areas on the back side of the berm at this time to prevent future problems. Remove silt deposits once they reach 30 percent of the height of the berm to provide storage volume for the next rain.
Inlet Protection. Inspect inlet protection devices at least once a week and after each rainfall event of greater than 0.5 inches. Make any required repairs immediately. Remove silt deposits once they reach 30 percent of the height of the device to provide storage volume for the next rain. Geotextiles and rock shall be cleaned or replaced as needed due to plugging and/or draw down restrictions.
Sediment Basins and Traps. Perform inspections at least once a week and after each rainfall event of greater than 0.5 inches. Remove sediment when the basin or trap becomes half full. Excavated sediment must be placed in a location where it will not easily erode again. If the outlet becomes clogged with sediment, it shall be cleaned to restore its flow capacity.
Mulch and Compost. Inspect mulch and compost blankets periodically, and after rainstorms to check for rill erosion, dislocation or failure. Where erosion is observed, apply additional mulch or compost.
Erosion Control Blankets and Turf Reinforcement Mats. Inspect at least once a week and after each rainfall event of greater than 0.5 inches. Make any required repairs immediately.

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Chapter 2

Post-Construction Stormwater Quality

Chapter 2

Post Construction Stormwater Quality

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Chapter 2 Post-Construction Stormwater Quality

2.1 General Statement

Land development changes not only the physical, but also the chemical and biological conditions of Rapid City's waterways and water resources. This section describes the changes that occur due to development, the resulting stormwater runoff impacts, and the Best Management Practices (BMPs) which can be used for improving stormwater quality. A stormwater treatment site plan is required per Rapid City Municipal Ordinance 5356. Listed below are the items required to be shown on the stormwater treatment site plan.

Stormwater Treatment Site Plan. The stormwater treatment site plan shall be 22" x 34" and be prepared at a minimum scale of one (1) inch equals one hundred (100) feet and include the following:

1. Property line. The property lines for the site where the work will be performed.

2. Existing topography. Existing topography with one- (1) or two foot (2) contour intervals, and encompass the area shown on the final drainage plan (drawn to scale). Additional information may be required.

3. Proposed topography. Proposed topography with one (1) or two foot (2) contour intervals; the map shall show elevations, dimensions (drawn to scale), location, extent, and the slope of all proposed grading.

4. Existing Facilities. Location of any existing structures or hydrologic features on the site.

5. Existing Conditions. Location of all structures or natural features on the land adjacent to the site as required for the final drainage plan. The plan shall show the location of the street, street right-of-way, storm sewer, channel, or other waters receiving storm water runoff from the site.

6. Proposed Facilities. Show all proposed structures and development on the site.

7. Proposed stormwater treatment facilities.

8. Detail drawings. Design drawings of the proposed stormwater treatment facilities.

9. Impervious area and water quality volume calculations.

2.1.1 Development Changes Land and Runoff

When land is developed, the hydrology, or the natural cycle of water is disrupted and altered. Clearing removes the vegetation that intercepts, slows and returns rainfall to the air through evaporation and transpiration. Grading flattens hilly terrain and fills in natural depressions that slow and provide temporary storage for rainfall. The topsoil and sponge-like layers of humus are scraped and removed and the remaining subsoil is compacted. Rainfall that once seeped into the ground now runs off the surface. The addition of buildings, roadways, parking lots and other surfaces that are impervious to rainfall further reduces infiltration and increases runoff.

Depending on the magnitude of changes to the land surface, the total runoff volume can increase dramatically. These changes not only increase the total volume of runoff, but also accelerate the rate at which runoff flows across the land. This effect is further exacerbated by drainage systems such as gutters, storm sewers and lined channels that are designed to quickly carry runoff to creeks and lakes.

Development and impervious surfaces also reduce the amount of water that infiltrates into the soil and groundwater, thus reducing the amount of water that can recharge aquifers and feed creek flow during periods of dry weather.

Finally, development and urbanization affect not only the quantity of stormwater runoff, but also its quality. Development increases both the concentration and types of pollutants carried by runoff. As it runs over rooftops and lawns, parking lots and industrial sites, stormwater picks up and transports a variety of contaminants and pollutants to downstream waterbodies. The loss of the original topsoil and vegetation removes a valuable filtering mechanism for stormwater runoff.

The cumulative impact of development and urban activities, and the resultant changes to both stormwater quantity and quality in the entire land area that drains to a creek or lake determines the conditions of the waterbody. This land area that drains to the waterbody is known as its watershed. Urban development within a watershed has a number of direct impacts on downstream waters and waterways. These impacts include:

- Changes to stream flow
- Changes to stream geometry
- Impacts to aquatic habitat
- Water quality impacts

2.1.2 Changes to Stream Flow

Urban development alters the hydrology of watersheds and streams by disrupting the natural water cycle. This results in:

- <u>Increased Runoff Volumes</u> – Land surface changes can dramatically increase the total volume of runoff generated in a developed watershed.

- Increased Peak Runoff Discharges – Increased peak discharges for a developed watershed can be two to five times higher than those for an undisturbed watershed.
- Greater Runoff Velocities – Impervious surfaces and compacted soils, as well as improvements to the drainage system such as storm drains, pipes and ditches, increase the speed at which rainfall runs off land surfaces within a watershed.
- Timing – As runoff velocities increase, it takes less time for water to run off the land and reach a creek or other waterbody.
- Increased Frequency of Bankfull and Near Bankfull Events – Increased runoff volumes and peak flows increase the frequency and duration of smaller bankfull and near bankfull events which are the primary channel forming events.
- Increased Flooding – Increased runoff volumes and peaks also increase the frequency, duration and severity of out-of-bank flooding.
- Lower Dry Weather Flows (Baseflow) – Reduced infiltration of stormwater runoff causes creeks to have less baseflow during dry weather periods and reduces the amount of rainfall recharging groundwater aquifers.

2.1.3 Changes to Creek Geometry

The changes in the rates and amounts of runoff from developed watersheds directly affect the morphology, or physical shape and character, of Rapid City's waterways. Some of the impacts due to urban development include:

- Creek Widening and Bank Erosion – Creek channels widen to accommodate and convey the increased runoff and higher stream flows from developed areas. More frequent small and moderate runoff events undercut and scour the lower parts of the creek bank, causing the steeper banks to slump and collapse during larger storms. Higher flow velocities further increase creek bank erosion rates. A creek can widen many times its original size due to post-development runoff.
- Creek Downcutting – Another way that creeks accommodate higher flows is by downcutting their creek bed. This causes instability in the creek profile, or elevation along a creek's flow path, which increases velocity and triggers further channel erosion both upstream and downstream.
- Loss of Riparian Tree Canopy – As creek banks are gradually undercut and slump into the channel, the trees that had protected the banks are exposed at the roots. This leaves them more likely to be uprooted during major storms, further weakening bank structure.
- Changes in the Channel Bed Due to Sedimentation – Due to channel erosion and other sources upstream, sediments are deposited in the stream as sandbars and other features, covering the channel bed, or substrate, with shifting deposits of mud, silt and sand.
- Increase in the Floodplain Elevation – To accommodate the higher peak flow rate, a stream's floodplain elevation typically increases following development in a watershed due to higher peak flows. This problem is compounded by building and filling in floodplain areas, which cause flood heights to rise even further.

Property and structures that had not previously been subject to flooding may now be at risk.

2.1.4 Impacts to Aquatic Habitat

Along with changes in stream hydrology and morphology, the habitat value of creeks diminishes due to development in a wastershed. Impacts on habitat include:

- Degradation of Habitat Structure – Higher and faster flows due to development can scour channels and wash away entire biological communities. Creek bank erosion and the loss of riparian vegetation reduce habitat for many fish species and other aquatic life, while sediment deposits can smother bottom-dwelling organisms and aquatic habitat.
- Loss of Pool-Riffle Structure – Creeks draining undeveloped watersheds often contain pools of deeper, more slowly flowing water that alternate with "riffles" or shoals of shallower, faster flowing water. These pools and riffles provide valuable habitat for fish and aquatic insects. As a result of the increased flows and sediment loads from urban watersheds, the pools and riffles disappear and are replaced with more uniform, and often shallower, streambeds that provide less varied aquatic habitat.
- Reduce Baseflows – Reduced baseflows due to increased impervious cover in a watershed and the loss of rainfall infiltration into the soil and water table adversely affect in-stream habitats, especially during periods of drought.
- Increased Creek Temperature – Runoff from warm impervious areas, storage in impoundments, loss of riparian vegetation and shallow channels can all cause an increase in temperature in urban creeks. Increased temperatures can reduce dissolved oxygen levels and disrupt the food chain. Certain aquatic species can only survive within a narrow temperature range. Thermal problems are especially critical for cold water fisheries such as Rapid Creek.
- Decline in Abundance and Biodiversity – When there is a reduction in various habitats and habitat quality, both the number and the variety, or diversity, of organisms (wetland plants, fish, macroinvertebrates, etc.) are also reduced.

Fish and other aquatic organisms are impacted not only by the habitat changes brought on by increased stormwater runoff quantity, but are often also adversely affected by water quality changes due to development and resultant land use activities in a watershed.

2.1.5 Water Quality Impacts

Nonpoint source pollution, which is the primary cause of polluted stormwater runoff and water quality impairment, comes from many diffuse or scattered sources – many of which are the result of human activities within a watershed. Development concentrates and increases the amount of these nonpoint source pollutants. As stormwater runoff moves across the land surface, it picks up and carries away both natural and human-made pollutants, depositing them into Rapid City's creeks, lakes, wetlands, and underground aquifers. Nonpoint source pollution is the leading source of water quality degradation in Rapid City.

Water quality degradation in urbanizing watersheds starts when development begins. Erosion from construction sites and other disturbed areas contribute large amounts of sediment to various waterbodies. As construction and development proceed, impervious surfaces replace the natural land cover and pollutants from human activities begin to accumulate on these surfaces. During storm events, these pollutants are then washed off into the various waterbodies. Stormwater also causes discharges from sewer overflows and leaching from septic tanks. There are a number of other causes of nonpoint source pollution in urban areas that are not specifically related to wet weather events including leaking sewer pipes, sanitary sewage spills, and illicit discharge of commercial/industrial wastewater and wash waters to storm drains.

Due to the magnitude of the problem, it is important to understand the nature and sources of urban stormwater pollution. Some of the most frequently occurring pollution impacts and their sources for urban creeks are:

- Reduced Oxygen in Creeks – The decomposition process of organic matter uses up dissolved oxygen (DO) in the water, which is essential to fish and other aquatic life. As organic matter is washed off by stormwater, dissolved oxygen levels in receiving waters can be rapidly depleted. If the DO deficit is severe enough, fish kills may occur and stream life can weaken and die. In addition, oxygen depletion can affect the release of toxic chemicals and nutrients from sediments deposited in a waterway.

  All forms of organic matter in urban stormwater runoff such as leaves, grass clippings and pet waste contribute to the problem. In addition, there are a number of non-stormwater discharges of organic matter to surface waters such as sanitary sewer leakage and septic tank leaching.

- Nutrient Enrichment – Runoff from urban watersheds contains increased nutrients such as nitrogen or phosphorus compounds. Increased nutrient levels are a problem as they promote weed and algae growth in lakes, creeks, and estuaries. Algae blooms block sunlight from reaching the underwater grasses and deplete oxygen in bottom waters. In addition, nitrification of ammonia by microorganisms can consume dissolved oxygen, while nitrates can contaminate groundwater supplies. Sources of nutrients in the urban environment include washoff of fertilizers and vegetative litter, animal wastes, sewer overflows and leaks, septic tank seepage, detergents, and the dry and wet fallout of materials in the atmosphere.
- Microbial Contamination – The level of bacteria, viruses and other microbes found in urban stormwater runoff often exceeds public health standards for water contact recreation such as swimming and wading. Microbes can also increase the cost of treating drinking water. The main sources of these contaminants are sewer

overflows, septic tanks, pet waste, and urban wildlife such as pigeons, waterfowl, squirrels, and raccoons.

- Hydrocarbons – Oils, greases and gasoline contain a wide array of hydrocarbon compounds, some of which have shown to be carcinogenic, tumorigenic and mutagenic in certain species of fish. In addition, in large quantities, oil can impact drinking water supplies and affect recreational use of waters. Oils and other hydrocarbons are washed off roads and parking lots, primarily due to engine leakage from vehicles. Other sources include the improper disposal of motor oil in storm drains and creeks, spills at fueling stations and restaurant grease traps.
- Toxic Materials – Besides oils and greases, urban stormwater runoff can contain a wide variety of other toxicants and compounds including heavy metals such as lead, zinc, copper, and cadmium, and organic pollutants such as pesticides, PCBs, and phenols. These contaminants are of concern because they are toxic to aquatic organisms and can bioaccumulate in the food chain. In addition, they also impair drinking water sources and human health. Many of these toxicants accumulate in the sediments of creeks and lakes. Sources of these contaminants include industrial and commercial sites, urban surfaces such as rooftops and painted areas, vehicles and other machinery, improperly disposed household chemicals, landfills, hazardous waste sites and atmospheric deposition.
- Sedimentation – Eroded soils are a common component of urban stormwater and are a pollutant in their own right. Excessive sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth and reproduction. Sediment particles transport other pollutants that are attached to their surfaces including nutrients, trace metals and hydrocarbons. High turbidity due to sediment increases the cost of treating drinking water and reduces the value of surface waters for industrial and recreational use. Sediment also fills ditches and small streams and clogs storm sewers and pipes, causing flooding and property damage. Erosion from construction sites, exposed soils, street runoff, and creek bank erosion are the primary sources of sediment in urban runoff.
- Higher Water Temperatures – As runoff flows over impervious surfaces such as asphalt and concrete, it increases in temperature before reaching a creek or lake. Water temperatures are also increased due to shallow lakes and impoundments along a watercourse as well as fewer trees along creeks to shade the water. Since warm water can hold less dissolved oxygen than cold water, this “thermal pollution” further reduces oxygen levels in depleted urban creeks. Temperature changes can severely disrupt certain aquatic species, such as trout and stoneflies, which can survive only within a narrow temperature range.
- Trash and Debris – Considerable quantities of trash and other debris are washed through storm drain systems and into creeks and lakes. The primary impact is the creation of an aesthetic “eyesore” in waterways and a reduction in recreational value. In smaller creeks, debris can cause blockage of the channel, which can result in localized flooding and erosion.

2.1.6 Effects on Lakes

Stormwater runoff into lakes and reservoirs can have some unique negative effects. A notable impact of urban runoff is the filing in of lakes with sediment. Another significant water quality impact on lakes related to stormwater runoff is nutrient enrichment. This can result in the undesirable growth of algae and aquatic plants. Lakes do not flush contaminants as quickly as creeks and act as sinks for nutrients, metals and sediments. This means that lakes can take longer to recover if contaminated.

2.1.7 Addressing Stormwater Impacts

The focus of this Manual is how to effectively deal with the impacts of urban stormwater runoff on water quality through effective and comprehensive *stormwater quaility management.* Stormwater quality management involves the prevention and mitigation of stormwater runoff quantity and quality impacts as described in this chapter through a variety of methods and mechanisms.

Developers in Rapid City can effectively implement stormwater management to address the impacts of new development and redevelopment, and both prevent and mitigate water quality problems associated with stormwater runoff. This is accomplished by:

- ✓ Developing land in a way that minimizes its impact on a watershed, and reduces both the amount of runoff and pollutants generated.
- ✓ Using the most current and effective erosion and sediment control practices during the construction phase of development.
- ✓ Controlling stormwater runoff peaks, volumes and velocities to prevent streambank channel erosion.
- ✓ Implementing pollution prevention practices to prevent stormwater from becoming contaminated in the first place.
- ✓ Using various techniques to maintain groundwater recharge.

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2.2 Stormwater Sizing Criteria

2.2.1 Provide Water Quality Capture Volume

A fundamental requirement for any site addressing storm water quality is to provide water quality capture volume (WQCV). One or more of five types of water quality basins, each draining slowly to provide for long-term settling of sediment particles, may be selected to provide WQCV as shown in **Figure 2.18**. These five BMPs are described in detail in the following sections:

Section	Structural BMP
2.3.3	**Porous Landscape Detention**
2.3.5	**Extended Detention Basin**
2.3.6	**Sand Filter Extended Detention Basin**
2.3.7	**Constructed Wetland Basin**

The following BMP must be used with a BMP that meets the WQCV criteria. It does not provide WQCV by itself. It can however provide additional water quality treatment and aesthetic value:

Section	Structural BMP
2.3.8	**Constructed Wetland Channel**

The following BMP does not meet the WQCV criteria. It is only intended for use in highly urbanized areas, such as redevelopment conditions, where existing development precludes the ability to meet the WQCV criteria. This BMP must be approved for use by the City Engineer. In determining BMP approval, preference will be given to structural BMPs providing WQCV as listed in this section.

Section	Structural BMP
2.3.9	**Water Quality Catch Basins and Water Quality Catch Basin Inserts**

The following BMP meets the WQCV criteria. Provide runoff capture volume as indicated in **Section 2.3.10.**

Section	Structural BMP
2.3.10	**Bioretention**

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2.3 Best Management Practices (BMPs)

2.3.1 Grass Buffer

Description

Grass buffer strips are uniformly graded and densely vegetated areas of turf grass. They require sheet flow to promote filtration, infiltration, and settling to reduce runoff pollutants. Grass buffers differ from grass swales as they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. They can be used to remove larger sediment from runoff from impervious areas.

Whenever concentrated runoff occurs, it should be evenly distributed across the width of the buffer via a flow spreader. This may be a porous pavement strip or another type of structure used to achieve uniform sheet-flow conditions. Grass buffers can also be combined with riparian zones in treating sheet flows and in stabilizing channel banks adjacent to major drainage ways and receiving waters. Grass buffers can be interspersed with shrubs and trees to improve their aesthetics and to provide shading.

General Application

A grass buffer can be used in residential and commercial areas. They are typically located adjacent to impervious areas. When used, they should be incorporated into site drainage, street drainage, and master drainage planning. Because their effectiveness depends on having an evenly distributed sheet flow over their surface, the size of the contributing area and the associated volume of runoff have to be limited. Flow can be directly accepted from an impervious area such as a parking lot or building roofs, provided the flow is distributed uniformly over the strip. Grass buffers provide only marginal pollutant removal and require that follow-up structural BMPs be provided. They do, however, help to reduce some of the runoff volume from small storms.

General Properties

a. General

The grass and other vegetation provide aesthetically pleasing green space, which can be incorporated into a development landscaping plan. Eventually, the grass strip next to the spreader or the pavement will accumulate sufficient sediment to block runoff. At that point, a portion of the grass buffer strip will need to be removed and replaced.

b. Physical Site Suitability

After final grading, the site should have a uniform slope and be capable of maintaining an even sheet flow throughout without concentrating runoff into shallow swales or rivulets. The allowable tributary area depends on the width, length, and the soils that lay under the grass buffer. Hydrologic Soil Groups A and B provide the best infiltration capacity, while Soil Groups C and D provide best site stability. The swelling potential of underlying soils should also be taken into account in how the soils may affect adjacent structures and pavement when water is delivered to the grassed areas.

c. Pollutant Removal

Pollutant removal depends on many factors, such as soil permeability; site slope; the flow path length along the buffer; the characteristics of drainage area; runoff volumes and velocities; and the type of vegetation. The general pollutant removal of both particulate and soluble pollutants is projected to be low to moderate. Grass buffers rely primarily upon the settling and interception of solids, and, to only a minor degree, on biological uptake and runoff infiltration. See **Table 2.1** (Appendix) for an estimated range of pollutant removals. Maintenance requirements for this BMP are listed in **Table 2.2** (Appendix).

Design Considerations

Design of grass buffers is based primarily on maintaining sheet-flow conditions across a uniformly graded, dense grass cover strip. When a grass buffer is used over unstable slopes, soils, or vegetation, rills and gullies will form that will disrupt sheet flow. The resultant short-circuiting will invalidate the intended water quality benefits. Grass buffers should be protected from excessive pedestrian or vehicular traffic that can damage the grass cover and affect even sheet-flow distribution. A mixture of grass and trees may offer benefits for slope stability and improved aesthetics.

Design Procedure and Criteria

The following steps outline the grass buffer design procedure and criteria. Figure **2.15** (Appendix) is a schematic of the facility and its components.

a. Step 1: Design Discharge

Determine the 2-year peak flow rate of the area draining to the grass buffer. Also, determine the flow control type: sheet or concentrated.

b. Step 2: Minimum Length

Calculate the minimum length (normal to flow) of the grass buffer. The upstream flow needs to be uniformly distributed over this length. General guidance suggests that the hydraulic load should not exceed 0.05 cfs/linear foot of buffer during a 2-year storm to maintain a sheet flow of less than 1 inch throughout dense grass that is at least 2 inches high. The minimum design length (normal to flow) is therefore calculated as:

$$L_G = \frac{Q_{2-year}}{0.05} \qquad \text{(Equation 6)}$$

In which:

L_G = Minimum design length (feet)

Q_{2-year} = Peak discharge supplied to the grass buffers by a 2-year event (cfs)

Longer lengths may be used.

c. Step 3: Minimum Width

The minimum width (WG) (the distance along the sheet flow direction) of the grass buffer shall be determined by the following criteria for onsite and concentrated flow control conditions:

- Sheet Flow Control (use the larger value)

  $W_G = 0.2L_I$ or 10 feet (Equation 7)

  In which:

  L_I = The length of flow path of the sheet flow over the upstream impervious surface (feet)

- Concentrated Flow Control (use the larger value)

  $W_G = 0.15(A_t/L_t)$ or 10 feet (Equation 8)

  In which:

  A_t = The tributary area (square feet)

  L_t = The length of the tributary inflow normal to flow spreader (i.e., width of flow spreader (feet))

  A generally rectangular-shaped strip is preferred and should be free of gullies or rills that concentrate the overland flow.

d. Step 4: Maximum Slope

Design slope in the direction of flow shall not exceed 4 percent.

e. Step 5: Flow Distribution

Incorporate a device on the upstream end of the buffer to evenly distribute flows along the design length. Slotted curbing, modular block porous pavement (MBP), or other spreader devices can be used to apply flows. Concentrated flow supplied to the grass buffer must use a level spreader (or a similar concept) to evenly distribute flow onto the buffer.

f. Step 6: Vegetation

Vegetate the grass buffer with dense turf to promote sedimentation and entrapment and to protect against erosion.

g. Step 7: Outflow Collection

Provide a means for outflow collection. Most of the runoff during significant events will not be infiltrated and will require a collection and conveyance system. In some cases, the use of under-drains can maintain better infiltration rates as the soils saturate and help dry out the buffer after storms or irrigation periods.

2.3.2 Grass Swale

Description

They are densely vegetated drainageways with low-pitched side slopes that collect and slowly convey runoff. Design of their longitudinal slope and cross section size forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion. Berms or check dams should be installed perpendicular to the flow as needed to slow it down and encourage settling and infiltration.

General Application

A grass swale can be located to collect overland flows from areas such as parking lots, buildings, residential yards, roadways, and grass buffer strips. They can be made a part of the plans to minimize a directly connected impervious area by using them as an alternative to a curb-and-gutter system if approved by the City Engineer. A grass swale is set below adjacent ground level, and runoff enters the swales over grassy banks. The potential exists for wetland vegetation to become established if the swale experiences standing water or if there is a base flow. A site with a base flow should be managed as either a swale with an unlined trickle channel, or as a wetland bottom channel, the latter providing an additional BMP to storm water runoff.

General Properties

a. General

A grass swale can be more aesthetically pleasing than concrete or rock-lined drainage systems. Although limited by the infiltration capacity of local soils, this BMP can also provide some reduction in runoff volumes from small storms. Dense grasses can reduce flow velocities and protect against erosion during larger storm events. Swales in residential and commercial settings can also be used to limit the extent of directly connected impervious areas.

b. Physical Site Suitability

A grass swale is practical only at sites with general ground slopes of less than 4 percent and are definitely not practical for sites steeper than 6 percent. The longitudinal slopes of a grass swale should be kept to less than 1.0 percent, which often necessitates the use of grade control checks or drop structures. Where the general terrain slope exceeds 4 percent, a grass swale is often practical only on the upslope side of the adjacent street.

When soils with high permeability (for example, Class A or B) are available, the swale will infiltrate a portion of the runoff into the ground, but such soils are not required for effective application of this BMP. When Class C and D soils are present, the use of a sand/gravel underdrain is recommended.

c. Pollutant Removal

Removal rates reported in literature vary and fall into the low to medium range. Under good soil conditions and low-flow velocities, moderate removal of suspended solids and associated other constituents can be expected. If soil conditions permit, infiltration can remove low to moderate loads of soluble pollutants when flow velocities are very low. As a result, small frequently occurring storms can benefit the most. See **Table 2.1** (Appendix) for estimated ranges in pollutant removal rates by this BMP. Maintenance considerations for this BMP are listed in **Table 2.3** (Appendix).

Design Considerations and Criteria

Figure 2.16 (Appendix) shows trapezoidal and triangular swale configurations. A grass swale is sized to maintain a low velocity during small storms and to collect and convey larger runoff events, all for the projected fully developed land use conditions.

A healthy turf grass cover must be developed to foster dense vegetation. Permanent irrigation in some cases may be necessary. Judicious use of grass swales can replace both the curb-and-gutter systems and greatly reduce the storm sewer systems in the upper portions of each watershed when designed to convey the "initial storm" (for example, a 2- or a 5-year storm) at slow velocities. However, if one or both sides of the grass swale are also to be used as a grass buffer, the design of the grass buffer has to follow the requirements of **Section 2.3.1**, Grass Buffers.

Design Procedure and Criteria

The following steps outline the grass swale design procedure and criteria.

a. Step 1: Design Discharge

Determine the 2-year flow rate in the proposed grass swale for water quality. The swale shall also meet the conveyance requirements of the Stormwater Design Criteria Manual.

b. Step 2: Swale Geometry

Select geometry for the grass swale. The cross section should be trapezoidal or triangular. The side slopes shall be flatter than 4:1 (horizontal/ vertical). The wider the wetted area of the swale, the slower the flow and the more effective it is in removing pollutants.

c. Step 3: Longitudinal Slope

Maintain a longitudinal slope for the grass swale between 0.2 and 1.0 percent. If the longitudinal slope requirements can not be satisfied with available terrain, grade control checks or small drop structures must be incorporated to maintain the required longitudinal slope. If the slope of the swale exceeds 0.5 percent, the swale must be vegetated with irrigated turf grass to establish the vegetation.

d. Step 4: Flow Velocity and Depth

Calculate the velocity and depth of flow through the swale. Based on Manning's equation and a Manning's roughness coefficient of n=0.05, find the channel velocity and depth using the 2-year flow rate determined in Step 1.

e. Step 5: Maximum Flow Velocity

Maximum flow velocity of the channel shall not exceed 1.5 feet per second and the maximum flow depth shall not exceed 2 feet at the 2-year peak flow rate. If these conditions are not attained, repeat steps 2 through 4, each time altering the depth and bottom width or longitudinal slopes until these criteria are satisfied.

f. Step 6: Vegetation

Vegetate the grass swale with dense turf grass to promote sedimentation, filtration, and nutrient uptake, and to limit erosion through maintenance of low-flow velocities.

g. Step 7: Street and Driveway Crossings

If applicable, small culverts at each street crossing and/or driveway crossing may be used to provide onsite WQCV in a similar fashion to an extended detention basin (if adequate volume is available).

h. Step 8: Drainage and Flood Control

Check the water surface during larger storms such as the 5-year through the 100-year event to assure that drainage from these larger events is being controlled without flooding critical areas.

2.3.3 Porous Landscape Detention

Description

Porous landscape detention consists of a low lying vegetated area underlain by a sand bed with an underdrain pipe. A shallow surcharge_zone exists above the porous landscape detention for temporary storage of the WQCV. During a storm, accumulated runoff ponds in the vegetated zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, or storm sewer. This BMP allows WQCV to be provided on a site that has little open area available for storm water detention.

General Application

a. Location

A porous landscape detention can be located in just about any of the open areas of a site. It is ideally suited for small installations such as:

- Parking lot islands
- Street medians
- Roadside swale features
- Site entrance or buffer features

This BMP may also be implemented at a larger scale, serving as an infiltration basin for an entire site if desired, provided the water quality capture volume and average depth requirements contained in this section are met.

Vegetation may consist of irrigated bluegrass or natural grasses with shrub and tree plantings if desired.

General Properties

a. General

A primary advantage of porous landscape detention is making it possible to provide WQCV on a site while reducing the impact on developable land. It works well with irrigated bluegrass, whereas experience has shown that conditions in the bottom of extended detention basins become too wet for bluegrass. A porous landscape detention provides a natural moisture source for vegetation, enabling "green areas" to exist with reduced irrigation.

The primary drawback of porous landscape detention is a potential for clogging if a moderate to high level of silts and clays is allowed to flow into the facility. Also, this BMP needs to be avoided close to building foundations or other areas where expansive soils are present, although an underdrain and impermeable liner can reduce some of this concern.

b. Physical Site Suitability

If an underdrain system is incorporated into this BMP, porous landscape detention is suited for about any site regardless of in-situ soil type. If sandy soils are present, the facility can be installed without an underdrain (infiltration option); sandy subsoils are not a requirement. This BMP has a relatively flat surface area, and may be more difficult to incorporate into steeply sloping terrain.

c. Pollutant Removal

Although not tested to date in the Rapid City area, the amount of pollutant removed by this BMP should be significant and should equal or exceed the removal rates provided by sand filters. In addition to settling, porous landscape detention provides for filtering, adsorption, and biological uptake of constituents in storm water. See **Table 2.1** (Appendix) for estimated ranges in pollutant removals. See **Table 2.4** (Appendix) for maintenance requirements for a porous landscape detention.

Design Considerations

Figure 2.17 (Appendix) shows a cross section for a porous landscape detention. When implemented using multiple small installations on a site, it is increasingly important to accurately account for each upstream drainage area tributary to each porous landscape detention site to make sure that each facility is properly sized, and that all portions of the development site are directed to a porous landscape detention.

Design Procedure

The following steps outline the porous landscape detention design procedure and criteria.

a. **Step 1: Basin Storage Volume**

Provide a storage volume based on a 12-hour drain time.

- Find the required storage volume (watershed inches of runoff). Using the tributary areas imperviousness, determine the required WQCV (watershed inches of runoff) using **Figure 2.18** (Appendix), based on the porous landscape detention 12-hour drain time.

- Calculate the design volume in cubic feet as follows:

$$Design\ Volume = \left(\frac{WaterQualityCaptureVolume}{12}\right) * Area \quad \text{(Equation 9)}$$

In which:

Area = The watershed area tributary to the porous landscape detention basin (square feet)

b. Step 2: Surface Area:

- Calculate the minimum required surface area as follows:

$$SurfaceArea = \left(\frac{DesignVolume(ft^3)}{d_{av}}\right) \quad \text{(Equation 10)}$$

In which:

d_{av} = average depth (feet) of the porous landscape detention basin.

c. **Step 3: Sand-Peat Media**

Provide, as a minimum, an 18-inch-thick layer of well mixed sand and peat (2/3 sand and 1/3 peat) for plant growth as shown in Figure **2.17**.

Keep the top surface as flat as possible, while avoiding side slopes steeper than 4:1.

When installing in type NRCS Type D or expansive soils and no subdrain outlet is possible, use a total sand-peat mixed layer thickness of 36-inches and no granular subbase.

d. Step 4: Granular Subbase

Whenever an under-drain is used or when the soils are not expansive (i.e., soils are NRCS Type A, B, or C) and an under-drain is not used, use an 8-inch layer of granular subbase with all fractured faces meeting the requirements of AASHTO #67 coarse aggregate.

e. Step 5: Membrane Liner

If expansive or NRCS Type D soils are present, install an impermeable 15 mil thick, or heavier, liner on the bottom and sides of the basin.

If soils are not expansive (i.e., NRCS Type A, B, or C), use porous geotextile fabric to line the entire basin bottom and sides. Porous membrane liner shall be of woven monofilament as manufactured by Carthage Mills-Carthage 15 percent (or equal) having an open surface area of 12–15 percent, with openings equivalent to AOS U.S. Std. Sieve size of 40 to 50.

f. Step 6: WQCV Depth

Maintain an average WQCV depth between 6 inches and 12 inches. Average depth is defined as water volume divided by the water surface area.

2.3.4 Incorporating Water Quality Capture Volume into Storm Water Quantity Detention Basins

Wherever possible, it is recommended that WQCV facilities be incorporated into storm water quantity detention facilities. This is relatively straightforward for an extended detention basin, constructed wetland basin, and a retention pond. The 100-year detention level is provided above the WQCV and the outlet structure is designed to control two or more different releases. **Figures 2.19a and 2.19b** (Appendix) show examples of combined quality/quantity outlet structures. Figure **2.19c (**Appendix) contains typical outlet structure notes applicable to the design of outlet structures.

Storm water quantity detention could be provided above the WQCV for porous pavement and landscape detention, provided the drain times for the larger events are kept short. The following approach is suggested:

- **Water Quality:** The full WQCV is to be provided according to the design procedures documented for the Structural BMP.
- **100-Year Storm:** The WQCV plus the full 100-year detention volume is to be provided.

2.3.5 Extended Detention Basin

Description

An extended detention basin is a sedimentation basin designed to totally drain dry over an extended time after storm water runoff ends. It is an adaptation of a detention basin used for flood control. The primary difference is in the outlet design. The extended detention basin uses a much smaller outlet that extends the draining time of the more frequently occurring runoff events to facilitate pollutant removal. The extended detention basin's drain time for the brim-full water quality capture volume (i.e., time to fully evacuate the design capture volume) of 40 hours is recommended to remove a significant portion of fine particulate pollutants found in urban storm water runoff. Soluble pollutant removal can be somewhat enhanced by providing a small wetland marsh or ponding area in the basin's bottom to promote biological uptake. The basins are considered to be "dry" because they are designed not to have a significant permanent pool of water remaining between storm water runoff events. However, an extended detention basin may develop wetland vegetation and sometimes shallow pools in the bottom portions of the facilities.

General Application

An extended detention basin can be used to enhance storm water runoff quality and reduce peak storm water runoff rates. If these basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use. Also, an extended detention basin can sometimes be retrofitted into existing flood control detention basins.

Extended detention basins can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and are generally used for regional or follow-up treatment. They can also be used as an onsite BMP and work well in conjunction with other BMPs, such as upstream onsite source controls and downstream infiltration/filtration basins or wetland channels. If desired, a flood routing detention volume can be provided above the WQCV of the basin.

General Properties

a. General

An extended detention basin can be designed to provide other benefits such as recreation and open space opportunities in addition to reducing peak runoff rates and improving water quality. They are effective in removing particulate matter and associated heavy metals and other pollutants. As with other BMPs, safety issues need to be addressed through proper design.

b. Physical Site Suitability

Normally, the land required for an extended detention basin is about 0.5 to 2.0 percent of the total tributary development area. In high groundwater areas, instead consider the use of retention ponds in order to avoid many of the problems that can occur when the extended detention basin's bottom is located below the seasonal high water table. Soil maps should be consulted, and soil borings may be needed to establish design geotechnical parameters.

c. Pollutant Removal

The pollutant removal range of an extended detention basin is presented in **Table 2.1** (Appendix). Removal of suspended solids and metals can be moderate to high, and removal of nutrients is low to moderate. The removal of nutrients can be improved when a small shallow pool or wetland is included as part of the basin's bottom or the basin is followed by BMPs more efficient at removing soluble pollutants, such as a filtration system, constructed wetlands, or wetland channels.

The major factor controlling the degree of pollutant removal is the emptying time provided by the outlet. The rate and degree of removal will also depend on influent particle sizes. Metals, oil and grease, and some nutrients have a close affinity for suspended sediment and will be removed partially through sedimentation.

d. Aesthetics and Multiple Uses

Since an extended detention basin is designed to drain very slowly, its bottom and lower portions will be inundated frequently for extended periods of time. Grasses in this frequently inundated zone will tend to die off, with only the species that can survive the specific environment at each site eventually prevailing. In addition, the bottom will be the depository of all the sediment that settles out in the basin. As a result, the bottom can be muddy and may have an undesirable appearance. To reduce this problem and to improve the basin's availability for other uses (such as open space, habitat, and passive recreation), the designer should provide a lower-stage basin as suggested in the Two-Stage Design procedure. As an alternative, a retention pond could be used, in which the settling occurs primarily within the permanent pool.

e. Design Considerations

Whenever desirable and feasible, incorporate the extended detention basin within a larger flood control basin. Whenever possible, try to provide for other urban uses such as passive recreation and wildlife habitat. If multiple uses are being contemplated, consider the multiple-stage detention basin to limit inundation of passive recreational areas to one or two occurrences a year. Generally, the area within the WQCV is not well suited for active recreation facilities such as ballparks, playing fields, and picnic areas. These are best located above the WQCV pool level. **Figure 2.20** (Appendix) shows a representative layout of an extended detention basin.

Perforated outlet and trash rack configurations are illustrated in Figures **2.19a, 2.19b, and 2.21 through 2.25** (Appendix). **Figure 2.21** (Appendix) equates the WQCV that needs to be emptied over 40 hours to the total required area of perforations per row for the standard configurations shown in that section. The chart is based on the rows being equally spaced vertically at 4-inch centers. The total area of perforations per row is then used to determine the number of uniformly sized holes per row as shown in **Figures 2.22 and 2.23** (Appendix). One or more perforated columns on a perforated orifice plate integrated into the front of the outlet can be used. Other types of outlets may also be used, provided they control the release of the WQCV in a manner consistent with the drain time requirements.

Although the soil types beneath the pond seldom prevent the use of this BMP, they should be considered during design. Any potential exfiltration capacity should be considered a short-term characteristic and ignored in the design of the WQCV because exfiltration will decrease over time as the soils clog with fine sediment and as the groundwater beneath the basin develops a mound that surfaces into the basin.

High groundwater should not preclude the use of an extended detention basin. Groundwater, however, should be considered during design and construction, and the outlet design must account for any upstream base flows that enter the basin or that may result from groundwater surfacing within the basin itself.

Stable, all weather access to critical elements of the pond, such as the inflow area, outlet, spillway, and sediment collection areas, must be provided for maintenance purposes. Maintenance requirements for the extended detention basin are provided in **Table 2.5** (Appendix).

Design Procedure and Criteria

The following steps outline the design procedure and criteria for an extended detention basin.

a. Step 1: Detention Pond Storage Volume

Provide a storage volume equal to 120 percent of the WQCV based on a 40-hour drain time, above the lowest outlet (i.e., perforation) in the basin. The additional 20 percent of storage volume provides for sediment accumulation and the resultant loss in storage volume.

- Determine the WQCV tributary catchment’s percent imperviousness. Account for the effects of DCIAs, if any, on effective imperviousness. Using **Figure 2.24** (Appendix), determine the reduction in impervious area to use with WQCV calculations.

- Find the required storage volume (watershed inches of runoff). Determine the required WQCV (watershed inches of runoff) using **Figure 2.18** (Appendix), based on the extended detention basin's 40-hour drain time. Calculate the design volume in acre-feet as follows:

$$Design\ Volume = \left(\frac{WaterQualityCaptureVolume}{12}\right) * Area * 1.2 \quad \text{(Equation 11)}$$

In which:

Area = The watershed area tributary to the extended detention basin (acres)

1.2 factor= Multiplier of 1.2 to account for the additional 20 percent of required storage for sediment accumulation

b. Step 2: Outlet Control

The outlet controls are to be designed to release the WQCV (i.e., not the "design volume") over a 40-hour period, with no more than 50 percent of the WQCV being released in 12 hours. Refer to the Appendix for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type (orifice plate or perforated riser pipe); cutoff collar size and location; and all other necessary components.

For a perforated outlet, use **Figure 2.21** (Appendix) to calculate the required area per row based on WQCV and the depth of perforations at the outlet. See Figures **2.22 and 2.23** (Appendix) to determine the appropriate perforation geometry and number of rows (the lowest perforations should be set at the water surface elevation of the outlet micropool). The total outlet area can then be calculated by multiplying the area per row by the number of rows. **Figure 2.19c** contains typical outlet structure notes applicable to the design of outlet structures.

c. Step 3: Trash Rack

Provide a trash rack of sufficient size to prevent clogging of the primary water quality outlet. Size the rack so as not to interfere with the hydraulic capacity of the outlet. Using the total outlet area and the selected perforation diameter (or height), Figures **2.19a, 2.19b, 2.25, or 2.26** (Appendix) will help to determine the minimum open area required for the trash rack. Use one half of the perforated plate's total outlet area to calculate the trash rack's size. This accounts for the variable inundation of the outlet orifices. Figures **2.19a, 2.19b, and 2.25** (Appendix) were developed as suggested standardized outlet designs for smaller sites.

d. Step 4: Basin Shape

Shape the pond whenever possible with a gradual expansion from the inflow area and a gradual contraction toward the outlet, thereby minimizing short circuiting. It is best to have a basin length to width ratio between 2:1 and 3:1. It may be necessary to modify the inflow and outlet points through the use of pipes, swales, or channels to accomplish this. Always maximize the distance between the inlet and the outlet.

e. Step 5: Two-Stage Design

A two-stage design with a pool that fills often with frequently occurring runoff minimizes standing water and sediment deposition in the remainder of the basin. The two stages are as follows:

- **Top Stage:** The top stage should be 2 or more feet deep with its bottom sloped at 2 percent toward the low-flow channel.

- **Bottom Stage:** The active surcharge storage basin of the bottom stage should be 1.0 to 2.0 feet deep below the bottom of the top stage and store no less than 3 percent of the WQCV. Provide a micropool below the bottom active storage volume of the lower stage at the outlet point. The pool should be one half the depth of the upper WQCV depth or 2.5 feet, whichever is larger.

f. Step 6: Low-Flow Channel

Conveys low flows from the forebay to the bottom stage. Erosion protection should be provided where the low-flow channel enters the bottom stage. Lining the low-flow channel with riprap is recommended. Make it at least 9 inches deep if buried riprap is used. At a minimum provide capacity equal to twice the release capacity at the upstream forebay outlet.

g. Step 7: Basin Side Slopes

Basin side slopes should be stable and gentle to facilitate maintenance and access. Side slopes shall be no steeper than 4:1.

h. Step 8: Dam Embankment

The embankment should be designed not to fail during a 100-year or larger storm. Embankment slopes should be no steeper than 3:1, and planted with turf-forming grasses. Poorly compacted native soils should be excavated and replaced. Embankment soils should be compacted to at least 95 percent of their maximum density according to ASTM D 698-70 (Modified Proctor).

i. Step 9: Vegetation

Bottom vegetation provides erosion control and sediment entrapment. Pond bottom, berms, and side sloping areas may be planted with native grasses or with irrigated turf, depending on the local setting.

j. Step 10: Maintenance Access

All weather stable access to the bottom, forebay, and outlet controls area shall be provided for maintenance vehicles. Maximum grades should not exceed 10 percent, and a stable driving surface capable for use by maintenance equipment. If conditions warrant, a gravel or hard surface shall be provided.

k. Step 11: Inflow Point

Dissipate flow energy at the pond's inflow point(s) to limit erosion and promote particle sedimentation.

l. Step 12: Forebay Design

Provide the opportunity for larger particles to settle out in the inflow area, the area that has a solid surface bottom, to facilitate mechanical sediment removal. A rock berm should be constructed between the forebay and the main extended detention basin. The forebay volume of the permanent pool should be about 5 percent of the design water quality capture volume. A pipe throughout the berm to convey water to the main body of the extended detention basin should be offset from the inflow streamline to prevent short circuiting and should be sized to drain the forebay volume in 5 minutes. Presedimentation forebays shall only be utilized when the extended detention basin water quality capture volume exceeds 4,000 cubic feet.

m. Step 13: Flood Storage

Combining the water quality facility with a flood control facility is recommended. The 100-year or other floods may be detained above the WQCV. See **Section 2.3.4**, Incorporating WQCV into Storm Water Quantity Detention Basins, for further guidance.

n. Step 14: Multiple Uses

Whenever desirable and feasible, incorporate the extended detention basin within a larger flood control basin. Also, whenever possible, try to provide for other urban uses such as active or passive recreation and wildlife habitat. If multiple uses are being contemplated, use the multiple-stage detention basin to limit inundation of passive recreational areas to one or two occurrences a year. Generally, the area within the WQCV is not well suited for active recreation facilities such as ballparks, playing fields, and picnic areas. These are best located above the WQCV level.

2.3.6 Sand Filter Extended Detention Basin

Description

A sand filter extended detention basin is a storm water filter consisting of a runoff storage zone underlain by a sand bed with an underdrain system. During a storm, accumulated runoff ponds in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, or storm sewer.

General Application

A sand filter extended detention basin is generally suited to off-line, onsite configurations where there is no base flow and the sediment load is relatively low.

General Properties

a. General

Primary advantages of sand filter extended detention basins include effective water quality enhancement through settling and filtering. The primary drawback is a potential for clogging if a moderate to high level of silts and clays is allowed to flow into the facility. For this reason, it should not be put into operation while construction activities are taking place in the tributary catchment. Also, this BMP should not be located close to building foundations or other areas where expansive soils are a concern, although an underdrain and impermeable liner can reduce some of this concern.

b. Physical Site Suitability

Since an underdrain system is incorporated into this BMP, a sand filter extended detention basin is suited for about any site; the presence of sandy subsoils is not a requirement. This BMP has a relatively flat surface area, so it may be more challenging to incorporate it into steeply sloping terrain.

c. Pollutant Removal

Although not fully tested to date in the Sioux Falls area, the tests on filter vaults throughout the United States show that the amount of pollutant removed by this BMP should be significant and should at least equal the removal rates by sand filters tested elsewhere. See **Table 2.1** (Appendix) for estimated ranges in pollutant removals.

d. **Maintenance Needs**

Before selecting this BMP, be sure that the maintenance specified in Table **2.6** (Appendix) will be provided by the owner with responsibilities negotiated with the City. This BMP's performance is dependant on having regular maintenance provided.

Design Procedure and Criteria

The layout of a sand filter extended detention basin is shown in **Figure 2.27** (Appendix). The following steps outline the design procedure and criteria for a sand filter extended detention basin.

a. **Step 1: Basin Storage Volume**

Provide a storage volume equal to 100 percent of the WQCV based on a 40-hour drain time, above the sand bed of the basin.

- Determine the WQCV tributary catchment's percent imperviousness. Account for the effects of DCIA, if any, on effective imperviousness. Using **Figure 2.24** (Appendix), determine the reduction in impervious area to use with WQCV calculations.
- Find the required storage volume (watershed inches of runoff).
- Determine the required WQCV (watershed inches of runoff) using **Figure 2.18** (Appendix), based on the sand filter extended detention basin's 40-hour drain time.
- Calculate the design volume in acre-feet as follows:

$$DesignVolume = \left(\frac{WaterQualityCaptureVolume}{12} \right) * Area \quad \text{(Equation 12)}$$

In which:

Area = The watershed area tributary to the sand filter extended detention basin (acres)

b. **Step 2: Basin Depth**

Maximum design volume depth shall be 3 feet.

c. Step 3: Filter's Surface Area

Calculate the minimum sand filter area (A_S) at the basin's bottom with the following equation:

A_s = *Design Volume / 3* *43,560 (square feet) (Equation 13)

d. Step 4: Outlet Controls

An 18-inch layer of sand (ASTM C-33) over an 8-inch gravel layer (AASHTO No. 8) shall line the entire sand filter extended detention basin for purposes of draining the WQCV.

If expansive soils are a concern or if the tributary catchment has chemical or petroleum products handled or stored, install a 15 mil thick impermeable membrane below the gravel layer.

In addition, an overflow shall be provided to convey flows in excess of the WQCV out of the basin.

2.3.7 Constructed Wetlands Basin

Description

A constructed wetlands basin is a shallow retention pond that requires a perennial base flow to permit the growth of rushes, willows, cattails, and reeds to slow down runoff and allow time for sedimentation, filtering, and biological uptake.

Constructed wetlands basins differ from "natural" wetlands as they are totally human artifacts that are built to enhance storm water quality. Sometimes small wetlands that exist along ephemeral drainageways could be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators.

General Application

A constructed wetlands basin can be used as a follow-up structural BMP in a watershed, or as a stand-alone onsite facility if the owner provides sufficient water to sustain the wetland. Flood control storage can be provided above the constructed wetlands basin's WQCV pool to act as a multiuse facility.

A constructed wetlands basin requires a net influx of water to maintain its vegetation and microorganisms. A complete water budget analysis is necessary to assure the adequacy of the base flow.

The basic formula for the water budget is as follows:

$$\Delta S / \Delta t = Q_i - Q_o \quad \text{(Equation 14)}$$

Where:

$\Delta S / \Delta t$ = the change in storage volume per change in time

Q_i = the flow rate of water entering the wetland, vol/time

Q_O = the flow rate of water leaving the wetland, vol/time

Equation 15 translates into the following equations where all values are given in consistent units of volume per unit time unless otherwise specified:

For water entering a wetland the formula is:

$$Q_i = P + R_i + B_i + G_I \quad \text{(Equation 15)}$$

Where:

P = Direct precipitation on impoundment area
R_I = Storm water runoff from contributing drainage area
B_I = Base flow entering the wetlands
G_I = Seepage and springs from ground water sources

For water leaving the formula is:

$$Q_O = E + T + R_O + B_O + G_O \quad \text{(Equation 16)}$$

Where:

E = Evaporation from surface
T = Transpiration from plants
R_O = Storm water outflow
B_O = Base flow leaving the wetlands
G_O = Deep percolation below the root zone of the substrate

To assure adequate base flow using the water budget analysis, the value of all variables should be determined and the net influx of water ($Q_I - Q_O$) must be greater than the change in storage volume divided by change in storage time.

General Properties

a. General

A constructed wetlands basin offers several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. It can also provide an effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles. In other words, it offers yet another effective structural BMP for larger tributary catchments.

The primary drawback of the constructed wetlands basin is the need for a continuous base flow to assure viable wetland growth. In addition, silt and scum can accumulate, and unless properly designed and built, can be flushed out during larger storms. In addition, in order to maintain a healthy wetland growth, the surcharge depth for WQCV above the permanent water surface cannot exceed 2 feet.

Along with routine good housekeeping maintenance, occasional cleaning will be required when sediment accumulations become too large and affect performance. Periodic sediment removal is also needed for proper distribution of growth zones and of water movement within the wetland.

b. Physical Site Suitability

A perennial base flow is needed to sustain a wetland, and should be determined using a water budget analysis. Loamy soils are needed in a wetland bottom to allow plants to take root. Exfiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom. Also, wetland basins require a near-zero longitudinal slope, which can be provided using embankments.

c. Pollutant Removal

See **Table 2.1** (Appendix) for estimated ranges in pollutant removals. Reported removal efficiencies of constructed wetlands vary significantly. Primary variables influencing removal efficiencies include design, influent concentrations, hydrology, soils, climate, and maintenance. With periodic sediment removal and routine maintenance, removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorous, low to high; and for nitrogen, zero to moderate. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.

d. Design Considerations

Figure 2.28 (Appendix) illustrates an idealized constructed wetlands basin. An analysis of the water budget is needed to show the net inflow of water is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage for each season of operation). Insufficient inflow can cause the wetland to become saline or to die off. Typical maintenance requirements for wetland BMPs include the items listed in **Table 2.8** (Appendix).

Design Procedure and Criteria

The following steps outline the design procedure for a constructed wetlands basin.

a. Step 1: Basin Surcharge Storage Volume

Provide a surcharge storage volume equal to the WQCV based on a 24-hour drain time, above the lowest outlet (i.e., perforation) in the basin.

- Determine the WQCV using the tributary catchments percent imperviousness. Account for the effects of DCIA, if any, on effective imperviousness. Using **Figure 2.24** (Appendix), determine the reduction in impervious area to use with WQCV calculations.

- Find the required storage surcharge volume (watershed inches of runoff) above the permanent pool level. Determine the required storage (watershed inches of runoff) using **Figure 2.18** (Appendix), based on the constructed wetland basin 24-hour drain time. Calculate the surcharge volume in acre-feet as follows:

$$Design\ \ Surcharge\ \ Volume = \left(\frac{WaterQualityCaptureVolume}{12} \right) * Area \quad \text{(Equation 17)}$$

In which:

Area = The drainage area tributary to the constructed wetlands basin (acres).

b. Step 2: Wetland Pond Depth and Volume

The volume of the permanent wetland pool shall be no less than 75 percent of the WQCV found in Step 1.

Proper distribution of wetland habitat is needed to establish a diverse ecology. Distribute pond area in accordance with **Table 2.7** (Appendix).

c. Step 3: Depth of Surcharge

The surcharge depth of the WQCV above the permanent pool's WQCV water surface shall not exceed 2.0 feet.

d. Step 4: Outlet Control

Provide outlet controls that limit WQCV depth to 2 feet or less. Use a water quality outlet that is capable of releasing the WQCV in no less than a 24-hour period. Refer to **Figures 2.29, 2.30, 2.31, and 2.32**(Appendix) for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type (orifice plate or perforated riser pipe); cutoff collar size and location; and all other necessary components.

Use Figure 11.66 (Appendix) to calculate the required area per row based on WQCV and the depth of perforations at the outlet. See **Figures 2.22 and 2.23** (Appendix) for the appropriate perforation geometry and number of rows (the lowest perforations should be set at the water surface elevation of the outlet pool). The total outlet area can then be calculated by multiplying the area per row by the number of rows. Minimize the number of columns and maximize the perforation hole diameter when designing the outlet to reduce chances of clogging. **Figure 2.19c** contains typical outlet structure notes applicable to the design of outlet structures.

e. Step 5: Trash Rack

Provide a trash rack of sufficient size to prevent clogging of the primary water quality outlet. Size the rack so as not to interfere with the hydraulic capacity of the outlet. Using the total outlet area and the selected perforation diameter (or height), **Figures 2.19a, 2.19b, 2.25, or 2.26** (Appendix) will help to determine the minimum open area required for the trash rack. If a perforated vertical plate or riser is used, use one half of the total outlet area to calculate the trash rack's size. This accounts for the variable inundation of the outlet orifices. **Figures 2.19a, 2.19b, and 2.25** (Appendix) were developed as suggested standardized outlet designs for smaller sites.

f. Step 6: Basin Use

Determine if flood storage or other uses will be provided for above the wetland surcharge storage or in a separate facility. Design for combined uses when they are to be provided.

g. Step 7: Basin Shape

Shape the pond with a gradual expansion from the inflow and a gradual contraction to the outlet, thereby limiting short circuiting. The basin length to width ratio between the inflow area and outlet should be 2:1 to 4:1, with 3:1 recommended. It may be necessary to modify the inflow area and outlet point through the use of pipes, swales, or channels to accomplish this. Always maximize the distance between the inlet and outlet.

h. Step 8: Basin Side Slopes

Basin side slopes are to be stable and gentle to facilitate maintenance and access needs. Side slopes should be no steeper than 4:1.

i. Step 9: Base Flow

A net influx of water that exceeds all of the losses must be available throughout the year. The following equation and parameters can be used to estimate the net quantity of base flow available at a site:

$$Q_{net} = Q_{Inflow} - Q_{Evap} - Q_{Seepage} - Q_{E.T.} \quad \text{(Equation 18)}$$

Where:

Q_{Net} = Net quantity of base flow (acre-feet/year)

Q_{Inflow} = Estimated base flow (acre-feet/year) (estimate by seasonal measurements and/or comparison to similar watersheds)

Q_{Evap} = Loss attributed to evaporation less the precipitation (acre-feet/year) (computed for average water surface)

$Q_{Seepage}$ = Loss (or gain) attributed to seepage to groundwater (acre-feet/year)

$Q_{E.T.}$ = Loss attributed to plant evapotranspiration (computed for average plant area above water surface, not including the surface)

j. Step 10: Inflow Area and Outlet Protection

Provide a means to dissipate flow energy entering the basin to limit sediment resuspension. Outlets should be placed in an outlet bay that is at least 3 feet deep. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the maximum capture volume depth. Also provide for a trash rack.

k. Step 11: Forebay Design

Provide the opportunity for larger particles to settle out in an area that has a solid driving surface bottom for vehicles to facilitate sediment removal. The forebay volume of the permanent pool should be 5 to 10 percent of the design water quality capture volume.

l. Step 12: Vegetation

Cattails, sedges, reeds, and wetland grasses should be planted in the wetland bottom. Berms and side-sloping areas should be planted with native or irrigated turf-forming grasses. Initial establishment of the wetlands requires control of the water depth. After planting wetland species, the permanent pool should be kept at 3 to 4 inches to allow growth and to help establish the plants, after which the pool should be raised to its final operating level.

m. Step 13: Maintenance Access

Vehicle access to the forebay and outlet area must be provided for maintenance and removal of bottom sediments. Maximum grades should not exceed 10 percent, and a stabilized, all-weather driving surface capable for use by maintenance equipment shall be provided. If conditions warrant, a gravel or hard surface shall be provided.

2.3.8 Constructed Wetlands Channel

Description

Constructed wetland-bottomed channels take advantage of dense natural vegetation (rushes, willows, cattails, and reeds) to slow down runoff and allow time for settling out sediment and biological uptake.

Constructed wetlands differ from "natural" wetlands as they are artificial and are built to enhance storm water quality. Sometimes small wetlands that exist along ephemeral drainageways may be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators.

General Application

Wetland bottom channels can be used in the following two ways:

- A wetland can be established in a totally man-made channel and can act as a conveyance system and water quality enhancement facility. This design can be used along wide and gently sloping channels.
- A wetland bottom channel can be located downstream of a storm water detention facility (water quality and/or flood control) where a large portion of the sediment load can be removed. The wetland channel then receives storm water and base flows as they drain from the detention facility, provides water quality enhancement, and at the same time conveys it downstream. The application of a wetland channel is recommended upstream of receiving waters and within lesser (i.e., ephemeral) receiving waters, thereby delivering better quality water to the more significant receiving water system.

  A constructed wetland channel requires a net influx of water to maintain its vegetation and microorganisms. A complete water budget analysis is necessary to assure the adequacy of the base flow.

General Properties

a. General

Constructed wetlands offer several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. Constructed wetlands provide an effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles.

The primary drawback to wetlands is the need for a continuous base flow to assure their presence. In addition, salts and scum can accumulate, and unless properly designed and built, can be flushed out during larger storms.

Other drawbacks include the need for regular maintenance to provide nutrient removal. Regular harvesting and removal of aquatic plants, cattails, and willows are required if the removal of nutrients in significant amounts has to be assured. Even with that, recent data puts into question the net effectiveness of wetlands in removing nitrogen compounds and some form of phosphates. Periodic sediment removal is also necessary to maintain the proper distribution of growth zones and of water movement within the wetland.

b. Physical Site Suitability

A perennial base flow is needed to sustain a wetland, and should be determined using a water budget analysis. Loamy soils are needed in wetland bottoms to allow plants to take root. Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom. Wetland bottom channels also require a near-zero longitudinal slope; drop structures are used to create and maintain a flat grade.

c. Pollutant Removal

Removal efficiencies of constructed wetlands vary significantly. Primary variables influencing removal efficiencies include design, influent concentrations, hydrology, soils, climate, and maintenance. With periodic sediment removal and plant harvesting, expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorous, low to moderate; and for nitrogen, zero to low. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.

Design Considerations

Wetlands can be set into a drainageway to form a wetland bottom channel as shown in **Figure 2.34** (Appendix). An analysis of the water budget is needed so that the inflow of water throughout the year is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage) for satisfactory functioning of the wetland. An insufficient base flow could cause the wetland bottom channel to dry out and die. Maintenance requirements for wetland BMPs are shown in **Table 2.8** (Appendix).

Design Procedure and Criteria

The following steps outline the constructed wetlands channel design procedure. Refer to **Figure 2.34** (Appendix) for its design components.

a. **Step 1: Design Discharge**

Determine the 2-year peak flow rate in the wetland channel without reducing it for any upstream ponding or flood routing effects. The channel shall also meet the conveyance requirements of the Stormwater Design Criteria Manual.

b. **Step 2: Channel Geometry**

Define the newly-built channel's geometry to pass the design 2-year flow rate at 2.0 feet per second with a channel depth between 2.0 and 4.0 feet. The channel cross section should be trapezoidal with side slopes of 4:1 (horizontal/vertical) or flatter. Bottom width shall be no less than 8.0 feet.

c. **Step 3: Longitudinal Slope**

Set the longitudinal slope using Manning's equation and a Manning's roughness coefficient of n=0.03, for the 2-year flow rate. If the desired longitudinal slope can not be satisfied with existing terrain, grade control checks or small drop structures must be incorporated to provide desired slope.

d. **Step 4: Final Channel Capacity**

Calculate the final (or mature) channel capacity during a 2-year flood using a Manning's roughness coefficient of n = 0.08 and the same geometry and slope used when initially designing the channel with n = 0.03. The channel shall also provide enough capacity to contain the flow during a 100-year flood while maintaining 1 foot of free-board. Adjustment of the channel capacity may be done by increasing the bottom width of the channel. Minimum bottom width shall be 8 feet.

e. **Step 5: Drop Structures**

Drop structures should be designed considering low and high flow hydraulic conditions using standard engineering practices.

f. **Step 6: Vegetation**

Vegetate the channel bottom and side slopes to provide solid entrapment and biological nutrient uptake. Cover the channel bottom with loamy soils, upon which cattails, sedges, and reeds should be established. Side slopes should be planted with native or irrigated turf grasses.

g. Step 7: Maintenance Access

Vehicle access along the channel length must be provided for maintenance. Maximum grades should not exceed 10 percent, and a stabilized, all-weather driving surface capable for use by maintenance equipment shall be provided.

2.3.9 Water Quality Catch Basins and Water Quality Catch Basin Inserts

Description

A catch basin is an inlet to the storm drain system that typically includes a grate or curb inlet and a sump to capture sediment, debris, and associated pollutants. Catch basins act as pretreatment for other treatment practices by capturing large sediments. The performance of catch basins at removing sediment and other pollutants depends on the design of the catch basin (e.g., the size of the sump) and maintenance procedures to retain the storage available in the sump to capture sediment. Catch basin efficiency can be improved using inserts, which can be designed to remove oil and grease, trash, debris, and sediment. There are various manufacturers of water quality catch basins and the efficiency may vary with the manufacturer.

Applicability

Catch basins are used in drainage systems throughout the United States. Ideal application of catch basins is as pretreatment to another storm water management practice. Catch basin inserts for both new development and retrofits at existing sites may be preferred when available land is limited, as in urbanized areas.

Siting and Design Considerations

The performance of catch basins is related to the volume in the sump (i.e., the storage in the catch basin below the outlet). Lager et al. (1997) described an "optimal" catch basin sizing criterion, which relates all catch basin dimensions to the diameter of the outlet pipe (D):

- The diameter of the catch basin should be equal to 4D.
- The sump depth should be at least 4D. This depth should be increased if cleaning is infrequent or if the area draining to the catch basin has high sediment loads.
- The top of the outlet pipe should be 1.5D from the bottom of the inlet to the catch basin.

Catch basins can also be sized to accommodate the volume of sediment that enters the system. Pitt et al. (1997) proposed a sizing criterion based on the concentration of sediment in storm water runoff. The catch basin is sized, with a factor of safety, to accommodate the annual sediment load in the catch basin sump. This method is preferable where high sediment loads are anticipated, and where the optimal design described above is suspected to provide little treatment.

References

Aronson, G., D. Watson, and W. Pisaro. *Evaluation of Catch Basin Performance for Urban Storm Water Pollution Control*. U.S. Environmental Protection Agency, Washington, DC.

Interagency Catch Basin Insert Committee (ICBIC). *Evaluation of Commercially-Available Catch Basin Inserts for the Treatment of Storm Water Runoff from Developed Sites*. Seattle, WA. 1995.

Lager, J., W. Smith, R. Finn, and E. Finnemore. *Urban Storm Water Management and Technology: Update and Users' Guide*. Prepared for U.S. Environmental Protection Agency. EPA-600/8-77-014. 313 pp. 1977.

Mineart, P., and S. Singh. *Storm Inlet Pilot Study.* Alameda County Urban Runoff Clean Water Program, Oakland, CA. 1994.

Pitt, R., and P. Bissonnette. *Bellevue Urban Runoff Program Summary Report.* U.S. Environmental Protection Agency, Water Planning Division, Washington, DC. 1984.

Pitt, R., M. Lilburn, S. Nix, S.R. Durrans, S. Burian, J. Voorhees, and J. Martinson. *Guidance Manual for Integrated Wet Weather Flow (WWF) Collection and Treatment Systems for Newly Urbanized Areas (New WWF Systems)*. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH. 2000.

2.3.10 Bioretention

Definition

A typical bioretention area is shown in **Figure 2.35** (Appendix). Two general types of bioretention facilities exist: off-line and on-line areas. Off-line bioretention areas consist of sand and soil mixtures planted with native plants, which receive runoff from overland flow or from a diversion structure in a traditional drainage system. On-line bioretention areas have the same composition as off-line areas, but are located in grass swales or other conveyance systems that have been modified to enhance pollutant removal by quiescent settling and biofiltration.

Purpose

Bioretention is an efficient method for removing a wide variety of pollutants, such as suspended solids and nutrients. It can also be an effective means of reducing peak runoff rates and recharging groundwater by infiltrating runoff. However, not all bioretention facilities will necessarily be optimized for all of these functions.

Application

Bioretention areas consisting of sand and soil mixtures planted with native plants, which filter urban runoff, can be used in residential and nonresidential developments. Sources of runoff can be overland flow from impervious areas or discharge diverted from a drainage pipe. Also, on-line bioretention facilities use check dams or other barriers to retain flow in grass swales.

Bioretention facilities are most effective if they receive runoff as close as possible to the source. A site designer needs to look for opportunities to incorporate bioretention facilities throughout the site and minimize the use of inlets, pipes, and downstream controls.

Bioretention should not be used in areas with the following characteristics:

- The water table is within 6 feet of the land surface (the use of collector pipes may reduce this limitation).
- Mature trees would be removed for constructing the bioretention area.
- Slopes are 20 percent or greater.
- An unstable soil stratum is in the area.

a. Off-Line

Off-line bioretention facilities can be applied to most development situations. They are particularly applicable in urban areas where the opportunities and the land available for controlling storm water reliably are scarce. Bioretention facilities may be installed in median strips, parking lot islands, or lawn areas of commercial developments. They also can be used in residential subdivisions with open drainage systems or in easements located around lots. **Figure 2.36** (Appendix) shows a bioretention area receiving runoff diverted from a storm sewer.

b. On-Line

On-line bioretention facilities use check dams to "collect" the water in the bioretention area, as shown in **Figure 2.37** (Appendix). Adding a bioretention area behind the check dam allows filtering and sedimentation to occur. Check dams should only be used in small open channels or in filter strips that drain 5 acres or less. Runoff from storms larger than the water quality design storm should safely flow over or bypass the bioretention area.

Recommended Design Criteria

a. Performance-Based Guidelines

Bioretention facilities should be optimized to treat the runoff generated by the water quality design storm. The peak discharge from larger storms should be bypassed, if possible.

A homogenous soil mix of 50 percent construction sand; 20 to 30 percent topsoil with less than 5 percent clay content, and 20 to 30 percent organic compost containing no animal waste provides a planting medium with adequate infiltration capacity. Soil amendments can be added according to the plant species selected. This soil guidance is taken from the North Carolina BMP manual.

In areas where clay contents are higher and the soil is not conducive to infiltration, the bioretention facility can be modified with a collector pipe system installed beneath the basin to form a bioretention filter. The City of Alexandria, Virginia, has developed design guidelines for bioretention filters (City of Alexandria, 1995) and collector pipes for areas of clay soil. As a standard practice, a collector pipe system is now used on all bioretention applications.

Bioretention areas can be used successfully in a wide range of drainage areas. Median strips, ramp loops, and parking lot islands are examples of small drainage areas (less than 1 acre). In large drainage areas (less than 10 acres), diversion structures and energy dissipation devices need to be incorporated into the design to preserve the integrity of the bioretention area.

It is recommended that the size of the bioretention area be 5 to 7 percent of the drainage area multiplied by the *c* coefficient of the Rational Formula (Prince George's County, 1993). However, both smaller and larger ranges are allowed. Ongoing monitoring data will provide better guidance on the design of these facilities. The land required for bioretention facilities can be reduced by partially substituting vertical-extended detention storage for horizontal storage.

Check dams, as shown in **Figure 2.37** (Appendix), reduce the velocity of concentrated storm water flows, promoting sedimentation behind the dam. If properly anchored, railroad ties, gabions, or rock filter berms may be used as check dams. The use of railroad ties is shown in **Figure 2.38** (**Appendix).** The use of gabions as a drop structure is shown in **Figure 2.39** (Appendix). These types of structures can be used in swales with moderate slopes.

Check dams must be sized and constructed correctly and maintained properly, or they will be either washed out or contribute to flooding. The relationship between ponding depth and discharge rate can be computed by using the critical-depth formula, which accounts for a generalized weir profile. The relevant equation is:

$$Q = \left((A^3 \times g) / T \right)^{1/2} \quad \text{(Equation 21)}$$

Where:

Q	=	discharge rate
A	=	area subtended by top of check dam and ponding elevation
T	=	width of check dam
g	=	gravitational constant

Check dams can be constructed of either rock or logs. The use of other natural materials available on the site that can withstand the storm water flow velocities is acceptable. Check dams should not be constructed from straw bales or silt fences because concentrated flows quickly wash out these materials.

Maximum velocity reduction is achieved if the toe of the upstream check dam is at the same elevation as the top of the downstream dam. The center section of the dam should be lower than the edge sections to minimize the potential for erosion of the abutments during frequently occurring storm events.

b. Operation and Maintenance

Monthly inspections are recommended until the plants are established. Annual inspections should then be performed. Accumulated sediment behind check dams should be removed when it reaches one half of the sump depth.

c. Considerations

If used, collector pipe systems in bioretention areas can become clogged by underlying clay soil. Pipe cleanouts are recommended to facilitate unclogging of the pipes without disturbing the bioretention areas.

Specifications and Methodology

a. Planting Plan

Using plants in bioretention areas is intended to replicate a terrestrial forest community ecosystem. The components of this community include trees, a shrub layer, and a herbaceous layer. Native plants should be able to tolerate typical storm water pollutant loads, variable soil moisture, and ponding fluctuations (Prince George’s County, 1993). Designers are encouraged to check other sources, such as The Agronomy Guide, the Field Office Technical Guide, and local nurseries, to identify plants that can adapt to specific site conditions.

The plant material layout should resemble a random and natural placement of plants rather than a standard landscaped approach with trees and shrubs in rows or other orderly fashion. The location of the plant material should provide optimal conditions for plant establishment and growth (Prince George’s County, 1993).

b. Off-Line Bioretention Areas

There are six major components to the bioretention area:

- Grass buffer strip or energy dissipation area
- Ponding or treatment area

- Planting soil
- Sand bed (optional)
- Organic layer
- Plant material

The grass buffer strip or energy-dissipation area filters particles from the runoff and reduces its velocity. The sand bed further slows the velocity of the runoff, spreads the runoff over the basin, filters part of the water, provides positive drainage to prevent anaerobic conditions in the planting soil, and enhances exfiltration from the basin.

The ponding area functions as storage area for runoff awaiting treatment and as presettling basin for particulates that have not been filtered out by the grass buffer. The organic or mulch layer acts as a filter for pollutants, protects the soil from eroding, and is an environment for microorganisms to degrade petroleum-based compounds and other pollutants.

The planting soil layer nurtures the plants with stored water and nutrients. Clay particles in the soil adsorb heavy metals, nutrients, hydrocarbons, and other pollutants. The plant species are selected on the basis of their documented ability to cycle and assimilate nutrients, pollutants, and metals through the interaction among plants, soil, and organic layers (Bitter and Bowers, 1994). The minimum depth of the planting soil layer should be 3 to 4 feet.

The number of tree and shrub plantings may vary, especially in areas where aesthetics and visibility are vital to site development, and the density should be determined on an individual site basis. The minimum and maximum number of individual plants and spacing recommended are shown in **Table 2.9** (Appendix). A minimum of three species of trees and three species of shrubs should be selected to assure diversity.

As with any BMP, sizing rules are continually changing. Although the site requirements will determine the actual dimensions, the following dimensions are recommended for bioretention areas:

- Minimum width is 10 to 15 feet.
- Minimum length is 30 to 40 feet.
- The ponded area should have a maximum depth of 6 inches. If collector pipes are used, the maximum pond depth can be increased to 12 inches.
- The planting soil should have a minimum depth of 4 feet.

Figures **2.40 and 2.41** (Appendix) show a profile and plan of a typical bioretention area. A curb diversion structure that can be installed to divert gutter flow to a bioretention area is shown in **Figure 2.42** (Appendix).

c. On-Line Bioretention Areas

A bioretention area upstream of a check dam is constructed with similar specifications as the off-line bioretention areas. The depth of the planting soil zone can be reduced (1 to 2 feet) if the drainage area is small (less than 2 acres).

Rock check dams usually are constructed of approximately 8- to 12-inch rock. The rock is placed either by hand or mechanically, but never just dumped into the swale. The dam must completely span the ditch or swale to prevent being washed out. The rock used must be large enough to stay in place, given the expected design flow through the channel.

Railroad tie check dams are illustrated in **Figure 2.38** (Appendix). The railroad ties should be embedded into the soil at least 18 inches. Gabion applications are illustrated in Figures **2.37 and 2.39** (Appendix).

Design Methodology for Controlling Runoff Volume

The runoff capture volume is the minimum volume of rainfall that must be retained and completely infiltrated onsite during every storm. It is also equal to the rainfall quantity associated with the runoff capture design storm.

The runoff capture volume is conveniently stated as a rainfall depth, in inches, over the area of the site. To achieve a suitable level of groundwater recharge, a minimum of 0.73 inch of rainfall from every storm should be detained and infiltrated. All rainfall events with less than 0.73 inch of rainfall should be completely infiltrated.

Analysis of the site will establish the total runoff capture storage that must be provided by infiltration BMPs at a particular site. In general, the retention volume of appropriately located bioretention areas can be applied to satisfy the runoff capture storage requirement for the site.

Bioretention facilities are effective measures for increasing the runoff capture capability of the site. Other methods that can be used to improve runoff capture and infiltration include:

- Installing permeable pavement.
- Installing infiltration trenches or dry wells.
- Modifying the site design to decrease imperviousness.

Design Methodology for Runoff Peak Attenuation

Only bioretention facilities with large retention storage capacities will be effective in controlling runoff peak discharge rates. To predict a change in peak runoff, the Natural Resources (formerly Soil) Conservation Service's (NRCS) methodology can be used. This methodology includes the so-called soil cover complex and nondimensionalized unit hydrograph techniques and is implemented in a variety of computer simulation packages. Alternative methodologies, including kinematic wave runoff routing and synthetic unit hydrograph generation, also are available in various computer software packages.

By retaining runoff during the initial stages of a storm, bioretention facilities can significantly reduce peak runoff rates. With these measures implemented, runoff from the site will be delayed until the storage capacity of the facilities is exceeded. When using the NRCS methodology, this effect can be accounted for as an increase in the initial abstraction, *Ia*, for the drainage subarea in which the facility is located. The relationship can be expressed as follows:

$$\mathrm{R} = \frac{(V - Ia)^2}{(V - Ia) + S} \quad \text{(Equation 22)}$$

$$S = \frac{1{,}000}{CN} - 10 \quad \text{(Equation 23)}$$

Where:

V = Rainfall volume (inches, over the drainage area)

R = Runoff volume (inches, over the drainage area)

Ia = Initial abstraction (inches, over the drainage area)

S = Potential maximum retention after runoff begins (inches, over the drainage area)

CN = NRCS runoff curve number

Ia can be approximated as the combined runoff capture storage divided by the surface area of the drainage subarea. The effect will be more important for small runoff peak attenuation design storms.

Some bioretention facilities may also include peak attenuation storage. The impacts of large flows and velocities on the plant material need to be carefully evaluated before using bioretention facilities as peak attenuation facilities. Bioretention facilities with small drainage areas (i.e., less than 0.25 acre) may be effective for peak attenuation if they are installed throughout a subdivision or nonresidential development.

References

Bitter, S. D. and J K. Bowers. "Bioretention as a Water Quality Best Management Practice." *Watershed Protection Techniques*. Vol. 1, No. 3. 1994.

CH2M HILL 2001. *Storm Water Best Management Practices*. Prepared for the North Carolina Department of Environment and Natural Resources Division of Water Quality.

City of Alexandria (Virginia). *Alexandria Supplement to the Northern Virginia BMP Handbook,* Section XIII, Bioretention and Bioretention Filters. Department of Transportation and Environmental Services. Alexandria, VA. February 1994.

Pennsylvania State University. *The Agronomy Guide*. College of Agricultural Sciences (latest edition).

Prince George's County Government. *Design Manual for Use of Bioretention in Storm Water Management*. Prepared by Engineering Technologies Associates, Inc. and Biohabitats, Inc. 1993.

Reeves, E. "Performance and Condition of Biofilters in the Pacific Northwest." *Watershed Protection Techniques*, Vol. 1, No. 3. Fall 1994.

Schueler, T. R. "How to Design Urban Storm Water Best Management Practices," Seminar Notebook. 1995.

2.3.11 Other BMPs

Use of BMPs other than those listed in this manual may be allowed when approved by the City Engineer on a case by case basis.

2.3.12 Acknowledgement

The descriptions of the BMPs contained in this chapter were adapted from descriptions of BMPs found in the Urban Drainage and Flood Control District (Colorado) Drainage Criteria Manual Volume 3 and the Pennsylvania Handbook of Best Management Practices for Developing Areas.

2.3.13 Reference Material

Hastead Quick TR-55.

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2.4 Stormwater Better Site Design

2.4.1 Overview

The first step in addressing stormwater management begins with site planning and the design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to conserve natural areas, reduce impervious cover and better integrate stormwater treatment. By implementing a combination of these nonstructural approaches collectively known as *stormwater better site design practices*, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide form some nonstructural on-site treatment and control of runoff. The goals of better site design include:

- Managing stormwater as close to the point of origin as possible and minimizing collection and conveyance
- Preventing stormwater impacts rather than mitigating them
- Utilizing simple, nonstructural methods for stormwater management that are lower cost and lower maintenance than structural controls
- Creating a multifunctional landscape
- Using Hydrology as a framework for site design

Better site design for stormwater management includes a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site for stormwater management. The aim is to reduce the environmental impact “footprint” of the site while retaining and enhancing the owner/developer’s purpose and vision for the site. Many of the better site design concepts can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

Reduction of adverse stormwater runoff impacts through the use of better site design should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of better site design practices offers significant benefits over treating and controlling runoff downstream. Therefore, all opportunities for using these methods should be explored and all options exhausted before considering structural stormwater controls.

The reduction in runoff and pollutants using better site design can reduce the required runoff peak and volumes that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural stormwater controls. In some cases, the use of better site design practices may eliminate the need for structural controls entirely. Hence, better site design concepts can be viewed as both a water quantity and water quality management tool.

Several of the site design practices described in this section provide a calculable reduction or site design “credit” which can be applied to the stormwater sizing criteria requirements.

The use of stormwater better site design can also have a number of other ancillary benefits including:

- Reduced construction costs
- Increased property value
- More open space for recreation
- More pedestrian friendly neighborhoods
- Protection of sensitive forests, wetlands and habitats
- More aesthetically pleasing and naturally attractive landscape
- Easier compliance with wetland and other resource protection regulations

2.4.2 List of Stormwater Better Site Design Practices and Techniques

The stormwater better site design practices and techniques covered in this manual are grouped into four categories and are listed below:

- **Conservation of Natural Features and Resources**
  - Preserve Undisturbed Natural Areas
  - Preserve Riparian Buffers
  - Avoid Floodplains
  - Avoid Steep Slopes
  - Minimize Siting on Porous or Erodible Soils

- **Lower Impact Site Design Techniques**
  - Fit Design to the Terrain
  - Locate Development in Less Sensitive Areas
  - Reduce Limits of Clearing and Grading
  - Utilize Open Space Development
  - Consider Creative Development Design

- **Reduction in Impervious Cover**
  - Reduce Roadway Lengths and Widths
  - Reduce Building Footprints
  - Reduce Parking Footprints
  - Reduce Setbacks and Frontages
  - Use Fewer or Alternative Cul-de-Sacs
  - Create Parking Lot Stormwater “Islands”

- **Utilization of Natural Features for Stormwater Management**
  - Use Buffers and Undisturbed Areas
  - Use Natural Drainageways Instead of Storm Sewers

- Use Vegetated Swale Instead of Curb and Gutter
- Drain Rooftop Runoff to Pervious Areas

2.4.2.1 Conservation of Natural Features and Resources

Conservation of natural features is integral to better site design. The first step in the better site design process is to identify and preserve the natural features and resources that can be used in the protection of water resources by reducing stormwater runoff, providing runoff storage, reducing flooding, preventing soil erosion, promoting infiltration, and removing stormwater pollutants. Some of the natural features that should be taken into account include:

- Areas of undisturbed vegetation
- Floodplains and riparian areas
- Ridgetops and steep slopes
- Natural drainage pathways
- Intermittent and perennial creeks
- Wetlands
- Aquifers and recharge areas
- Soils
- Shallow bedrock or high water table
- Other natural features or critical are:

Some of the ways used to conserve natural features and resources described over the next several pages include the following methods:

- Preserve Undisturbed Natural Areas
- Preserve Riparian Buffers
- Avoid Floodplains
- Avoid Steep Slopes
- Minimize Siting on Porous or Erodible Soils

Delineation of natural features is typically done through a comprehensive site analysis and inventory before any site layout design is performed. From this site analysis, a concept plan for a site can be prepared that provides for the conservation and protection of natural features.

<u>Preserve Undisturbed Natural Areas</u>

Important natural features and areas such as undisturbed forested and vegetated areas, natural drainageways, stream corridors, wetlands and other important site features should be delineated and placed into conservation areas.

The key benefits include:

- Conserving undisturbed natural areas helps to preserve a portion of the site's natural predevelopment hydrology
- Can be used as nonstructural stormwater filtering and infiltration zones
- Helps to preserve the site's natural character and aesthetic features
- May increase the value of the developed property
- A stormwater site design credit can be taken

Use this practice by:

- ✓ Delineating natural areas before performing site layout and design
- ✓ Ensure that conservation areas and native vegetation are protected in an undisturbed state throughout construction and occupancy

Site Design Credit

A stormwater credit can be taken when undisturbed natural areas are conserved on a site, thereby retaining their pre-development hydrologic and water quality characteristics. Under this credit, a designer would be able to subtract conservation areas from the total site area when computing the water quality volume requirements. An added development will be that the post-development peak discharges will be smaller, and hence water quantity control volumes will be reduced due to lower post-development curve numbers or rational formula "C" values.

Rule: Subtract conservation areas from total site area when computing water quality volume requirements.

Criteria:

- Conservation area cannot be disturbed during project construction
- Shall be protected by limits of disturbance clearly shown on all construction drawings
- Shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management], and
- Shall have a minimum contiguous area requirement of 10,000 square feet
- R_V is kept constant when calculating WQ_V

Example:

Residential Subdivision
Area = 38 acres
Natural Conservation Area = 7 acres
Impervious Area = 13.8 acres

Credit:

7.0 acres in natural conservation area
New drainage area = 38 – 7 = 31 acres

Before credit:
WQ_V = (1.2)(0.22)(38)/12 = 0.84 ac-ft
With credit:
WQ_V = (1.2)(0.22)(31)/12 = 0.68 ac-ft

(18% reduction in water quality volume)

Preserve Riparian Buffers

Naturally vegetated buffers should be delineated and preserved along perennial creeks, lakes, and wetlands.

The key benefits include:

- Riparian buffers can be used as nonstructural stormwater filtering and infiltration zones
- Keeps structures out of the floodplain and provides a right-of-way for large flood events
- Helps to preserve riparian ecosystems and habitats
- A stormwater site design credit can be taken

Use this practice by:

- ✓ Delineate and preserve naturally vegetated riparian buffers
- ✓ Ensure that buffers and native vegetation are protected throughout construction and occupancy

Site Design Credit

This credit can be taken when stormwater runoff is effectively treated by a stream buffer. Effective treatment constitutes treating runoff through overland flow in a naturally vegetated or forested buffer. Under the proposed credit, a designer would be able to subtract areas draining via overland flow to the buffer from total site area when computing water quality volume requirements. An added development will be that the post-development peak discharges will be smaller, and hence water quantity control volumes will be reduced due to lower post-development curve numbers or rational formula "C" values. The design of the stream buffer treatment system must use appropriate methods for conveying flows above the 2-yr storm event.

Rule: Subtract areas draining via overland flow to the buffer from total site area when computing water quality volume requirements.

Criteria:

- The minimum undisturbed buffer width shall be 50 feet
- The maximum contributing length shall be 150 feet for pervious surfaces and 75 feet for impervious surfaces
- The average contributing slope shall be 3% maximum unless a flow spreader is used
- Runoff shall enter the buffer as overland sheet flow. A flow spreader can be supplied to ensure this, or if average contributing slope criteria cannot be met
- Not applicable if **overland flow filtration/groundwater recharge** credit is already being taken
- Buffers shall remain unmanaged other than routine debris removal
- Shall be located within an acceptable buffer easement instrument that ensures perpetual protection of the proposed area.
- R_V is kept constant when calculating WQ_V

Example:

Residential Subdivision
Area = 38 acres
Area Draining to Buffer = 5 acres
Impervious Area = 13.8 acres

Credit:

5.0 acres draining to buffer
New drainage area = 38 – 5 = 33 acres

Before credit:
$\mathbf{WQ_V = (1.2)(0.22)(38)/12 = 0.84}$ **ac-ft**
With credit:
$\mathbf{WQ_V = (1.2)(0.22)(33)/12 = 0.73}$ **ac-ft**

(13% reduction in water quality volume)

Avoid Floodplains

Floodplain areas should be avoided for homes and other structures to minimize risk to human life and property damage, and to allow the natural stream corridor to accommodate flood flows.

The key benefits include:

- Preserving floodplains provides a natural right-of-way and temporary storage for large flood events
- Keeps people and structures out of harm's way
- Helps to preserve riparian ecosystems and habitats

- Can be combined with riparian buffer protection to create linear greenways

Use this practice by:

- ✓ Obtain maps of the 100-year floodplain and floodway
- ✓ Ensure that all development activities do not encroach on the designated floodplain areas

Avoid Steep Slopes

Steep slopes should be avoided due to the potential for soil erosion and increased sediment loading. Excessive grading and flattening of hills and ridges should be minimized.

The key benefits include:

- Preserving steep slopes helps to prevent soil erosion and degradation of stormwater runoff
- Steep slopes can be kept in an undisturbed natural condition to help stabilize hillsides and soils
- Building on flatter areas will reduce the need for cut-and-fill and grading

Use this practice by:

- ✓ Avoid development on steep slope areas, especially those with a grade of 15% or greater
- ✓ Minimize grading and flattening of hills and ridges

Minimize Siting on Porous or Erodible Soils

Porous soils such as sand and gravels provide an opportunity for groundwater recharge of stormwater runoff and should be preserved as a potential stormwater management option. Unstable or easily erodible soils should be avoided due to their greater erosion potential.

The key benefits include:

- Areas with highly permeable soils can be used as nonstructural stormwater infiltration zones. A stormwater site design credit can be taken
- Avoiding high erodible or unstable soils can prevent erosion and sedimentation problems and water quality degradation

Use this practice by:

- ✓ Use soil surveys to determine site soil types
- ✓ Leave areas of porous or highly erodible soils as undisturbed conservation areas

Site Design Credit

This credit can be taken when “overland flow filtration/infiltration zones” are incorporated into the site design to receive runoff from rooftops or other small impervious areas (e.g., driveways, small parking lots, etc.). This can be achieved by grading the site to promote overland vegetative filtering or by providing infiltration or “rain garden” areas. If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality volume requirements. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

Rule: If impervious areas are adequately disconnected, they can be deducted from total site area when computing the water quality volume requirements.

Criteria:

- Relatively permeable soils should be present
- Runoff shall not come from a designated hotspot
- The maximum contributing impervious flow path length shall be 75 feet
- Downspouts shall be at least 10 feet away from the nearest impervious surface to discourage “re-connections”
- The disconnection shall drain continuously through a vegetated channel, swale, or filter strip to the property line or structural stormwater control
- The length of the “disconnection” shall be equal to or greater than the contributing length
- The surface impervious area to any one discharge location shall not exceed 5,000 square feet
- For those areas draining directly to a buffer, either the overland flow filtration **or** the stream buffer credit can be used
- R_V is kept constant when calculating WQ_V

Example:

Site Area = 3.0 acres
“Disconnected” Impervious Area = 0.5 acres
Impervious Area = 1.9 acres (or 63.3% impervious cover)

Credit:

0.5 acres of surface imperviousness hydrologically disconnected
New drainage area = 3 – 0.5 = 2.5 acres

Before credit:
$\mathbf{WQ_V = (1.2)(0.31)(3)/12 = 0.093}$ **ac-ft**
With credit:
$\mathbf{WQ_V = (1.2)(0.31)(2.5)/12 = 0.078}$ **ac-ft**

(17% reduction in water quality volume)

2.4.2.2 Lower Impact Site Design Techniques

Fit Design to the Terrain

The layout of roadways and buildings on a site should generally conform to the landforms on a site. Natural drainage ways and stream buffer areas should be preserved by designing road layouts around them. Buildings should be sited to utilize the natural grading and drainage system and avoid the unnecessary disturbance of vegetation and soils.

The key benefits include:

- Helps to preserve the natural hydrology and drainage ways of a site
- Reduces the need for grading and land disturbance
- Provides a framework for site design and layout

Use this practice by:

- ✓ Develop roadway patterns to fit the site terrain. Locate buildings and impervious surfaces away from steep slopes, drainage ways and floodplains

Locate Development in Less Sensitive Areas

To minimize the hydrologic impacts on the existing site land cover, the area of development should be located in areas of the site that are less sensitive to disturbance or have a lower value in terms of hydrologic function.

The key benefits include:

- Helps to preserve the natural hydrology and drainage ways of a site
- Makes most efficient use of natural site features for preventing and mitigating stormwater impacts
- Provides a framework for site design and layout

Use this practice by:

- ✓ Lay out the site design to minimize the hydrologic impact of structures and impervious surfaces

Reduce Limits of Clearing and Grading

Clearing and grading of the site should be limited to the minimum amount needed for the development and road access. Site footprinting should be used to disturb the smallest possible land area on a site.

The key benefits include:

- Preserves more undisturbed natural areas on a development site
- Techniques can be used to help protect natural conservation areas and other site features

Use this practice by:

- ✓ Establish limits of disturbance for all development activities
- ✓ Use site footprinting to minimize clearing and land disturbance

Utilize Open Space Development

Open space site designs incorporate smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources.

The key benefits include:

- Preserves conservation areas on a development site
- Can be used to preserve natural hydrology and drainage ways
- Can be used to help protect natural conservation areas and other site features
- Reduces the need for grading and land disturbance
- Reduces infrastructure needs and overall development costs

Use this practice by:

- ✓ Use a site design which concentrates development and preserves open space and natural areas of the site

Consider Creative Development Design

Planned Unit Developments (PUDs) allow a developer or site designer the flexibility to design a residential, commercial, industrial, or mixed-use development in a fashion that best promotes effective stormwater management and the protection of environmentally sensitive areas.

The key benefits include:

- Allows flexibility to developers to implement creative site designs which include stormwater better site design practices
- May be useful for implementing an open space development

Use this practice by:

- ✓ Determine the type and nature of deviations allowed and other criteria for receiving PUD approval

2.4.2.3 Reduction of Impervious Cover

The level of impervious cover, i.e. rooftops, parking lots, roadways, sidewalks and other surfaces that do not allow rainfall to infiltrate into the soil, is an essential factor to consider in better site design for stormwater management. Increased impervious cover means increased stormwater generation and increased pollutant loadings.

Thus by reducing the area of total impervious surface on a site, a site designer can directly reduce the volume of stormwater runoff and associated pollutants that are generated. It can also reduce the size and cost of necessary infrastructure for stormwater drainage, conveyance, and control and treatment. Some of the ways that impervious cover can be reduced in a development include:

- Reduce Roadway Lengths and Widths
- Reduce Building Footprints
- Reduce Parking Footprints
- Reduce Setbacks and Frontages
- Use Fewer or Alternative Cul-de-Sacs
- Create Parking Lot Stormwater Islands

<u>Reduce Roadway Lengths and Widths</u>

Roadway lengths and widths should be minimized on a development site where possible to reduce overall imperviousness.

The key benefits include:

- Reduces the amount of impervious cover and associated runoff and pollutants generated
- Reduces the costs associated with road construction and maintenance

Use this practice by:

- ✓ Consider different site and road layouts that reduce overall street length
- ✓ Minimize street width by using narrower street designs

<u>Reduce Building Footprints</u>

The impervious footprint of commercial buildings and residences can be reduced by using alternate or taller buildings while maintaining the same floor to area ratio.

The key benefits include:

- Reduces the amount of impervious cover and associated runoff and pollutants generated

Use this practice by:

- ✓ Use alternate or taller building designs to reduce the impervious footprint of buildings

Reduce the Parking Footprint

Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, parking decks, and using porous paver surfaces or porous concrete in overflow parking areas where feasible and possible.

The key benefits include:

- Reduces the amount of impervious cover and associated runoff and pollutants generated

Use this practice by:

- ✓ Reduce the number of parking spaces
- ✓ Minimize stall dimensions
- ✓ Consider parking structures and shared parking
- ✓ Use alternative porous surface for overflow area

Reduce Setbacks and Frontages

Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths.

The key benefits include:

- Reduces the amount of impervious cover and associated runoff and pollutants generated

Use this practice by:

- ✓ Reduce building and home front and side setbacks
- ✓ Consider narrower frontages

Use Fewer or Alternative Cul-de-Sacs

Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should also be considered.

The key benefits include:

- Reduces the amount of impervious cover and associated runoff and pollutants generated

Use this practice by:

- ✓ Consider alternative cul-de-sac designs

<u>Create Parking Lot Stormwater "Islands"</u>

Provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

The key benefits include:

- Reduces the amount of impervious cover and associated runoff and pollutants generated
- Provides an opportunity for the siting of structural control facilities
- Trees in parking lots provide shading for cars and are more visually appealing

Use this practice by:

- ✓ Integrate porous areas such as landscaped islands, swales, filter strips and bioretention areas in a parking lot design

2.4.2.4 Utilization of Natural Features for Stormwater Management

Traditional stormwater drainage design tends to ignore and replace natural drainage patterns and often results in overly efficient hydraulic conveyance systems. Structural stormwater controls are costly and often can require high levels of maintenance for optimal operation. Through use of natural site features and drainage systems, careful site design can reduce the need and size of structural conveyance systems and controls.

Almost all sites contain natural features which can be used to help manage and mitigate runoff from development. Features on a development site might include natural drainage patterns, depressions, permeable soils, wetlands, floodplains, and undisturbed vegetated areas that can be used to reduce runoff, provide infiltration and stormwater filtering of pollutants and sediment, recycle nutrients, and maximize on-site storage of stormwater. Site design should seek to utilize the natural and/or nonstructural drainage system and improve the effectiveness of natural systems rather than to ignore or replace them. These natural systems typically require low or no maintenance and will continue to function many years into the future.

Some of the methods of incorporating natural features into an overall stormwater management site plan include the following practices:

- Use Buffers and Undisturbed Areas
- Use Natural Drainage Ways Instead of Storm Sewers
- Use Vegetated Swales instead of Curb and Gutter
- Drain Runoff to Pervious Areas

Use Buffers and Undisturbed Areas

Undisturbed natural areas such as forested conservation areas and stream buffers can be used to treat and control stormwater runoff from other areas of the site with proper design.

The key benefits include:

- Riparian buffers and undisturbed vegetated areas can be used to filter and infiltrate stormwater runoff
- Natural depressions can provide inexpensive storage and detention of stormwater flows
- A stormwater site design credit can be taken (see Site Design Credit under Preserve Riparian Buffers)

Use this practice by:

- ✓ Direct runoff towards buffers and undisturbed areas using a level spreader to ensure sheet flow
- ✓ Utilize natural depressions for runoff storage

Use Natural Drainage Ways Instead of Storm Sewers

The natural drainage paths of a site can be used instead of constructing underground storm sewers or concrete open channels. Vegetated swales in lieu of curb and gutter should only be used with prior approval from the Growth Management Department.

The key benefits include:

- Use of natural drainage ways reduces the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading
- Natural drainage paths are less hydraulically efficient than man-made conveyances, resulting in longer travel times and lower peak discharges
- Can be combined with buffer systems to allow for stormwater filtration and infiltration

Use this practice by:

- ✓ Preserve natural flow paths in the site design
- ✓ Direct runoff to natural drainage ways, ensuring that peak flows and velocities will not cause channel erosion

<u>Use Vegetated Swales Instead of Curb and Gutter</u>

Where density, topography, soils, slope, and safety issues permit, vegetated open channels can be used in the street right-of-way to convey and treat stormwater runoff from roadways.

The key benefits include:

- Reduces the cost of road and storm sewer construction
- Provides for some runoff storage and infiltration, as well as treatment of stormwater
- A stormwater site design credit can be taken

Use this practice by:

- ✓ Use vegetated open channels (enhanced wet or dry swales or grass channels) in place of curb and gutter to convey and treat stormwater runoff

<u>Site Design Credit</u>

This credit may be taken when vegetated (grass) channels are used for water quality treatment. Under the proposed credit, a designer would be able to subtract the areas draining to a grass channel from total site area when computing water quality volume requirements. A vegetated channel can fully meet the water quality volume requirements for certain kinds of low-density residential development. An added benefit will be that the post-development peak discharges will likely be lower due to a longer time of concentration for the site.

This credit cannot be taken if grass channels are being used as a limited application structural stormwater control towards meeting the 80% TSS removal goal for WQ_V treatment.

Rule: Subtract the areas draining to a grass channel from total site area when computing water quality volume requirements.

<u>Criteria:</u>

- The credit shall only be applied to moderate or low density residential land uses (3 dwelling units per acre maximum)

- The maximum flow velocity for water quality design storm shall be less than or equal to 1.0 foot per second
- The minimum residence time for the water quality storm shall be 5 minutes
- The bottom width shall be a maximum of 6 feet. If a larger channel is needed use of a compound cross section is required
- The side slopes shall be 4:1 (horizontal:vertical) or flatter
- The channel slope shall be 3 percent or less
- R_V is kept constant when calculating WQ_V

Example:

Residential Subdivision
Area = 38 acres
Impervious Area = 13.8 acres

Credit:

12.5 acres meet grass channel criteria
New drainage area = 38 – 12.5 = 25.5 acres

Before credit:
WQ_V = (1.2)(0.22)(38)/12 = 0.84 ac-ft
With credit:
WQ_V = (1.2)(0.22)(25.5)/12 = 0.56 ac-ft

(33% reduction in water quality volume)

<u>Drain Runoff to Pervious Areas</u>

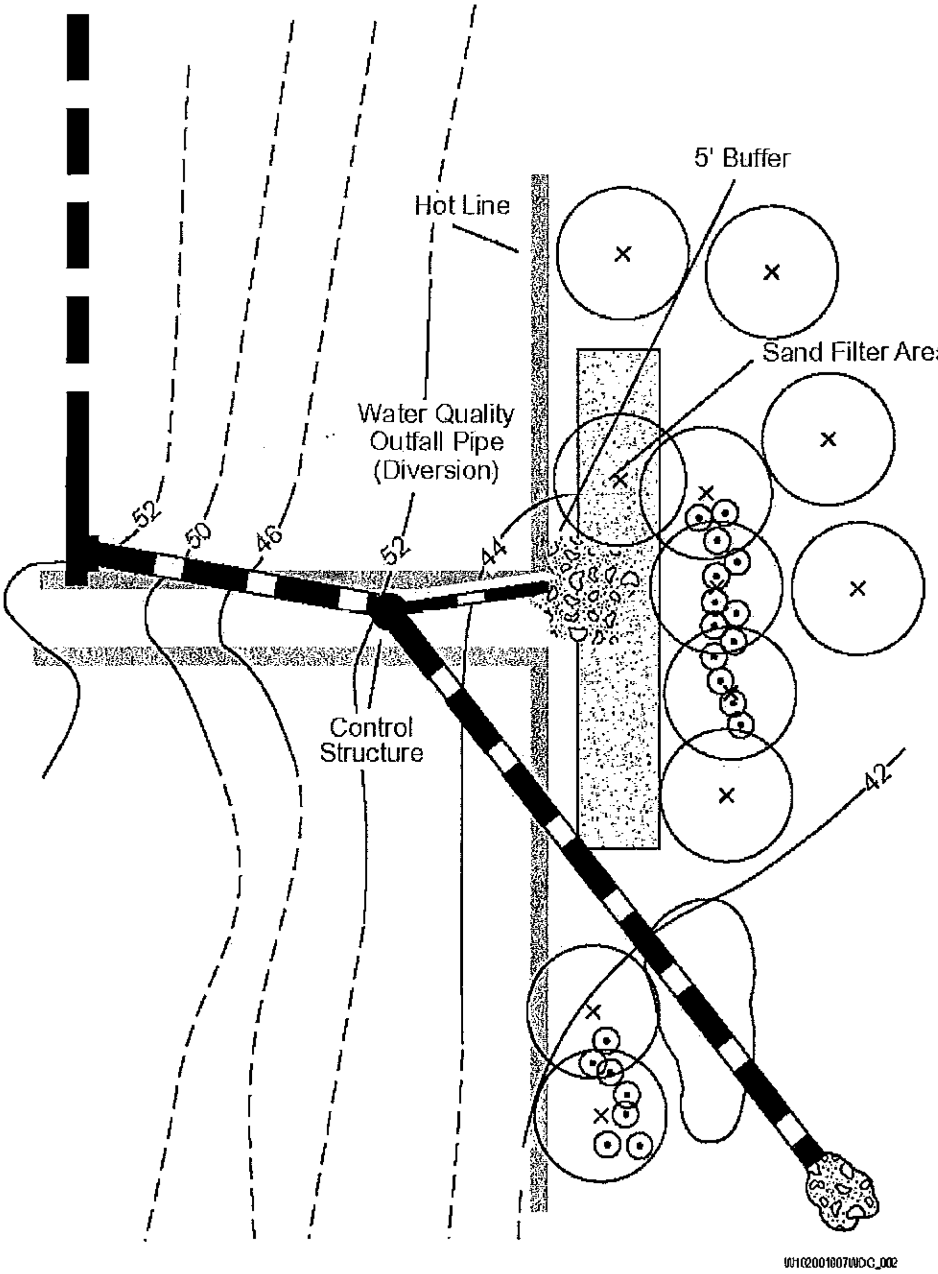
Where possible, direct runoff from impervious areas such as rooftops, roadways, and parking lots to pervious areas, open channels or vegetated areas to provide for water quality treatment and infiltration. Avoid routing runoff directly to the structural stormwater conveyance system.

The key benefits include:

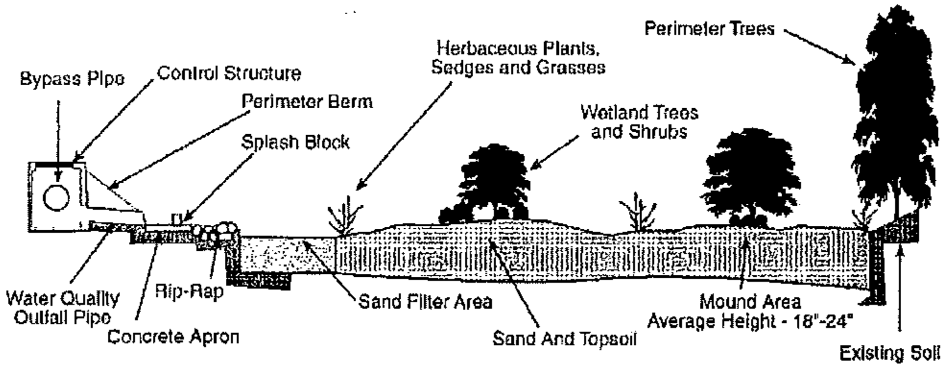
- Sending runoff to pervious vegetated areas increases overland flow time and reduces peak flows
- Vegetated areas can often filter and infiltrate stormwater runoff
- A stormwater site design credit can be taken (see Site Design Credit under Minimize Siting on Porous or Erodible Soils)

Use this practice by:

✓ Minimize directly connected impervious areas and drain runoff as sheet flow to pervious vegetated areas



DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	**CITY OF RAPID CITY** **Engineering Services** 300 Sixth Street Rapid City, SD 57701-2724 Telephone: (605) 394-4154 FAX: (605) 394-6636 www.rcgov.org	BIORETENTION PLAN VIEW	ISSUED: ______ REVISED: ______ FIGURE NO. **2.41**



Bioretention cross section: Runoff from large storms is bypassed through the main drainage system. Runoff from small storms is ***diverted*** *at the control structure (manhole). The energy of the stormwater flow is* ***dissipated*** *by the splash block or the rip rap. The stormwater is* ***filtered*** *through an open sand filter. Excess stormwater is* ***treated*** *in the bioretention area.*

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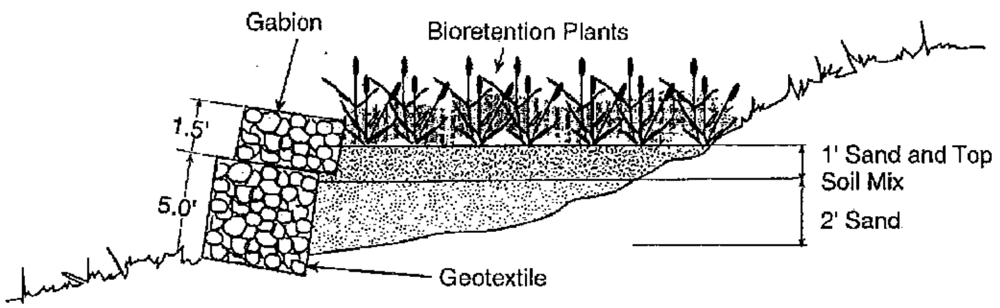

Bioretention cross section; bioretention facility incorporated in a grass swale with mild to moderate slope.

NOTE: Provide protective railing where required by code.

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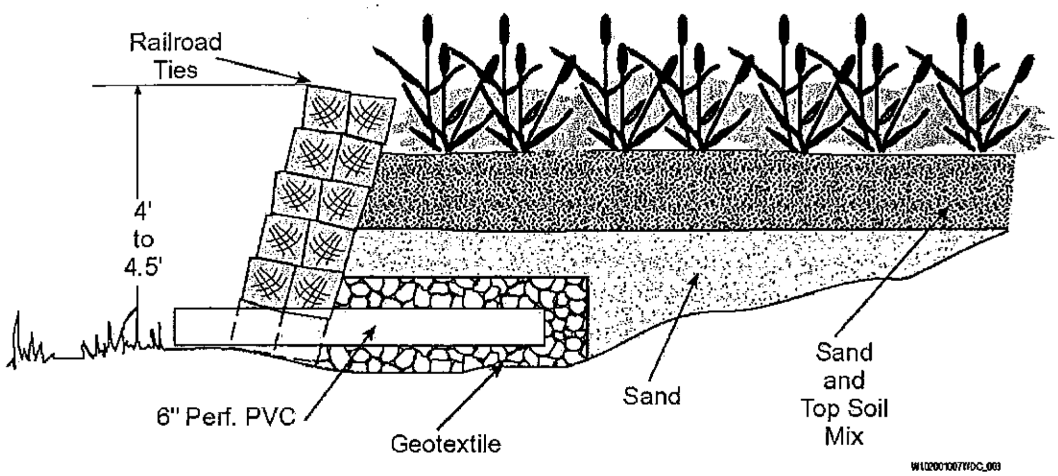

NOTE: Provide protective railing where required by code.

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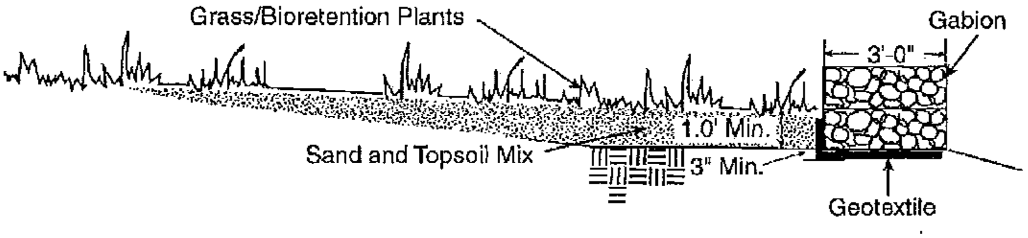

Bioretention cross section; bioretention facility incorporated in a grass swale with flat to mild slope

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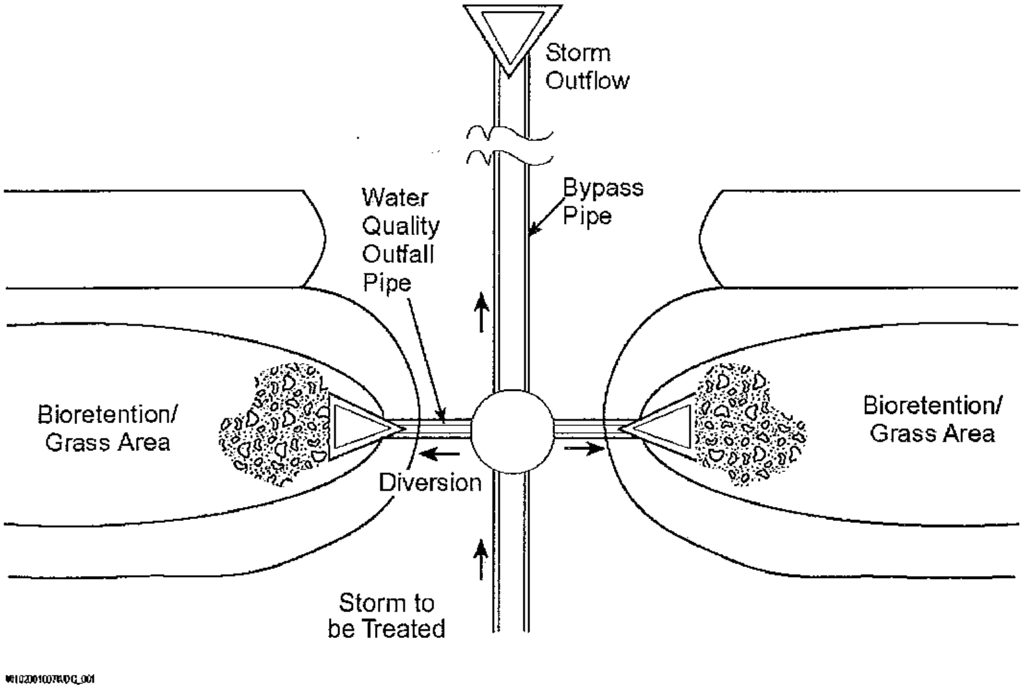
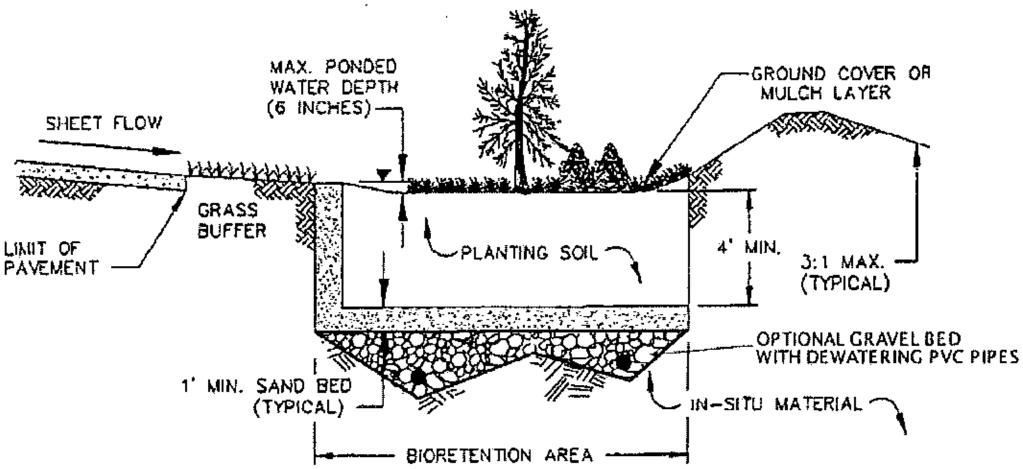


DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	STORM SEWER DIVERSION INTO BIORENTION AREA	ISSUED: ______ REVISED: ______ FIGURE NO. 2.36



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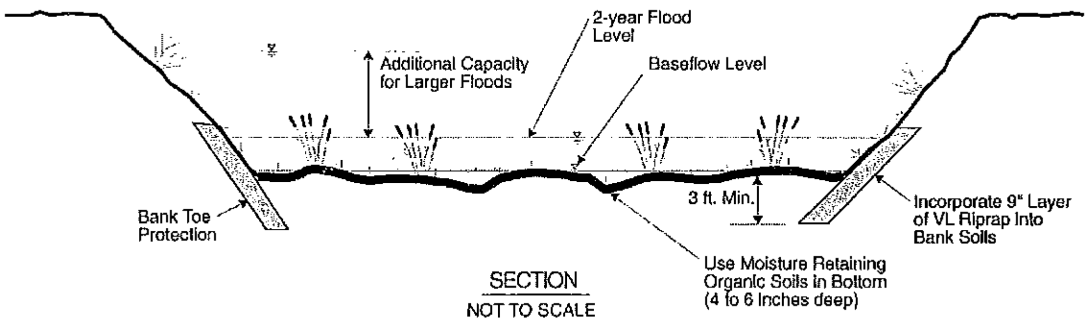
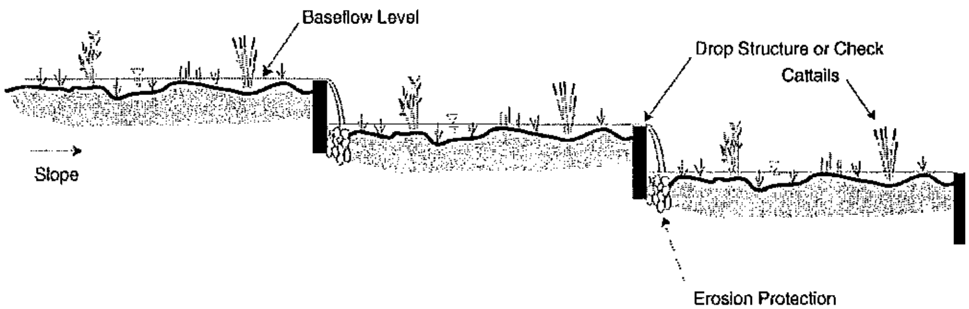
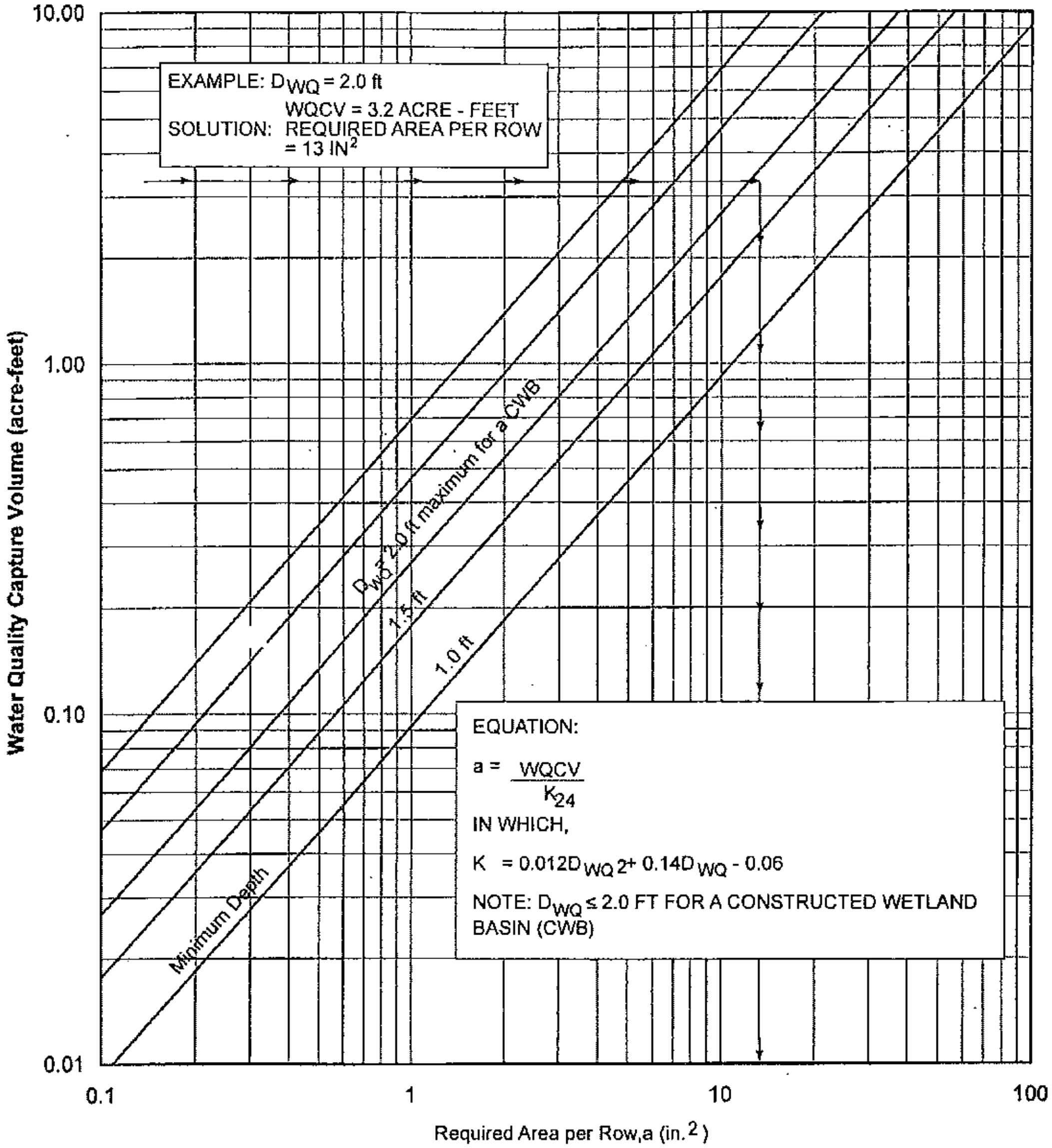


SECTION
NOT TO SCALE



SECTION
NOT TO SCALE

DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	PLAN AND SECTION OF A CONSTRUCTED WETLAND CHANNEL	ISSUED: ______ REVISED: ______ FIGURE NO. 2.34



Source: Douglas County Storm Drainage and Technical Criteria, 1986.

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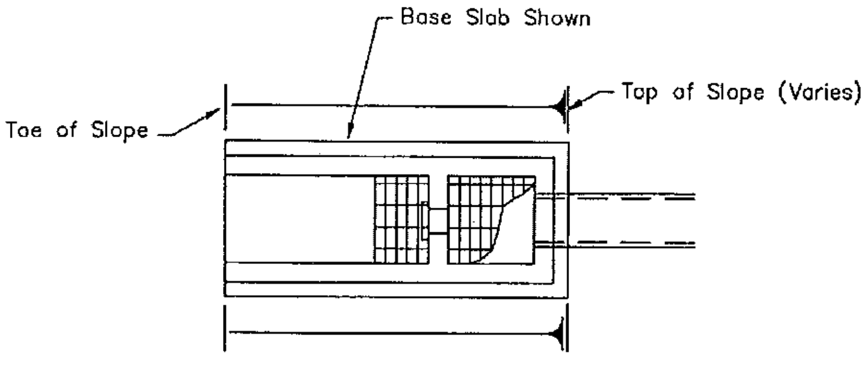
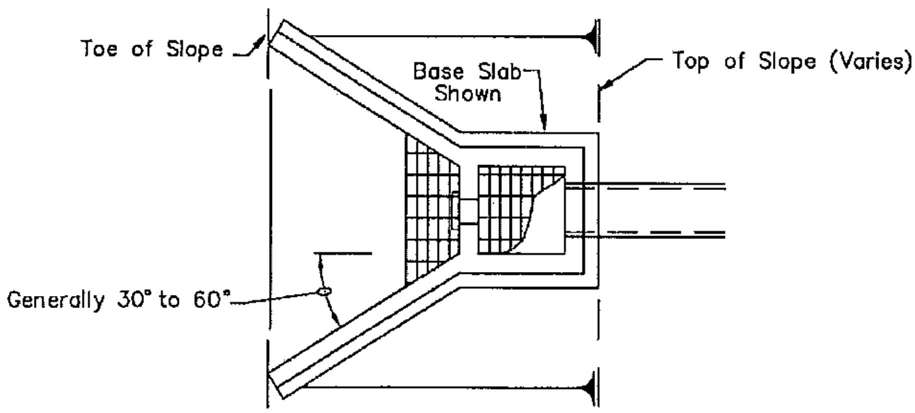


Plan View—Straight Wingwall Option



For either a Vertical or Adverse–Slope Trash Rack
a handrail may be required.

Plan View—Flared Wingwall Option

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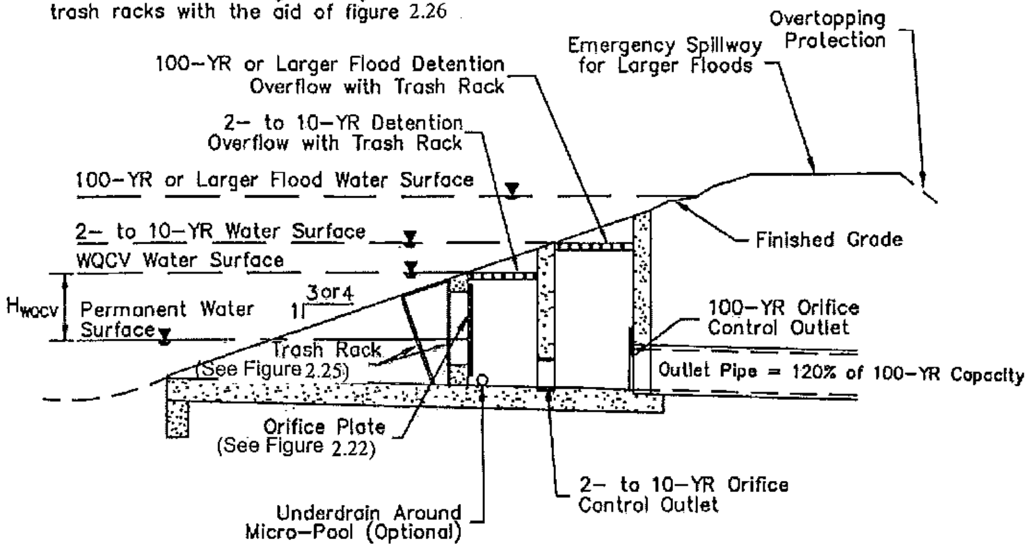
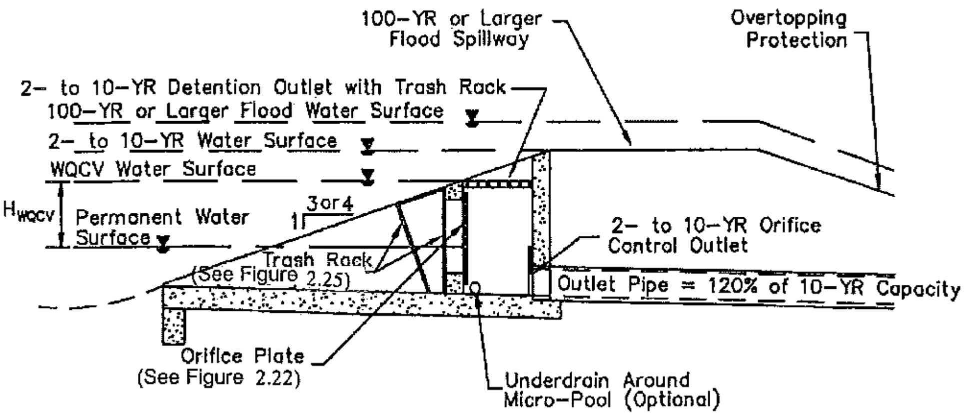
Note: Size 2– through 100–year overflow trash racks with the aid of figure 2.26

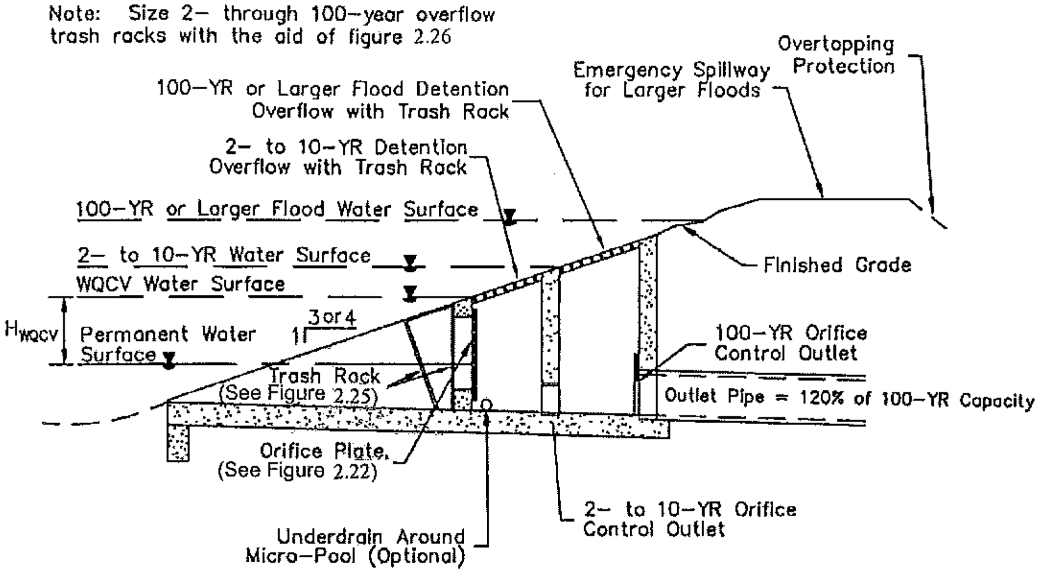


Drop Box Outlet Option

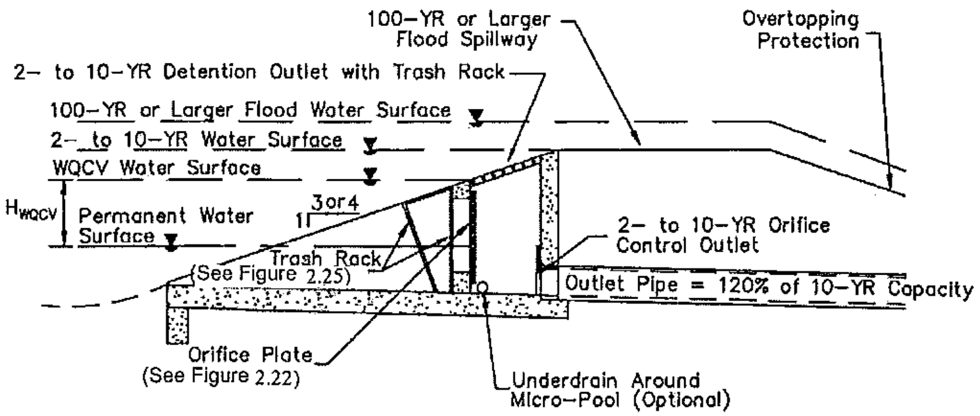


Overtopping Spillway Option

DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	TYPICAL WQCV OUTLET STRUCTURE PROFILES INCLUDING 2- TO 10-YEAR AND 100-YEAR DETENTION	ISSUED: ______ REVISED: ______ FIGURE NO. 2.31



Drop Box Outlet Option



Overtopping Spillway Option

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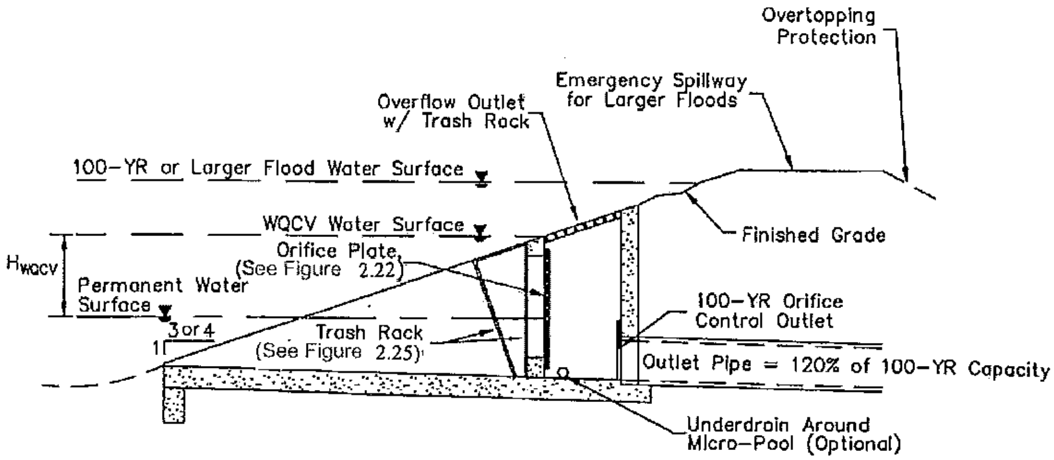
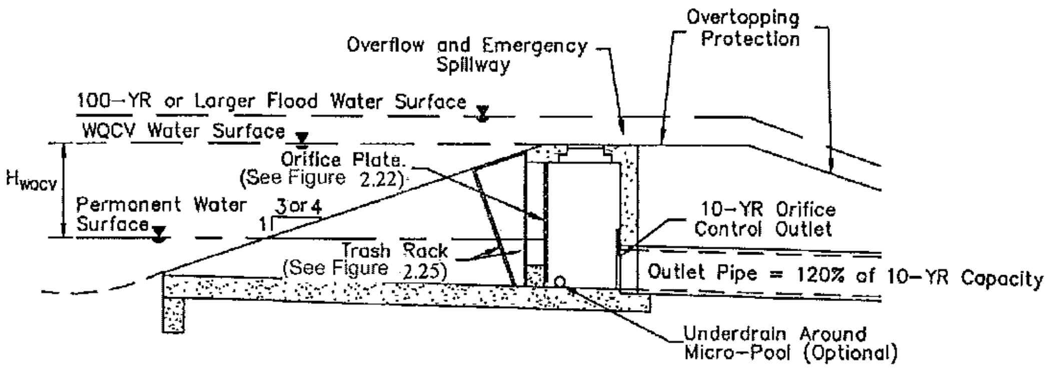
Note: Size 2- through 100-year overflow trash racks with the aid of figure 2.26



Drop Box Outlet Option



Overtopping Spillway Option

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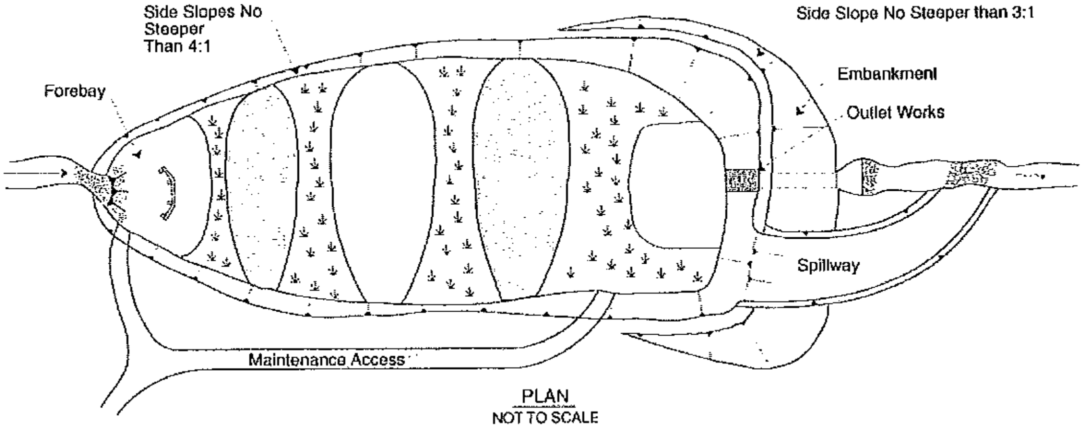
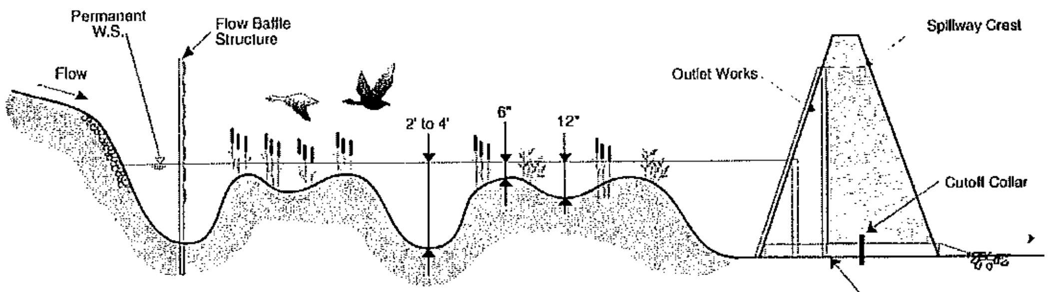


PLAN
NOT TO SCALE

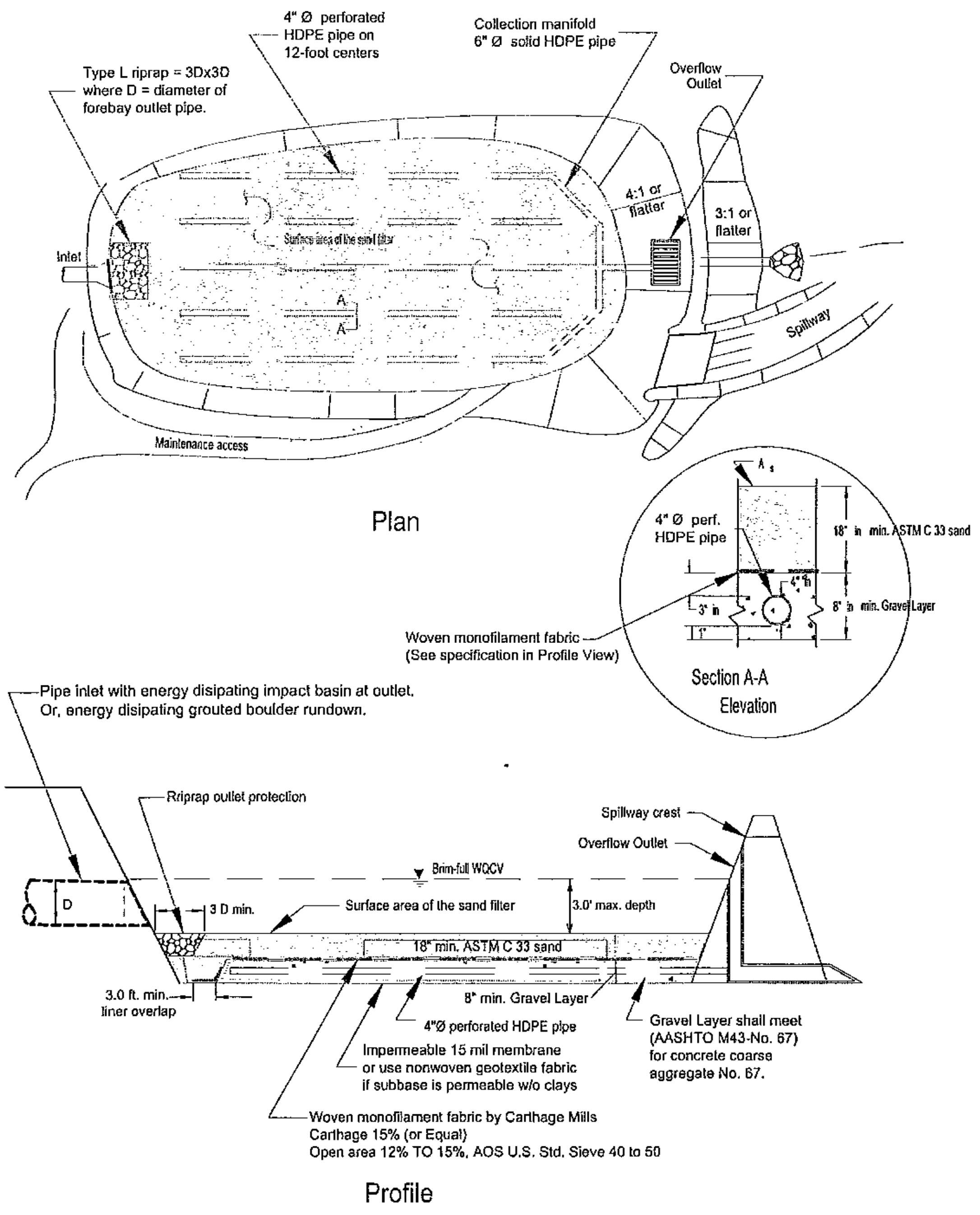
Depth Variation Legend

- Innundated 6" below permanent pool
- Innundated to 12" below permanent pool
- Inundated 2' to 4' below permanent pool



PROFILE
NOT TO SCALE

DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	PLAN AND PROFILE OF A CONSTRUCTED WETLAND BASIN SEDIMENTATION FACILITY	ISSUED: ______ REVISED: ______ FIGURE NO. 2.28



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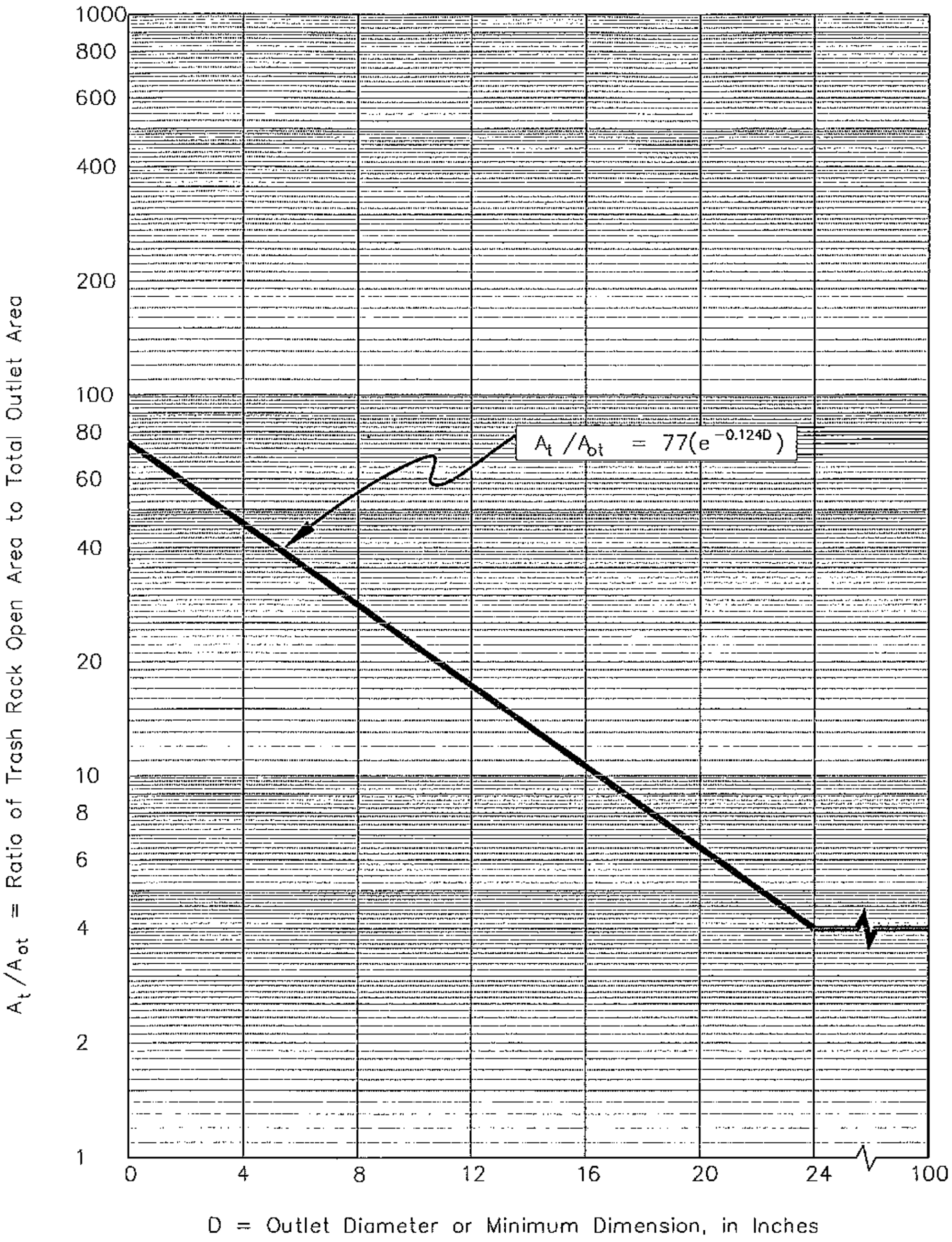

DRAWN BY:

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APPROVED BY:

CITY OF RAPID CITY

Engineering Services

300 Sixth Street

Rapid City, SD 57701-2724

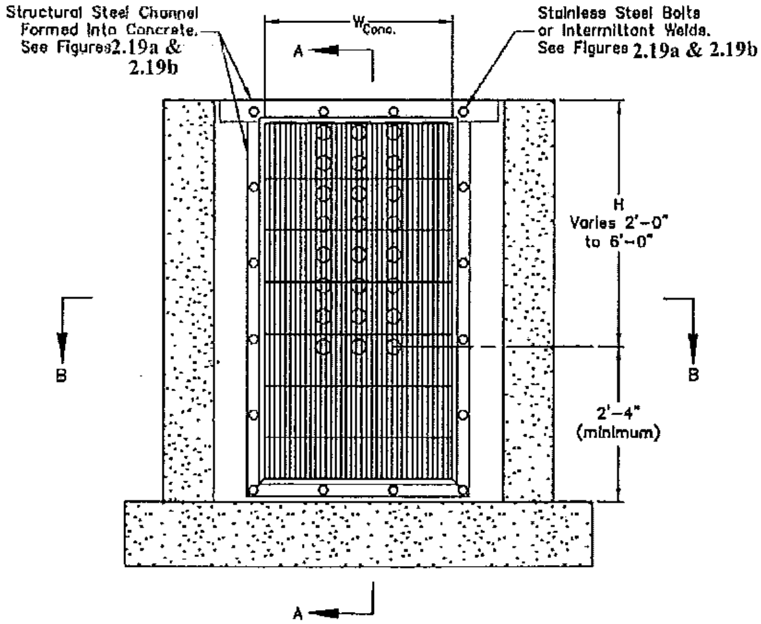
MINIMUM TRASH RACK OPEN AREA - EXTENDED RANGE

ISSUED:

REVISED:

FIGURE NO. 2.26

Note: Vertical WQCV Trash Racks are shown in Figures 2.19a, 2.19b & 2.19c for suggested standardized outlet design. Adverse–Slope Trash Rack design may be used for non–standardized designs, but must meet minimum design criteria.



Elevation

WQCV Trash Racks:

1. Well–screen trash racks shall be stainless steel and shall be attached by intermittent welds along the edge of the mounting frame.
2. Bar grate trash racks shall be aluminum and shall be bolted using stainless steel hardware.
3. Trash Rack widths are for specified trash rack material. Finer well–screen or mesh size than specified is acceptable, however, trash rack dimensions need to be adjusted for materials having a different open area/gross area ratio (R value)
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Overflow Trash Racks:

1. All trash racks shall be mounted using stainless steel hardware and provided with hinged and lockable or boltable access panels.
2. Trash racks shall be stainless steel, aluminum, or steel. Steel trash racks shall be hot dip galvanized and may be hot powder painted after galvanizing.
3. Trash Racks shall be designed such that the diagonal dimension of each opening is smaller than the diameter of the outlet pipe.
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

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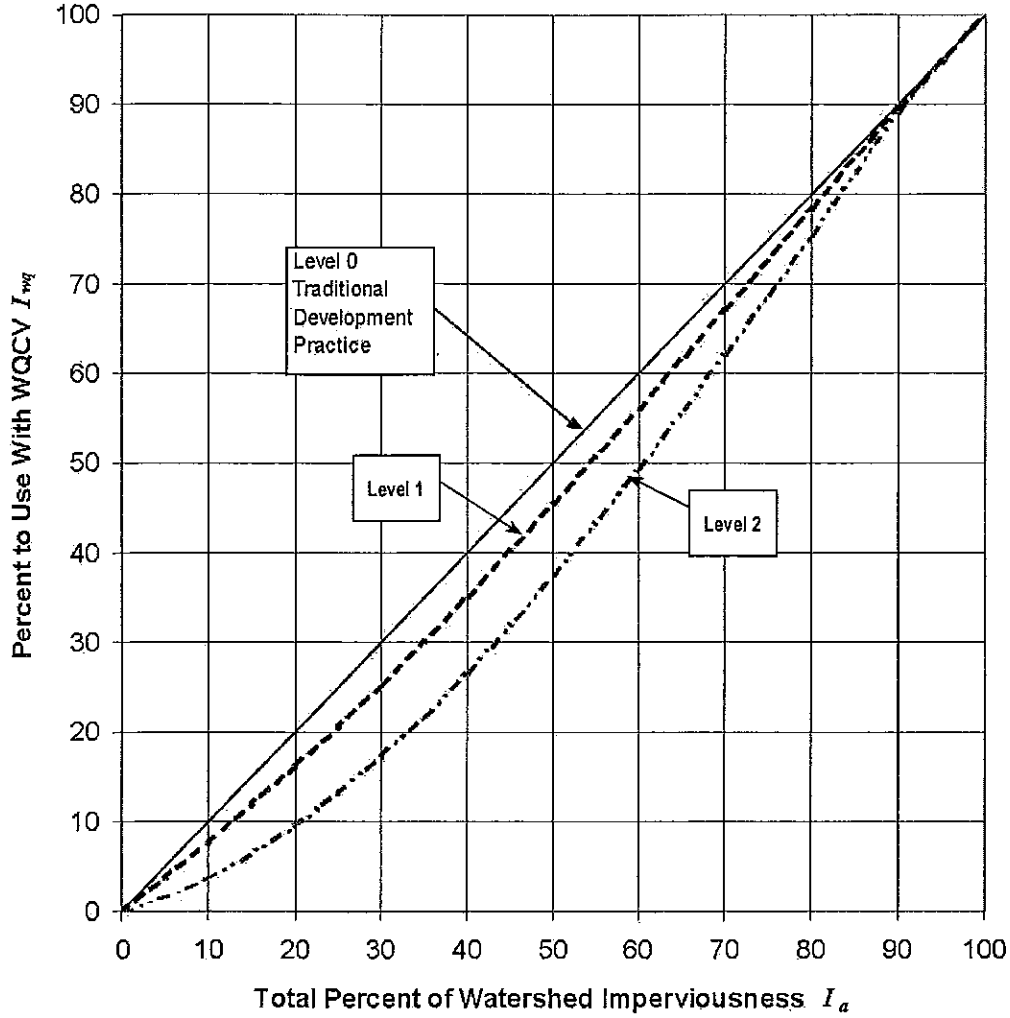

DRAWN BY: ________ CHECKED BY: ________ APPROVED BY: ________	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	IMPERVIOUSNESS TO USE WITH WATER QUALITY CAPTURE VOLUME (WQCV)	ISSUED: ________ REVISED: ________ FIGURE NO. 2.24

Orifice Plate Perforation Sizing

Circular Perforation Sizing

Chart may be applied to orifice plate or vertical pipe outlet.

Hole Dia (in) *	Hole Dia (in)	Min. Sc (in)	Area per Row (sq in)		
			n=1	n=2	n=3
1/4	0.250	1	0.05	0.10	0.15
5/16	0.313	2	0.08	0.15	0.23
3/8	0.375	2	0.11	0.22	0.33
7/16	0.438	2	0.15	0.30	0.45
1/2	0.500	2	0.20	0.39	0.59
9/16	0.563	3	0.25	0.50	0.75
5/8	0.625	3	0.31	0.61	0.92
11/16	0.688	3	0.37	0.74	1.11
3/4	0.750	3	0.44	0.88	1.33
13/16	0.813	3	0.52	1.04	1.56
7/8	0.875	3	0.60	1.20	1.80
15/16	0.938	3	0.69	1.38	2.07
1	1.000	4	0.79	1.57	2.36
1 1/16	1.063	4	0.89	1.77	2.66
1 1/8	1.125	4	0.99	1.99	2.98
1 3/16	1.188	4	1.11	2.22	3.32
1 1/4	1.250	4	1.23	2.45	3.68
1 5/16	1.313	4	1.35	2.71	4.06
1 3/8	1.375	4	1.48	2.97	4.45
1 7/16	1.438	4	1.62	3.25	4.87
1 1/2	1.500	4	1.77	3.53	5.30
1 9/16	1.563	4	1.92	3.83	5.75
1 5/8	1.625	4	2.07	4.15	6.22
1 11/16	1.688	4	2.24	4.47	6.71
1 3/4	1.750	4	2.41	4.81	7.22
1 13/16	1.813	4	2.58	5.16	7.74
1 7/8	1.875	4	2.76	5.52	8.28
1 15/16	1.938	4	2.95	5.90	8.84
2	2.000	4	3.14	6.28	9.42
n = Number of columns of perforations					
Minimum steel plate thickness			1/4 "	5/16 "	3/8 "

* Designer may interpolate to the nearest 32nd inch to better match the required area, if desired.

Rectangular Perforation Sizing

Only one column of rectangular perforations allowed.

Rectangular Height = 2 inches

$$\text{Rectangular Width (inches)} = \frac{\text{Required Area per Row (sq in)}}{2"}$$

Rectangular Hole Width	Min. Steel Thickness
5"	1/4 "
6"	1/4 "
7"	5/32 "
8"	5/16 "
9"	11/32 "
10"	3/8 "
>10"	1/2 "

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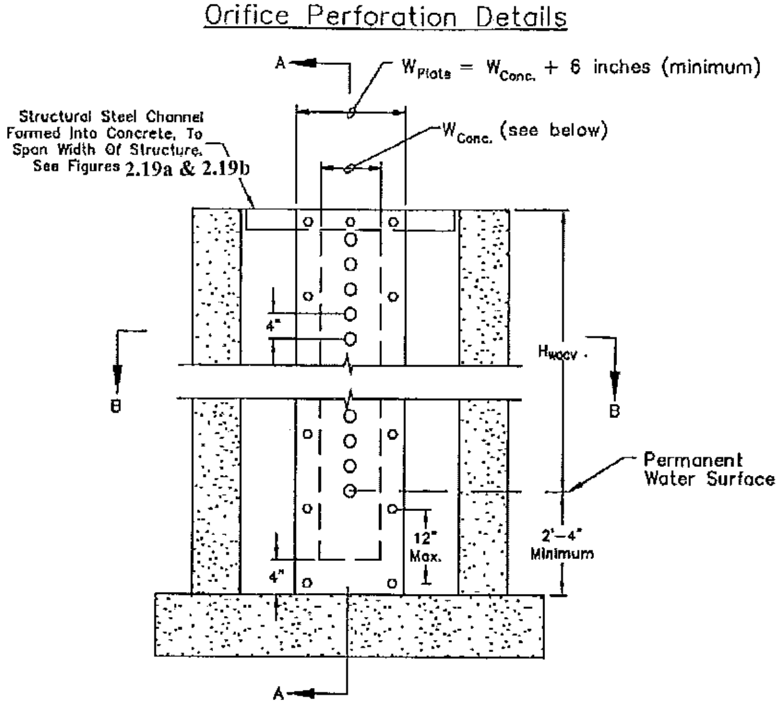
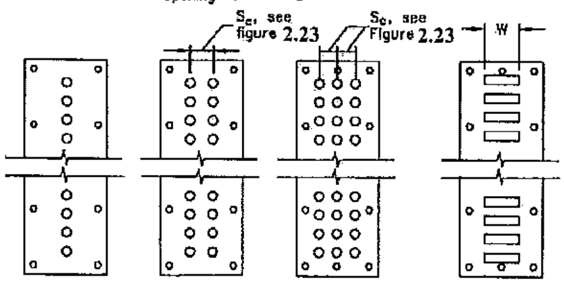


Circular Openings: $W_{Conc.}$ Obtained From Table 2.10a

Rectangular Openings: $W_{Conc.}$ = (Width of Rectangular Perforation W) + 12"

Rectangular Openings: $W_{Opening}$ (see Figure2.19a) Obtained From Table 2.10a



Example Perforation Patterns

Note: The goal in designing the outlet is to minimize the number of columns of perforations that will drain the WQCV in the desired time. Do not, however, increase the diameter of circular perforations or the height of the rectangular perforations beyond 2 inches. Use the allowed perforation shapes and configurations shown above along with Figure 2.23 to determine the pattern that provides an area per row closest to that required without exceeding it.

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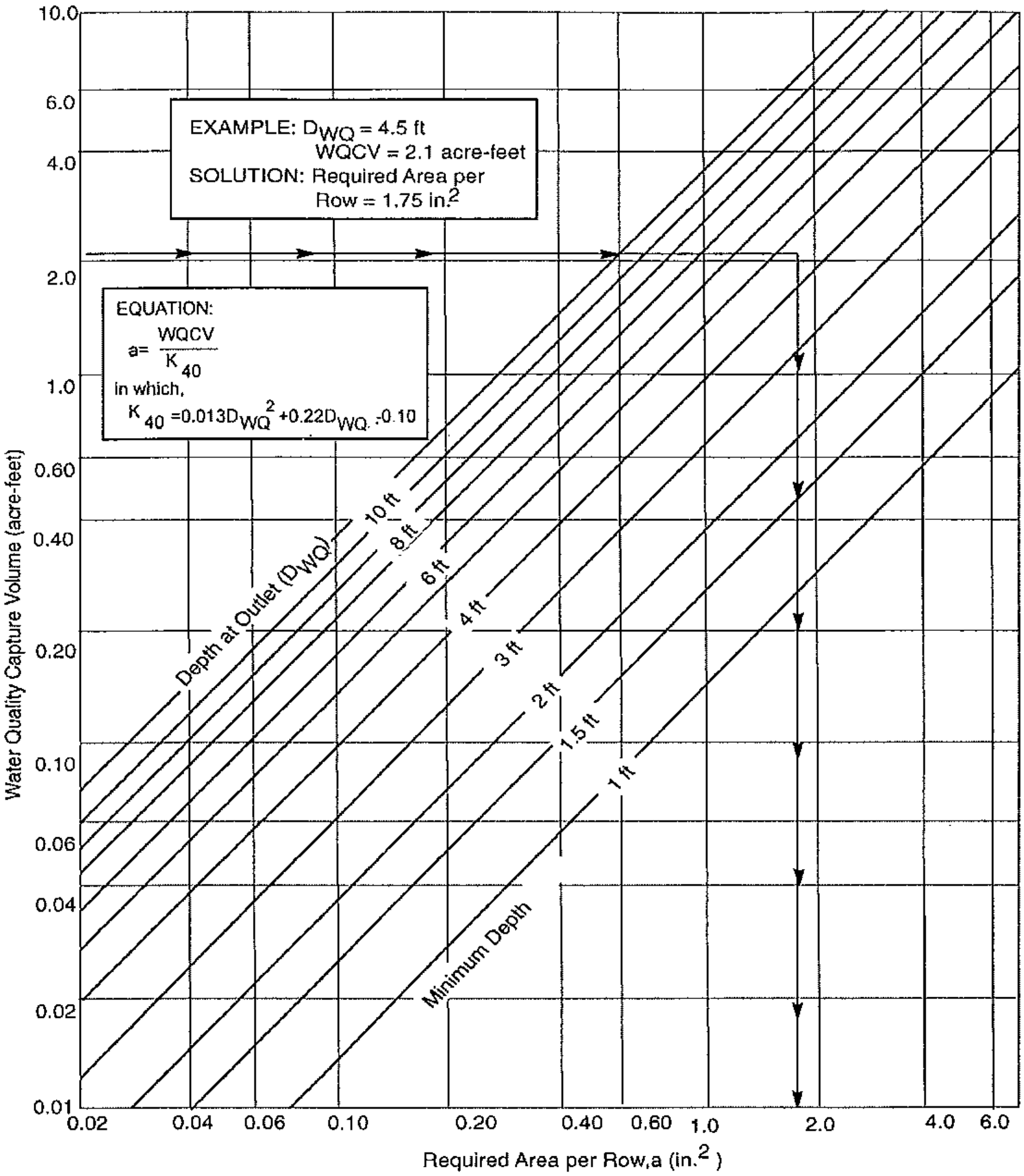
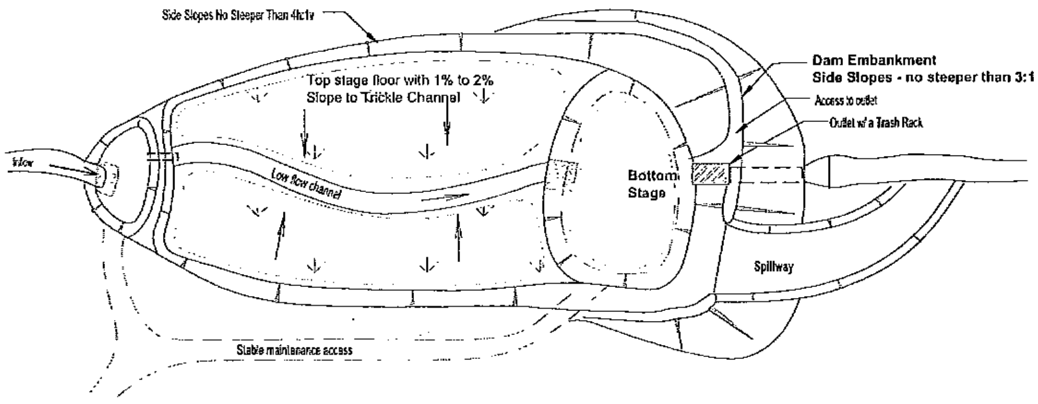
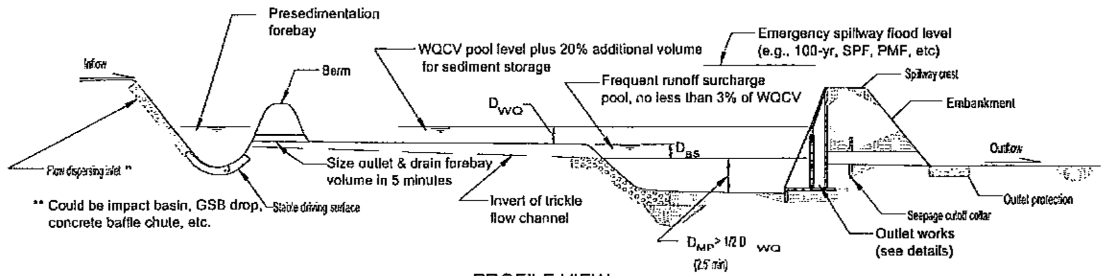
CHECKED BY:			FIGURE NO. 2.22
APPROVED BY:			



DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724 Telephone: (605) 394-4154 FAX: (605) 394-6636 www.rcgov.org	WATER QUALITY OUTLET SIZING: DRY EXTENDED DETENTION BASIN, SAND FILTER BASIN WITH A 40-HOUR DRAIN TIME OF THE CAPTURE VOLUME	ISSUED: ______ REVISED: ______ FIGURE NO. 2.21



PLAN VIEW
Not to Scale



PROFILE VIEW
Not to Scale

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Typical Outlet Structure Notes:

1. The details shown are intended to show design concepts. Preparation of final design plans, addressing details of structural adequacy, excavation, foundation preparation, concrete work, reinforcing steel, backfill, metalwork, and appurtenances, including preparation of technical specifications, are the responsibility of the design engineer.

2. Alternate designs to the typical outlet structures shown may be considered; however, alternate designs must address the hydraulic and trash handling functional elements of the structures shown.

3. Wingwalls shown are intended to enable the structure to be backfilled to be flush with the side slopes of the basin, which is the recommended geometry. Other geometries may be considered if their designs related to public safety, aesthetics, maintainability, and function are equal to or better than the designs shown.

4. Permanent Water Surface shown refers to micro-pool for Extended Detention Basin or permanent pool for Constructed Wetland Basin or Retention Pond.

5. An orifice plate is shown as the outflow control; however, an upturned pipe, with orifices may also be used. See Figure 2.22 for orifice design information.

6. A Vertical Trash Rack option is generally shown; however, an Adverse-Slope Trash Rack may also be used. Continuous-Slope Trash Racks for use with WQCV outlets are not recommended. See Figure 2.25 for trash rack design information.

7. References are made to 2- or 10-year detention above the WQCV; however, detention above the WQCV may be sized for any storm event.

8. The underdrain, including a shutoff valve, from the perimeter of the pond is required for a Wetland Basin and a Retention Pond. An underdrain, without a shutoff valve, is optional for the micro-pool and may be used to help dry the micro-pool during dry-weather periods.

9. When outlet designs differ from those shown herein:

   a) Provide needed orifices that are distributed over the vertical height of the WQCV, with the lowest orifice located at 2'-6" or more above the bottom of the micro-pool.

   b) Provide full hydraulic calculations demonstrating that the outlet will provide no less than the minimum required drain time of the Water Quality Capture Volume for the BMP type being designed.

   c) All outlet openings (i.e., orifices) shall be protected by a trash rack sized to provide a minimum net opening area called for by Figure 2.26 , and all trash rack opening dimensions shall be smaller than the smallest dimension of the outlet orifices.

   d) Trash racks shall be manufactured from stainless steel or aluminum alloy structurally designed to not fail under a full hydrostatic load on the upstream side.

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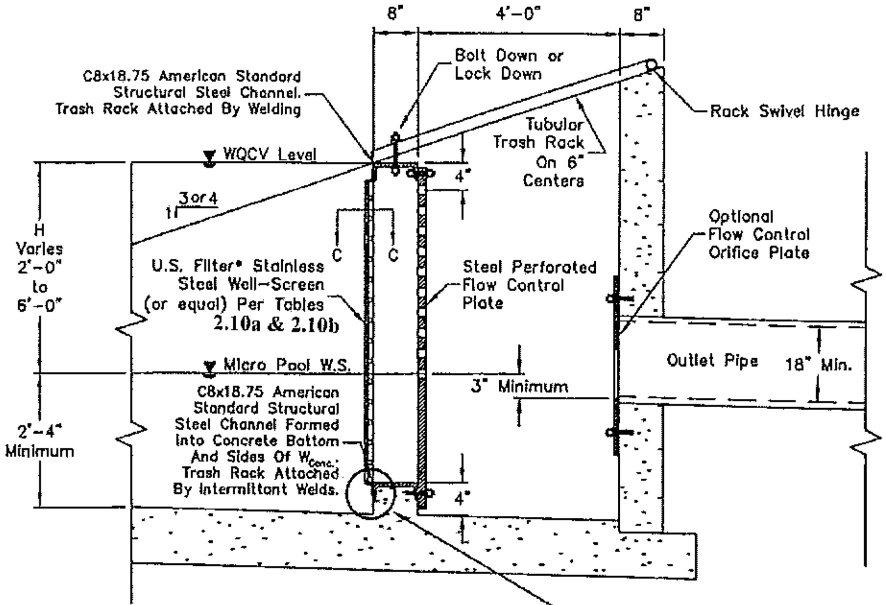
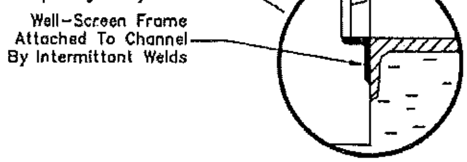
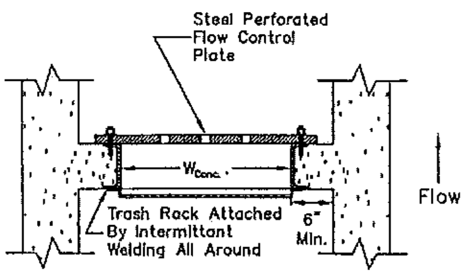


Section A–A

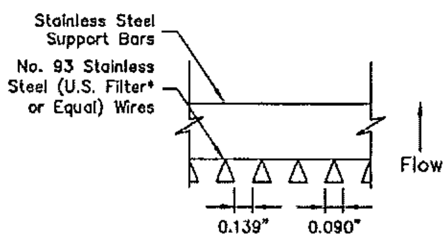
From Figure 2.25, Circular Openings Only





Section B–B – Plan View

From Figure 2.25, Circular Openings Only



Section C–C

From Figure 2.25, Circular Openings Only

R Value = (net open area)/(gross rack area) = 0.60

Limits for this Standardized Design:

1. All outlet plate openings are circular.
2. Maximum diameter of opening = 2 inches.

*U.S. Filter, St. Paul, Minnesota, USA

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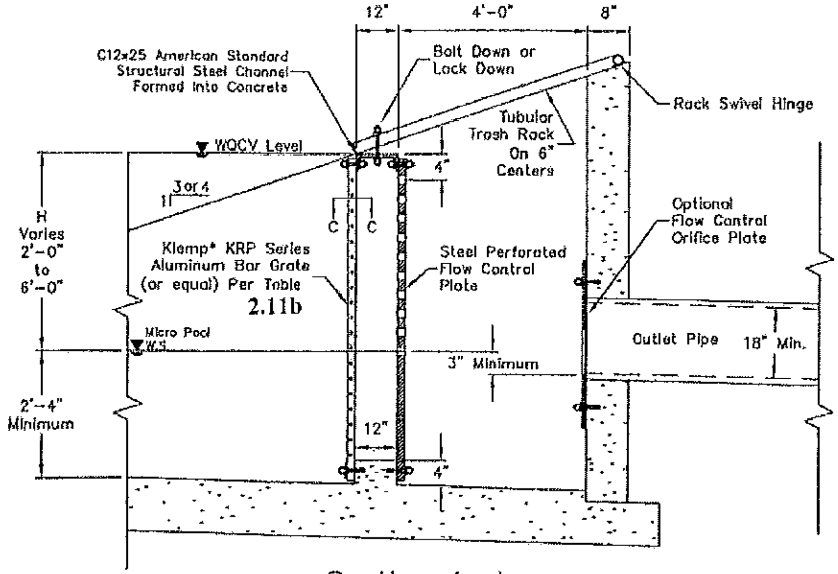
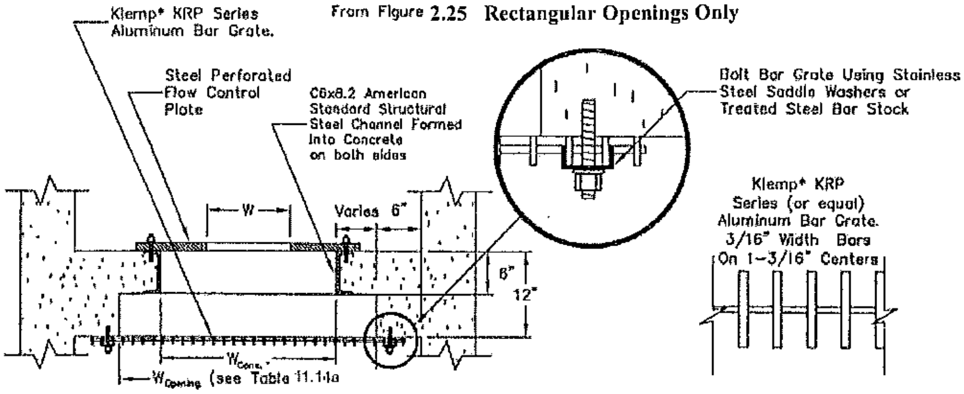


Section A–A

From Figure 2.25 **Rectangular Openings Only**



Section B–B – Plan View

From Figure 2.25 **Rectangular Openings Only**

Limits for this Standardized Design:

1. All outlet plate openings are rectangular.
2. Height of all rectangular openings = 2 inches.
3. For trash rack opening width ($W_{Opening}$), see Table **2.11a**
4. Concrete opening for outlet plate ($W_{Conc.}$) = W + 12 inches

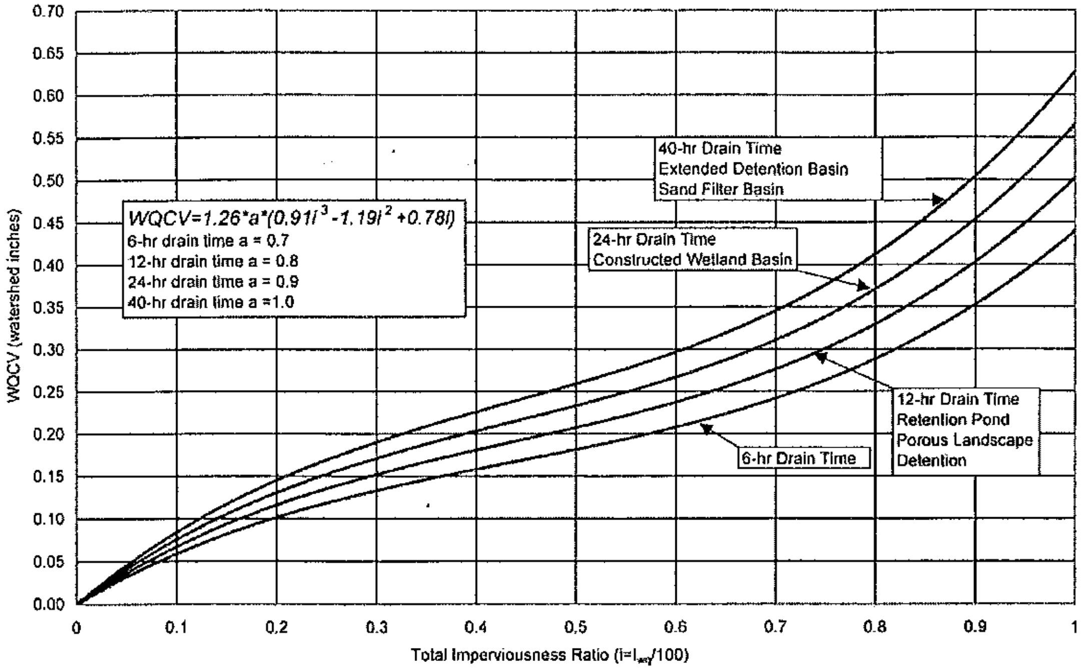
*Klemp Corporation, Orem, Utah, USA

Section C–C

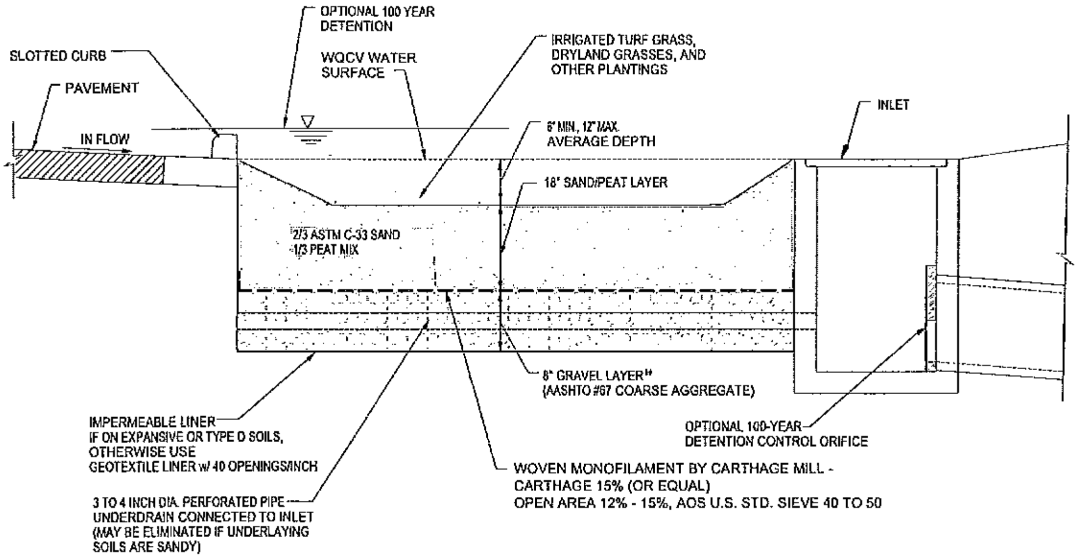
From Figure 2.25 **Rectangular Openings Only**

R Value = (net open area)/(gross rack area)
= 0.71 for cross rods on 2" centers
= 0.77 for cross rods on 4" centers

DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	SUGGESTED STANDARDIZED TRASH RACK AND OUTLET DESIGN FOR WQCV OUTLETS WITH RECTANGULAR OPENINGS	ISSUED: ______ REVISED: ______ FIGURE NO. **2.19a**



DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724	WATER QUALITY CAPTURE VOLUME (WQCV), 80^{th} PERCENTILE RUNOFF EVENT	ISSUED: ______ REVISED: ______ FIGURE NO. 2.18



** SUBSTITUTE AN 18" LAYER OF SAND/PEAT MIX FOR THE 8" GRAVEL LAYER WHEN NO UNDERDRAIN IS USED IN NRCS TYPE D SOILS OR IN EXPANSIVE SOILS. USE IMPERMEABLE LINER UNDER AND ON SIDES OF BASIN.

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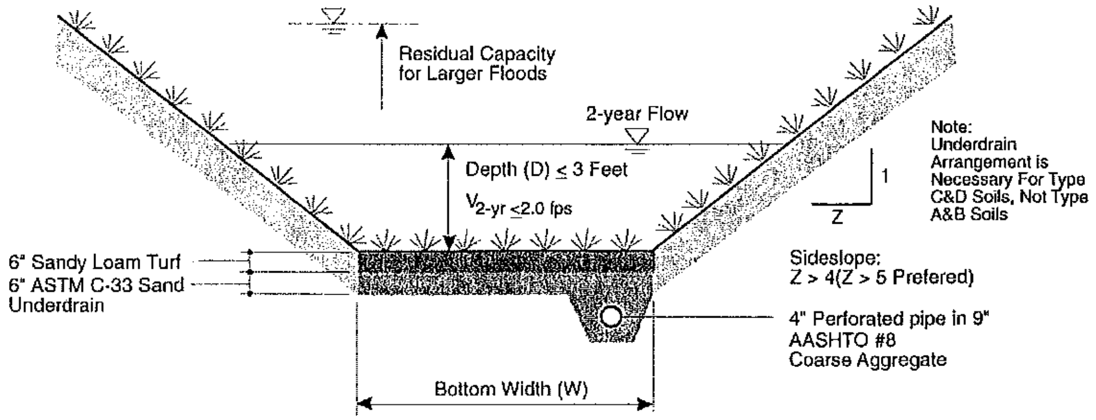
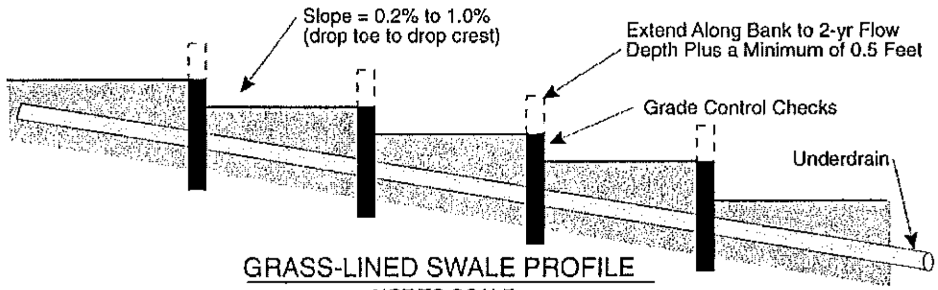
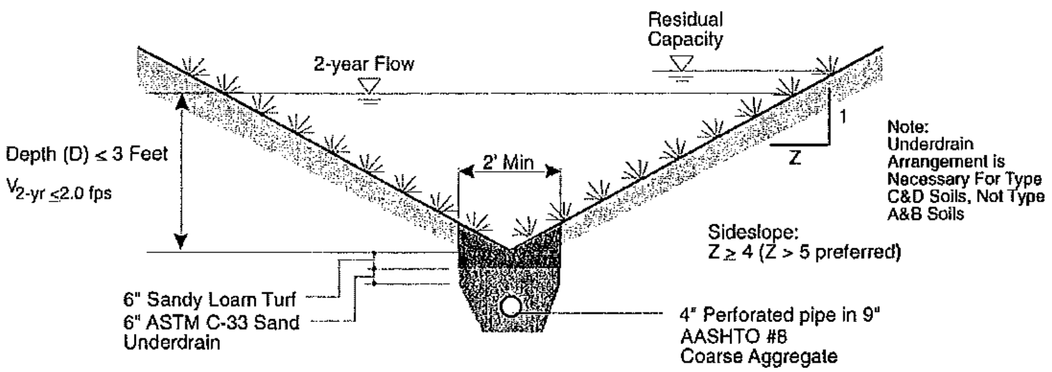


TRAPEZOIDAL GRASS-LINED SWALE SECTION
NOT TO SCALE



GRASS-LINED SWALE PROFILE
NOT TO SCALE



TRIANGULAR GRASS-LINED SWALE SECTION
NOT TO SCALE

DRAWN BY: ______
CHECKED BY: ______
APPROVED BY: ______

CITY OF RAPID CITY
Engineering Services
300 Sixth Street
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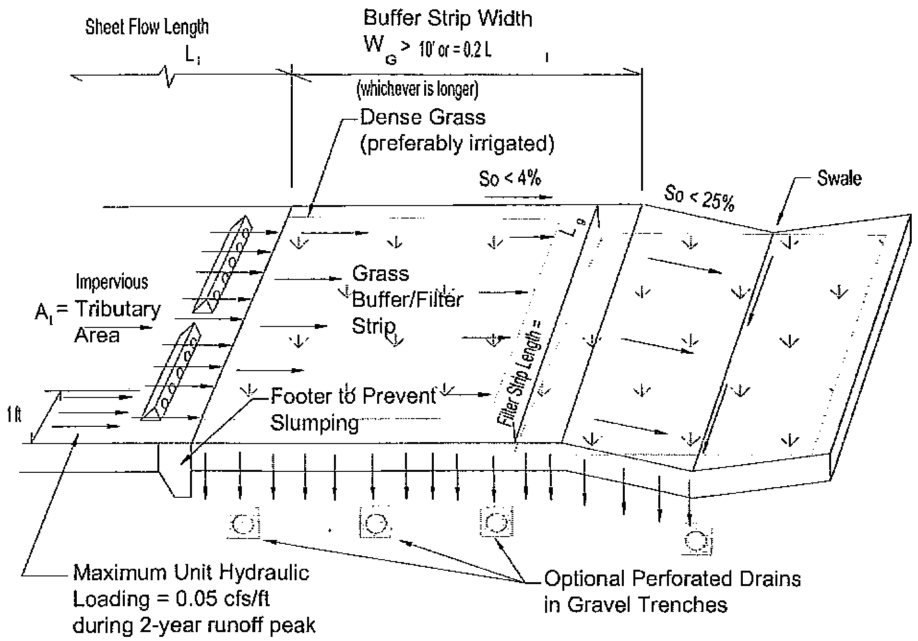
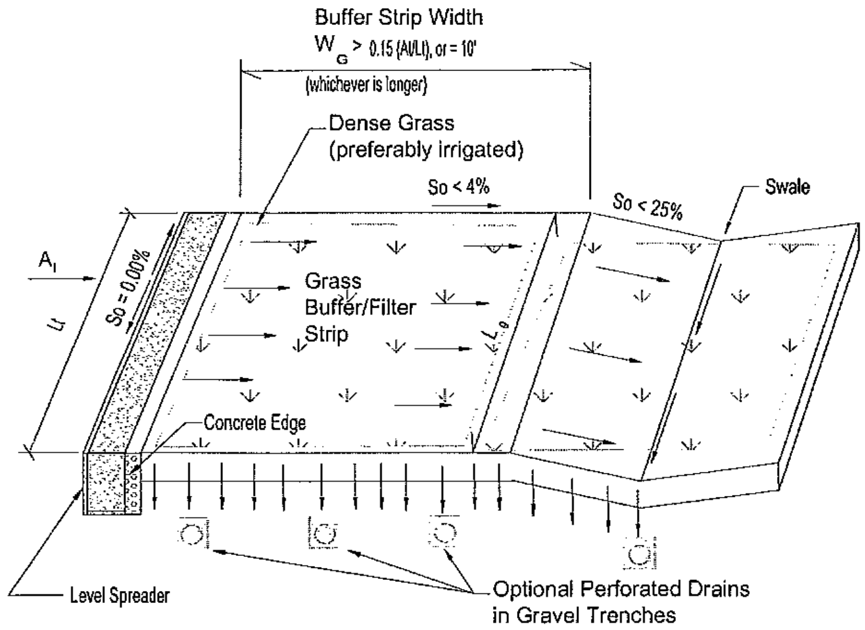
PROFILE AND SECTIONS OF A GRASS SWALE

ISSUED: ______
REVISED: ______
FIGURE NO. 2.16



SHEET FLOW CONTROL

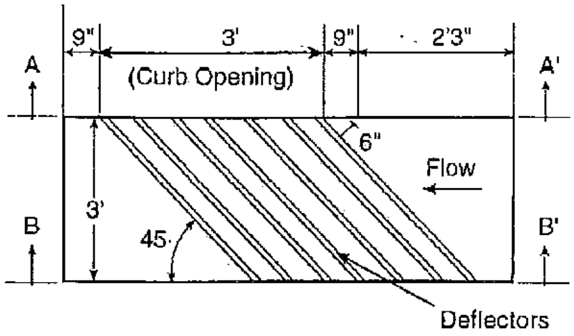
Not To Scale



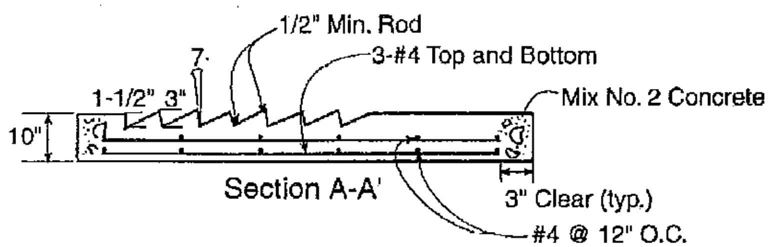
CONCENTRATED FLOW CONTROL

Not To Scale

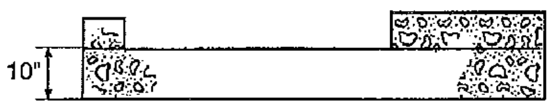
DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	CITY OF RAPID CITY Engineering Services 300 Sixth Street Rapid City, SD 57701-2724 Telephone: (605) 394-4154 FAX: (605) 394-6636 www.rcgov.org	APPLICATIONS OF GRASS BUFFERS	ISSUED: ______ REVISED: ______ FIGURE NO. 2.15



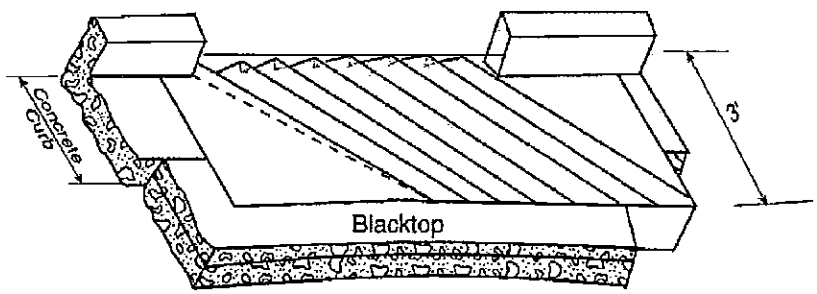
Plan



Section A-A'



Section B-B'



Isometric

DRAWN BY: ______ CHECKED BY: ______ APPROVED BY: ______	**CITY OF RAPID CITY** Engineering Services 300 Sixth Street Rapid City, SD 57701-2724 Telephone (605) 394-4154 FAX: (605) 394-6636 www.rcgov.org	PLAN AND SECTION VIEWS OF A CURB DIVERSION STRUCTURE	ISSUED: ______ REVISED: ______ FIGURE NO. 2.42

TABLE 2.11b

Standardized WQCV Outlet Design Using 2" Height Rectangular Openings. Klemp™ KRP Series Aluminum Bar Grate* (or equal) Trash Rack Design Specifications

Water Depth Above Lowest Opening, H	Minimum Bearing Bar Size, Bearing Bars Aligned Vertically
2.0 ft	1" × 3/16"
3.0 ft	1¼" × 3/16"
4.0 ft	1¾" × 3/16"
5.0 ft	2" × 3/16"
6.0 ft	2¼" × 3/16"

*Klemp Corporation, Orem, Utah, USA

DESIGN EXAMPLE:

Given: A WQCV outlet with an orifice plate consisting of 2" high by 6.5" wide openings with Water Depth H = 4.5 feet above the lowest orifice plate opening.

Solution: The dimensions of the concrete structure and the dimensions within the mounting frame for an aluminum bar grate trash rack are determined as follows.

Trash Rack and Structure Widths: There are three widths shown in Section B-B of Figure 11.50a: W = the width of the rectangular openings in the orifice plate, W_{conc} = the width of the concrete opening where the orifice plate attaches, and $W_{opening}$ = the width of the concrete opening where the trash rack attaches.

> $W_{conc.}$ = W + 12" (from Figure 11.53) = 6.5" + 12" = 18.5".
>
> $W_{opening}$: Given an orifice plate with rectangular openings 6.5" wide and Water Depth H = 5 feet (i.e., rounded up from 4.5 feet), Table 11-14a shows the minimum trash rack width, $W_{opening}$, is 7.5 feet.

Trash Rack Height: The total trash rack height is the sum of the Water Depth H plus 2' (the height of the trash rack below the water depth, as shown in Section A-A of Figure 11.50a). Thus, the trash rack height equals 4.5' + 2' = 6.5'.

Dimensions Note: These trash rack dimensions are the minimum dimensions <u>within</u> the mounting frame. The trash rack mounting frame must be properly sized by a structural engineer taking into account the minimum trash rack dimensions, the intended method of fabrication, and the method of connection to the outlet structure.

Ordering Specifications: From Tables 11.14a and 11.14b, the ordering specifications for H=5.0 feet or less is a Klemp Corporation aluminum bar grate (or equal) with 2" by 3/16" bearing bars spaced at 1-3/16" on-center, with cross rods spaced at 4" on-center. **Bearing bars are to be aligned vertically.**

TABLE 2.11a

Standardized WQCV Outlet Design Using 2" Height Rectangular Openings. Minimum Width ($W_{opening}$) of Opening for an Aluminum Bar Grate Trash Rack

Maximum Width W of 2" Height Rectangular Opening (inches)	Minimum Width of Trash Rack Opening as a Function of Water Depth H					
	H=2.0 ft	H=3.0 ft	H=4.0 ft	H=5.0 ft	H=6.0 ft	Spacing of Bearing Bars, Cross Rods
< 2.0	2.0 ft	2.5 ft	2.5 ft	2.5 ft	3.0 ft	1-3/16", 2"
< 2.5	2.5 ft	3.0 ft	3.0 ft	3.5 ft	3.5 ft	1-3/16", 2"
< 3.0	3.0 ft	3.5 ft	3.5 ft	4.0 ft	4.0 ft	1-3/16", 2"
< 3.5	3.5 ft	4.0 ft	4.5 ft	4.5 ft	5.0 ft	1-3/16", 2"
< 4.0	3.5 ft	4.5 ft	5.0 ft	5.0 ft	5.5 ft	1-3/16", 2"
< 4.5	4.0 ft	4.5 ft	5.0 ft	5.5 ft	5.5 ft	1-3/16", 4"
< 5.0	4.0 ft	5.0 ft	5.5 ft	6.0 ft	6.0 ft	1-3/16", 4"
< 5.5	4.5 ft	5.5 ft	6.0 ft	6.5 ft	7.0 ft	1-3/16", 4"
< 6.0	5.0 ft	6.0 ft	6.5 ft	7.0 ft	7.5 ft	1-3/16", 4"
< 6.5	5.5 ft	6.5 ft	7.0 ft	7.5 ft	8.0 ft	1-3/16", 4"
< 7.0	6.0 ft	7.0 ft	7.5 ft	8.5 ft	8.5 ft	1-3/16", 4"
< 7.5	6.0 ft	7.5 ft	8.5 ft	9.0 ft	9.5 ft	1-3/16", 4"
< 8.0	6.5 ft	8.0 ft	9.0 ft	9.5 ft	10.0 ft	1-3/16", 4"
< 8.5	7.0 ft	8.5 ft	9.5 ft	10.0 ft	N/A	1-3/16", 4"
< 9.0	7.5 ft	9.0 ft	10.0 ft	N/A	N/A	1-3/16", 4"
< 9.5	8.0 ft	9.5 ft	N/A	N/A	N/A	1-3/16", 4"
< 10.0	8.5 ft	10.0 ft	N/A	N/A	N/A	1-3/16", 4"
< 10.5	8.5 ft	N/A	N/A	N/A	N/A	1-3/16", 4"
< 11.0	9.0 ft	N/A	N/A	N/A	N/A	1-3/16", 4"
< 11.5	9.5 ft	N/A	N/A	N/A	N/A	1-3/16", 4"
< 12.0	10.0 ft	N/A	N/A	N/A	N/A	1-3/16", 4"

TABLE 2.9
Recommended Tree and Shrub Spacing

	Tree Spacing (feet)	Shrub Spacing (feet)	Total Density (stems/acre)
Maximum	19	12	400
Average	12	8	1,000
Minimum	11	7	1,250

Source: Prince George's County, 1993.

TABLE 2.8
Constructed Wetlands Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Mow occasionally to limit unwanted vegetation. Maintain irrigated turf grass at 2 to 4 inches tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine—depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from entire pond to minimize outlet clogging and aesthetics. Include removal of floatable material from the pond's surface.	Routine —including just before annual storm seasons (that is, in April and May) and following significant rainfall events.
Sediment removal	Remove accumulated sediment and muck along with much of the wetland growth. Reestablish growth zone depths and spatial distribution. Revegetate with original wetland species.	Nonroutine—every 10 to 20 years as needed by inspection if no construction activities take place in the tributary watershed. More often if they do. Expect to clean out forebay every 1 to 5 years.
Aquatic plant harvesting	Cut and remove plants growing in wetland (such as cattails and reeds) to remove nutrients permanently with manual work or specialized machinery.	Nonroutine until further evidence indicates such action would provide significant nutrient removal. In the meantime, perform this task once every 5 years or less frequently as needed to clean the wetland zone out.
Inspections	Observe inlet and outlet works for operability. Verify the structural integrity of all structural elements, slopes, and embankments.	Routine—at least once a year, preferably once during one rainfall event resulting in runoff.

TABLE 2.7
Wetland Pool Area Distribution

Components	Percent of Permanent Pool Surface Area	Water Design Depth
Forebay, outlet and free water surface areas	30% to 50%	2 to 4 feet deep
Wetland zones with emergent vegetation	56% to 70%	6 to 12 inches deep*

*One-third to one-half of this zone should be 6 inches deep.

TABLE 2.6
Sand Filter Detention Basin Maintenance Considerations

Required Action	Maintenance Objectives	Frequency
Debris and litter removal	Remove debris and litter from detention area to minimize clogging of the sand media.	Routine—depending on aesthetic requirements
Landscaping removal and replacement	If the sand filter is covered with rock mulch, bluegrass, or other landscaping covers, the cover must be removed to allow access to the sand media. Replace landscaping cover after maintenance of sand media is complete.	Every 2 to 5 years
Scarify filter surface	Scarify top 3 to 5 inches by raking the filter's surface.	Once per year or when needed to promote drainage.
Sand filter removal	Remove the top 3 inches of sand from the sand filter. After a third removal, backfill with 9 inches of new sand to return the sand depth to 18 inches. Minimum sand depth is 12 inches.	If no construction activities take place in the tributary watershed, every 2 to 5 years, depending on observed drain times, namely when it takes more than 24 hours to empty a 3-foot deep pool. Otherwise more often. Expect to clean out forebay every 1 to 5 years.
Inspections	Inspect detention area to determine if the sand media is allowing acceptable infiltration.	Routine—biannual inspection of hydraulic performance, one after a significant rainfall.

TABLE 2.5
Extended Detention Basin Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Occasional mowing to limit unwanted vegetation. Maintain irrigated turf grass as 2 to 4 inches tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine—depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from the entire pond to minimize outlet clogging and improve aesthetics.	Routine—including just before annual storm seasons (that is, April and May) and following significant rainfall events.
Erosion and sediment control	Repair and revegetate eroded areas in the basin and channels.	Nonroutine—periodic and repair as necessary based on inspection.
Structural	Repair pond inlets, outlets, forebays, low flow channel liners, and energy dissipators whenever damage is discovered.	Nonroutine—repair as needed based on regular inspections.
Inspections	Inspect basins to insure that the basin continues to function as initially intended. Examine the outlet for clogging, erosion, slumping, excessive sedimentation levels, overgrowth, embankment and spillway integrity, and damage to any structural element.	Routine—annual inspection of hydraulic and structural facilities. Also check for obvious problems during routine maintenance visits, especially for plugging of outlets.
Nuisance control	Address odor, insects, and overgrowth issues associated with stagnant or standing water in the bottom zone.	Nonroutine—handle as necessary per inspection or local complaints.
Sediment removal	Remove accumulated sediment from the forebay, micro-pool, and the bottom of the basin.	Nonroutine—performed when sediment accumulation occupies 20 percent of the WQCV. This may vary considerably, but expect to do this every 10 to 20 years, as necessary per inspection if no construction activities take place in the tributary watershed. More often if they do. The forebay and the micro-pool will require more frequent cleanout than other areas of the basin, say every 1 or 2 years.

TABLE 2.4
Porous Landscape Detention Maintenance Considerations

Required Action	Maintenance Objectives	Frequency
Lawn mowing and vegetative care	Occasional mowing of grasses and weed removal to limit unwanted vegetation. Maintain irrigated turf grass as 2 to 4 inches. tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine—depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from detention area to minimize clogging of the sand media.	Routine—depending on aesthetic requirements
Landscaping removal and replacement	The sandy loam turf and landscaping layer will clog with time. This layer will need to be removed and replaced, along with all turf and other vegetation growing on the surface, to rehabilitate infiltration rates.	Every 5 to 10 years; depending on infiltration rates needed to drain the WQCV in 12 hours or less. May need to do it more frequently if exfiltration rates are too low to achieve this goal.
Inspections	Inspect detention area to determine if the sand media is allowing acceptable infiltration	Routine—biannual inspection of hydraulic performance

TABLE 2.3
Grass-Lined Swale Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn Mowing and Lawn Care	Maintain irrigated grass at 2 to 4 inches tall and nonirrigated native grass at 6 to 8 inches tall. Collect cuttings and dispose of them offsite or use a mulching mower.	Routine—as needed.
Debris and Litter Removal	Keep the area clean for aesthetic reasons, which also reduces floatables being flushed downstream.	Routine—as needed by inspection, but no less than two times per year.
Sediment Removal	Remove accumulated sediment near culverts and in channels to maintain flow capacity. Replace the grass areas damaged in the process	Routine—as needed by inspection. Estimate the need to remove sediment from 3 to 10 percent of total length per year, as determined by annual inspection.
Grass Reseeding and Mulching	Maintain a healthy dense grass in channel and side slope.	Nonroutine—as needed by annual inspection.
Inspections	Check the grass for uniformity of cover, sediment accumulation in the swale, and near culverts.	Routine—annual inspection is suggested.

TABLE 2.2
Irrigated Grass Buffer Strip Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn Mowing	Maintain a dense grass cover at a recommended length of 2 to 4 inches. Collect and dispose of cuttings offsite or use a mulching mower.	Routine—as needed or recommended by inspection
Lawn care	Use the minimum amounts of biodegradable, nontoxic fertilizers and herbicides needed to maintain dense grass cover, free of weeds. Reseed and patch damaged areas	Routine—as needed.
Irrigation	Adjust the timing sequence and water cover to maintain the required minimum soil moisture for dense grass growth. Do not overwater	As needed.
Litter removal	Remove litter and debris to prevent gully development, enhance aesthetics, and prevent floatables from being washed offsite.	Routine—as needed by inspection.
Inspections	Inspect irrigation, turf grass density, flow distribution, gully development, and traces of pedestrian or vehicular traffic and request repairs as needed.	Annually and after each major storm (that is, larger than 0.75 inch in precipitation).
Turf replacement	To lower the turf below the surface of the adjacent pavement, use a level flow spreader so that sheet flow is not blocked and will not cause water to back up onto the upstream pavement.	As needed when water ponding becomes too high or too frequent a problem. The need for turf replacement will be higher if the pavement is sanded in winter to improve tire traction on ice. Otherwise, expect replacement once every 5 to 15 years.

TABLE 2.1
BMP Pollutant Removal Ranges for Stormwater Runoff and Most Probable Range for BMPs

Type of BMP	(1)	TSS	TP	TN	TZ	TPb	BOD	Bacteria
Grass Buffer	LRR:	10–50	0–30	0–10	0–10	N/A	N/A	N/A
	EPR	10–20	0–10	0–10	0–10	N/A	N/A	N/A
Grass Swale	LRR:	20–60	0–40	0–30	0–40	N/A	N/A	N/A
	EPR	20–40	0–15	0–15	0–20	N/A	N/A	N/A
Modular Block Porous Pavement	LRR:	80–95	65	75–85	98	80	80	N/A
	EPR	70–90	40–55	10–20	40–80	60–70	N/A	N/A
Porous Pavement Detention	LRR:	8–96	5–92	-130–85	10–98	60–80	60–80	N/A
	EPR	70–90	40–55	10–20	40–80	60–70	N/A	N/A
Porous Landscape Detention	LRR:	8–96	5–82	-100–85	10–98	60–90	60–80	N/A
	EPR	70–90	40–55	20–55	50–80	60–80	N/A	N/A
Extended Detention Basin	LRR:	50–70	10–20	10–20	30–60	75–90	N/A	50–90
	EPR	55–75	45–55	10–20	30–60	55–80	N/A	N/A
Constructed Wetland Basin	LRR:	40–94	-4–90	21	-29–82	27–94	18	N/A
	EPR	50–60	40–80	20–50	30–60	40–80	N/A	N/A
Retention Pond	LRR:	70–91	0–79	0–80	0–71	9–95	0–69	N/A
	EPR	80–90	45–70	20–60	20–60	60–80	N/A	N/A
Sand Filter Extended Detention	LRR:	8–96	5–92	-129–84	10–98	6D–80	60–80	N/A
	EPR	80–90	45–55	35–55	50–80	60–80	60–80	N/A
Constructed Wetland Channel*	LRR:	20–60	0–40	0–30	0–40	N/A	N/A	N/A
	EPR	30–50	20–40	10–30	20–40	20–40	N/A	N/A

(1) LRR Literature reported range, **EPR**-expected probable range of annual performance by BMPs.
N/A Insufficient data to make an assessment.

* The **EPR** rates for a Constructed Wetland Channel assume the wetland surface area is equal or greater than 0.5% of the tributary total impervious area.

TABLE 2.10a

Standardized WQCV Outlet Design Using Circular Openings (2" diameter maximum). Minimum Width ($W_{conc.}$) of Concrete Opening for a Well-Screen-Type Trash Rack. Requires minimum water depth below lowest perforation of 2' 4". See Figure 11.50b for Explanation of Terms.

Maximum Dia. of Circular Opening (in.)	Width of Trash Rack Opening ($W_{conc.}$) Per Column of Holes as a Function of Water Depth H					
	H=2.0'	H=3.0'	H=4.0'	H=5.0'	H=6.0'	Maximum Number of Columns
≤ 0.25	3 in.	3 in.	3 in.	3 in.	3 in.	14
≤ 0.50	3 in.	3 in.	3 in.	3 in.	3 in.	14
≤ 0.75	3 in.	6 in.	6 in.	6 in.	6 in.	7
≤ 1.00	6 in.	9 in.	9 in.	9 in.	9 in.	4
≤ 1.25	9 in.	12 in.	12 in.	12 in.	15 in.	2
≤ 1.50	12 in.	15 in.	18 in.	18 in.	18 in.	2
≤ 1.75	18 in.	21 in.	21 in.	24 in.	24 in.	1
≤ 2.00	21 in.	24 in.	27 in.	30 in.	30 in.	1

TABLE 2.10b

Standardized WQCV Outlet Design Using 2" Diameter Circular Openings. US Filter™ Stainless Steel Well-Screen* (or equal) Trash Rack Design Specification.

Max. Width of Opening	Screen #93 VEE Wire Slot Opening	Support Rod Type	Support Rod, On-Center Spacing	Total Screen Thickness	Carbon Steel Frame Type
9"	0.139	#156 VEE	3/4"	0.31"	3/8" × 1.0" flat bar
18"	0.139	TE .074" × .50"	1"	0.655"	3/4" × 1.0 angle
24"	0.139	TE .074" ×.75"	1"	1.03"	1.0" × 1½" angle
27"	0.139	TE .074" × .75"	1"	1.03"	1.0" x 1½" angle
30"	0.139	TE .074" × 1.0"	1"	1.155"	1¼" x ½" angle
36"	0.139	TE .074" × 1.0"	1"	1.155"	1¼" x 1½" angle
42"	0.139	TE .105" × 1.0"	1"	1.155"	1¼" x 1½" angle

*US Filter, St. Paul, Minnesota, USA

DESIGN EXAMPLE:

Given: A WQCV outlet with an orifice plate consisting of three columns of 5/8 in. (0.625 in) diameter openings. Water Depth H above the lowest orifice plate opening of 3.5 ft.

Solution: The dimensions within the mounting frame for a well screen trash rack are determined as follows.

Trash Rack Width: Given an orifice plate with 0.75 in. openings (i.e., rounded up from 5/8 in. actual diameter of the opening) and the Water Depth H = 4 ft (i.e., rounded up from 3.5 ft), Table 11.13a shows the minimum width for each column of openings is 6 in. Thus, the total trash rack width, W_{conc}, equals 3 columns × 6 in. = 18 in.

Trash Rack Height: Total trash rack height is the sum of the Water Depth H plus 2' (the height of the trash rack below the water depth; see Section A-A of Figure 11.50b). Thus, trash rack height equals 3'6" + 2' 0" = 66 in.

Dimensions Note: These trash rack dimensions are the minimum dimensions within the mounting frame. The trash rack mounting frame must be properly sized by a structural engineer taking into account the minimum trash rack dimensions, the intended method of fabrication, and the method of connection to the outlet structure.

Ordering Specifications: From Table 11.13b, select ordering specifications for an 18", or less, wide opening trash rack using US Filter (or equal) stainless steel well-screen with #93 VEE wire, 0.139" openings between wires, TE 0.074" × .50" support rods on 1.0" on-center spacing, total screen thickness of 0.655", with ¾ × 1.0" welded carbon steel frame.